Incorporation of Local Ecological Knowledge (LEK) into Biodiversity Management and Climate Change Variability Scenarios for Threatened Fish Species and Fishing Communities—Communic...

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Incorporation of local ecological knowledge (LEK) into biodiversity management and climate change variability scenarios for threatened fish species and fishing communities. Communication Patterns among BioResources users as a prerequisite for Co-management: a case study of Berlenga MNR, Portugal and Resex-Mar of Arraial do Cabo, RJ, Brazil

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Abstract Under current marine environmental problems and climate change scenarios, marine reserves emerge as an alternative management tool to protect marine resources and biodiversity and local ecological knowledge (LEK) can provide a valuable base for resource management. This study approaches the current situation of artisanal fisheries in two marine protected areas (MPAs) and proposes biodiversity management scenarios, under a changing climate, using fishers´ local ecological knowledge (LEK) in two hemispheres: The Berlenga Marine Natural Reserve (Berlenga MNR), Portugal and the Marine Extractive Reserve (Resex-Mar) of Arraial do Cabo, Rio de Janeiro, Brazil. The most targeted species of artisanal fisheries in both protected areas were reviewed for habitat use, threats and conservation status. The use of LEK is a powerful tool for developing new conservation strategies namely dealing with climate change responses of biological bioresources and fishing communities' adaptation. Participatory management by all users in a protected area is regarded as an effective means to improve decision making among stakeholders. LEK studies of taxonomy, population dynamics, ecology, habitat use, threats, and reproduction as well as the assessment of this information for artisanal fisheries are still very scarce in Europe and Brazil. The use of LEK provides important biological information and insight into the attitudes of fishermen towards biodiversity conservation in both MPAs. Other MPAs in mainland Portugal and the Madeira and Azores Autonomic Regions are also potential areas for the administration of LEK studies. Also the social network used for communication of knowledge and information related to natural resources among different professionals and resource extractors operating in a coastal seascape is critical under a scenario of biodiversity loss and climate change impacts.

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1 Introduction

With the current increasing exploitation of the world's oceans (Gaines et al. 2010), marine reserves have emerged as an essential tool for the management of the marine ecosystem (Worm et al. 2006). Most marine protected areas (MPAs) are located in high biodiversity sites, and fishing appears to be the main threat in most of these marine protected areas (Gaines et al. 2010). Thus, development of MPAs is closely related to artisanal fisheries, cultural factors, survival and livelihood of coastal communities (Diegues 2008). As there is no sufficient knowledge on the capacity of marine organisms to adapt to the current changes in the marine environment (Munday et al. 2013), it is increasingly important to recognize humans as one component of the ecosystem to better understand ecological change (Yáñez-Arancibia et al. 2013).

The incorporation of both the ecological and human dimensions into conservation plans can be beneficial for management models focused on conservation of biodiversity (Novacek and Cleland 2001) and facing climate change variability. Biocultural approaches in conservation studies, management and governance (also climate governance) are an alternative and fully effective approach to addressing the accelerated loss of biological and cultural diversity (Gavin et al. 2015).

In this context, local ecological knowledge (LEK) appears as a conservation tool that can generate data to test new hypotheses and thus contribute to a more sensitive, culturally relevant research approach (Drew 2005) and communication interface. The detection of environmental changes, the development of strategies to adapt to these changes, and the implementation of sustainable management principles are all important climate action items that can be informed by LEK (Viegas et al. 2016). LEK can contribute valuable ecological information when properly acquired and may be useful for evaluating most vulnerable ecosystems and long-term environmental change (Beaudreau and Levin 2014).

Portuguese artisanal fisheries face difficulties due to European Union legislation despite the social importance, wide-spread locations and source of livelihood for coastal communities of these fisheries (Santos et al. 2012; Viegas et al. 2016). Their low economic profitability and the lack of manpower puts the permanence of artisanal fishing activities at risk in many places (Santos et al. 2012; Viegas et al. 2016). In Brazil, solutions to conservation issues are often confused by rapid economic growth and political decisions; the resulting management decisions may threaten global tropical biodiversity (Pelicice et al. 2014).

Due to commonly observed abrupt nonlinear changes in the marine ecosystem (Rocha et al. 2015), studies on artisanal fisheries in Portugal and Brazil using LEK data can be extremely important for more sustainable management of fisheries resources and the maintenance of traditional fishing practices in both areas. Thus, the general objective of this study is to briefly characterize the biology and ecology of the main species of threatened small fish fauna in two marine protected areas located in different hemispheres (The Berlenga Marine Natural Reserve (MNR), Peniche, Portugal and the Marine Extractive Reserve (Resex-Mar) of Arraial do Cabo - Rio de Janeiro, Brazil). To address this goal, this work emphasizes the positive aspects of the use of ethnobiology tools in fisheries and biodiversity management scenarios using fishers' local ecological knowledge, and propose that this line of research can be used to assist in the perception of climate change (Viegas et al. 2016) through of ethnoecological studies. Climate change perceptions in the Peniche fishing community started with Santos et al. (2012) and Viegas et al. (2016). This follow up study about LEK and Climate Change Communication continues the already started Building resilience for adaptation to climate change in the fisheries. Climate researchers must improve their ability to explain uncertainties and risks (Ward 2010) in this changing climate where knowledge is continuously evolving and particularly within the most vulnerable when it comes to preparing for adapting to change in resource-dependent communities (Joshua et al. 2015) (e.g. marine bioresources and fisheries coastal communities) that are particularly at risk from the impacts of a changing climate (Islam et al.2014).

2 Methodology

2.1. Study area

2.1.1. Study area The Resex-Mar of Arraial do Cabo and Berlenga MNR

The Resex-Mar of Arraial do Cabo was created on January 3, 1997 by Presidential Decree. According to the National System of Conservation created by Law No. 9.985/2000, this marine reserve is one of the Brazilian Conservation Unit modalities (ICMBio 2015). Resex-MAR is included in Category IV (i.e., protected area with sustainable use of natural resources) according to the IUCN Protected Areas Categories System.

Resex-MAR is located in the municipality of Arraial do Cabo (Figure 1), Cabo Frio region, Rio de Janeiro, Brazil (23° 00’ S, 42° 00’ W) and lies within the Marine Biome in the South Atlantic system three nautical miles from shore, with an area of 56.769 hectares (ICMBio 2015).

According to Koppen's classification, the region of Cabo Frio and Arraial do Cabo has a dry climate BSh (low latitude steppe). The average annual temperature is 25ºC, with precipitation that can reach

800 mm/year. Due to upwelling of cold water along the coastline, the climate is semi-arid, with reduced local precipitation (Scheel-Ybert 2000). This marine reserve is located in one of the most attractive regions of the Brazilian coast and supports tourism and local recreational activities (Pereira et al. 2008).

The Berlenga MNR (39º 24′ N, 9º, 30 W) is located in the Northern Atlantic system in Portugal (Figure 2) to the east of Cabo Carvoeiro on the Iberian Peninsula. This Marine Nature Reserve (MNR) was designated as a Nature Reserve in 1981 and is considered Category Ia: Strict Nature Reserve, according to the IUCN Protected Areas Categories System.

The MNR consists of a large island (Berlenga Grande) and adjacent reefs (Estela, Farilhões and some rocks) located 10 km west from mainland Portugal of the Peniche coast (Pardal and Azeiteiro 2001; Radhouani et al. 2010). Berlenga Grande is a granite boulder with a field of seventy-eight hectares, reaching a height of eighty-eight meters and a maximum length of fifteen hundred meters (Santos et al. 2011). The distinct climatic conditions present make the zone an important area for biological studies (Pardal and Azeiteiro 2001).

The self-preservation and sustainable use of renewable natural resources traditionally used by the fishing communities in the region (i.e., Arraial do Cabo, Brazil and Peniche, Portugal) are the main goals of both marine reserves.

2.1.2. Upwelling events and biodiversity in both Marine Protected Areas (MPAs)

Upwelling events are extremely important for maintaining the high biodiversity and productivity of marine areas. In an upwelling event, deep water enriched by nutrients moves upwards with the help of the winds. These nutrients on the sea surface contribute to the expansion of fish populations in conjunction with the development of plankton communities (Godoy et al. 2013).

The Brazilian Southwest Atlantic is notable for its remarkable tropical and subtropical features, with a considerable amount of endemism (Mckenna and Allen 2002). An upwelling system located in the Brazilian Exclusive Economic Zone (EEZ), influences the external conditions (climatic and oceanographic) of the region, with important implications for local biodiversity (Amaral and Jablonski 2005). Upwelling events are most intense in the Cabo Frio region (State of Rio de Janeiro), primarily due to the northeasterly (NE) winds that are more frequent in austral spring and summer (Godoy et al. 2013). The annual variation in upwelling observed in Cabo Frio has been associated with the El Niño/La Niña system, and the magnitude of the upwelling is influenced by coastline geomorphology and ocean bottom topography (Rodrigues and Lorenzzetti 2001). The occasional occurrence of upwelling in this region contributes to increased local productivity (Amaral and Jablonski 2005). Indeed, the State of Rio de Janeiro stands out for its diversity of flora and fauna within the Brazilian subtropical waters (Monteiro-Neto et al. 2013), and the Resex-Mar of Arraial do Cabo is an area of great faunal abundance, primarily due to the occurrence of the intense marine upwelling along this coast (Da Silva 2004).

The Berlenga MNR is located in the upper portion of the southern slope of the Nazaré Submarine Canyon. Submarine canyons are considered key structures for ecosystem functioning (Würtz 2012) and are associated with enriched productivity (Vetter and Dayton 1998; Vetter et al. 2010). It is assumed that physical processes present around submarine canyons have the potential to influence the permanence of marine organisms in this habitat (Bosley et al. 2004).

Nazaré Canyon is recognized as one of the largest and deepest submarine canyons in the world (Curdia et al. 2004). Upwelling occurs there primarily between April and September (Haynes et al. 1993) and has contributed to the maintenance of fish stocks on the west coast of the Iberian Peninsula (Loureiro et al. 2005). Along the west coast of Portugal, upwelling is governed by equatorward winds, which influence oceanographic conditions in the summer (Oliveira et al. 2009). Upwelling conditions off the Portuguese coast are more persistent and active during the summer, which contributes to the high productivity of phytoplankton and zooplankton.

2.2. Literature review

An exhaustive search of articles in the B-on database (http://www.b-on.pt/) was performed to gather information on the target species for most artisanal fisheries in the Resex-Mar of Arraial do Cabo and the Berlenga MNR, and threatened species by the consequences of climate change in the Atlantic Ocean. We focused on a subset of papers discussing the importance of fisher´s local ecological knowledge (LEK) for resources fisheries and LEK used for management of marine protected areas in Brazil and Portugal; we also used a brief review of ethnobiology studies of artisanal fisheries in Portugal.

3. Results and Discussion

3.1. Artisanal Fisheries in both Marine Protected Areas (MPAs)

According to (Azevedo 2004), in the Resex-Mar of Arraial do Cabo, there are 82 species of pelagic organisms, including 65 species of Actinopterygii, 12 species of Condrichthyes and 5 species of invertebrates (crustaceans and mollusks). The most representative fish species are as follows: bluefish (*Pomatomus saltatrix*), largehead hairtail (*Trichiurus lepturus*), little tunny (*Euthynnus alletteratus*), chub mackerel (*Scomber japonicus*), horse-eye jack (*Caranx latus*), common dolphinfish (*Coryphaena hippurus*) and Brazilian sardine (*Sardinella brasiliensis*). These fish comprise a considerable portion of the fishery production in the Cabo Frio region (Azevedo 2004; Coelho-Souza et al. 2012). *S. brasiliensis* is historically the most landed teleost in Arraial do Cabo, accounting for approximately 14% of all marine fish fisheries extractions in Brazil (ICMBio 2010). In addition, *Mycteroperca acutirostris* (comb grouper) is one of the groupers most commonly fished in Arraial do Cabo (Floeter et al. 2006). Bender et al. (2014) identified a sharp decline in abundance of *Pomatomus saltatri*x, the groupers *Epinephelus marginatus*, *Mycteroperca acutiros*tris, *M. bonaci* and *M. microlepis*, and large parrotfishes (mainly S*carus trispinosus*) over the last six decades.

The following paragraphs describe the fish species considered to exhibit the greatest decline in abundance in local artisanal fisheries (Bender et al. 2014) and other species that are important for local fisheries in the study area (Azevedo 2004; ICMBio 2010; Coelho-Souza et al. 2012).

The comb grouper, (*Mycteroperca acutirostris* Valenciennes, 1828), from the Serranidae family, has a distribution within the Western Atlantic from Bermuda and the Gulf of Mexico to southern Brazil in shallower waters (Heemstra et al. 2003). This species is called Badejo mira or Miracelo locally (Bertoncini et al. 2008a; IUCN 2016). *M. acutirostris* is not in significant decline and is listed as Least Concern (LC) in the IUCN Red List Category and Criteria (Bertoncini et al. 2008a; IUCN 2016). However, the species suffers from heavy fishing pressures in some areas (Floeter et al. 2006).

The Brazilian sardine, (*Sardinella brasiliensis* Steindachner, 1879) is a marine species belonging to the Clupeidae family and is of great importance to the Brazilian fishing fleet (Baloi et al. 2014). This species is typical of the western Atlantic (Gulf of Mexico, Caribbean, West Indies southward, north of Uruguay and Brazil) (Whitehead et al. 1985). Paiva and Falcão (2002) note that this species is endemic to the Brazilian coast and is geographically isolated from other species of this genus in the Atlantic Ocean. In Brazil, *S. brasiliensis* is found mainly in the south and southeast of the country, specifically between Cabo de São Tomé - Rio de Janeiro State (22º S) and Cabo de Santa Marta - Santa Catarina State (29º S) (Jablonski 2007). Large variations were observed in catches of *S. brasiliensis* in recent decades (Cergole and Dias-Neto 2011; Dias et al. 2014). Landings in Rio de Janeiro, Santos (São Paulo State) and Itajaí (Santa Catarina State) showed a downward trend in 2000, which was possibly linked to overfishing, fluctuations in reproduction and spawning habitat changes (Soares et al. 2011). The sharp decline in production in 2010 may be a warning to managers and co-management fisheries of the possibility of a new downward cycle in production in Brazil (Dias-Neto et al. 2011). This taxon has not yet been assessed for the IUCN Red List (IUCN 2016).

The marine bluefish, (*Pomatomus saltatrix* Linnaeus, 1766) is a cosmopolitan coastal pelagic fish of the family Pomatomidae that is widely distributed along the continental shelf in temperate and warm Atlantic waters (Juanes et al. 1996). Estuaries are extremely important for this species. These fish are targeted for both commercial and recreational purposes, including in a artisanal fisheries (Ceyhan et al. 2007), and populations have fluctuated in abundance (Candelmo et al. 2010). The marine bluefish is listed as Least Concern (LC) in the IUCN Red List Category and Criteria (Bizsel et al. 2011; IUCN 2016).

The dusky grouper (*Epinephelus marginatus* Lowe, 1834) is a well-known teleost fish of the family Serranidae that is widely distributed in tropical and temperate seas (Heemstra and Randall 1993; Marino et al. 2001). It is found along the southeast coast of Brazil in tropical and subtropical waters, with the Cabo Frio upwelling presenting a zoogeographical divisor (Paiva and Andrade-Tubino 1998). Overexploitation is considered the main threat to populations of this reef-associated species (Echwikhi et al. 2015). Bender et al. (2014) described the downward trend in abundance of this species in the subtropical reefs of Arraial do Cabo, Rio de Janeiro. Along the southern and southeastern coast of Brazil, there are restrictions on the minimum landing size of *E. marginatus* (MMA 2005), and in the Berlenga MNR, this species has been strictly protected (Inglês 2010). This taxon is in danger, facing a very high risk of extinction in the wild and is listed as Endangered (EN) in the IUCN Red List Category and Criteria (Cornish and Harmelin-Vivien 2004; IUCN 2016).

The black grouper (*Mycteroperca bonaci* Poey 1860) is a typically solitary reef species (Claro 1994; Fishbase 2014) of the family Serranidae and is found in the Western Atlantic, from the United States to southern Brazil, including around Cuba, the Bahamas, the Florida Keys and in the southern Gulf of Mexico (Heemstra and Randall 1993). Groupers are targets of various types of fisheries (Craig et al. 2011). Members of the genera *Mycteroperca* are at particular risk due to their large body size, long life-span and late age at reproduction (Morris et al. 2000). Bender et al. (2013) identifies *M. bonaci* as one of the species that is overexploited in artisanal fisheries in the Recife de Fora Marine Park in Bahia state, northeast Brazil. In northeastern Brazil, specifically between the States of Ceará and Alagoas, this species is the target of some artisanal and compressor-assisted spear fishing (Teixeira et al. 2004). *M. bonaci* is listed as Near Threatened (NT) in the IUCN Red List Category and Criteria (Ferreira et al. 2008; IUCN 2016).

Gag (*Mycteroperca microlepis* Goode and Bean, 1879) is a shallow-water serranid species that ranges from the Western Atlantic (North Carolina, USA) to Bermuda, Cuba, the Yucatán Peninsula (Mexico) and Brazil (southeast to Santa Catarina State) (Heemstra and Randall 1993). This grouper has a strong relationship with coral reef ecosystems and may be vulnerable to overexploitation due to their life history characteristics (Brulé et al. 2011). In the United States, this species is exploited in recreational and commercial fisheries (McGovern et al. 1998). It is listed under Least Concern (LC) in the IUCN Red List Category and Criteria because of the considerable distribution and abundance of individuals (Bertoncini et al. 2008b; IUCN 2016). However, *M. microlepis* is targeted by commercial fishermen and sport fisheries, and sharp declines in abundance have been observed in southwestern Brazil (Bender et al. 2014).

The green back parrotfish (*Scarus trispinosus* Valenciennes, 1840) is a member of the family Scaridae that is endemic to Brazil. It is called "bico-verde" and "budião-azul" by local artisanal fishermen (Moura et al. 2001; Floeter et al. 2007). *S. trispinosus* occurs strictly in the southwestern Atlantic, from the northern to the southeastern coast of Brazil (Moura et al. 2001). Parrotfish populations are a constant target of fisheries (Comeros-Raynal et al. 2012; Bender et al. 2014), with spearfishing being a major cause of the decline of green back populations on Brazilian reefs (Ferreira et al. 2005). Floeter et al. (2007) described the extinction of the species in Arraial do Cabo, primarily due to spearfishing. This species is listed as endangered in the IUCN Red List Category and Criteria (Padovani-Ferreira et al. 2012; IUCN 2016).

The marine fish fauna in Berlenga MNR is renowned for its biological richness and diversity (Inglês 2010). Approximately seventy-six species of fish occur around the MNR islands (Rodrigues et al. 2008). Some species are of particular commercial fishing importance, especially small pelagic fish such as sardines (*Sardina pilchardus*), Atlantic mackerel (*Scomber scombrus*), chub mackerel (*Scomber japonicus*) and horse mackerel (*Trachurus trachurus*). Eleven species from the family Sparidae are present in this area.

The occurrence of pelagic species is common in Berlenga and the communities of reefs are dominated by macrocarnivores, omnivorous and invertivores species (Vasco-Rodrigues et al. 2011). The *Epinephelus marginatus* is commonly hunted by divers in this area (Queiroga et al. 2008); this species appears on the Red List of the International Union for Conservation of Nature (IUCN) as endangered (Cornish and Harmelin-Vivien 2004; IUCN 2016). According to Inglês (2010), the species most exploited in artisanal fisheries within the Berlenga MNR are chub mackerel, sardine, horse mackerel, gilthead seabream (*Sparus aurata*), seabass *(Dicentrarchus labrax*) and white seabream (*Diplodus sargus*).

The chub mackerel, (*Scomber japonicus*) is a coastal, cosmopolitan species inhabiting oceanic tropical and temperate waters (Atlantic, Indian, Pacific) and adjacent seas (Scoles et al. 1998). *S. japonicus* is still recognized as an important fishery resource many parts of the world (Vasconcelos et al. 2012); in the Berlenga MNR, this pelagic species is considered a major target for local artisanal fisheries (Inglês 2010). This species is caught primarily with purse seines, hook and line and nets, and it can still be caught in both sport and recreational fisheries. It is listed under Least Concern (LC) in the IUCN Red List Category and Criteria (Collette et al. 2012; IUCN 2016).

The sardine (*Sardina pilchardus*) is a small pelagic fish from the family Clupeidae and is primarily distributed in the eastern North Atlantic, North Sea, Mediterranean, Sea of Marmara and Black Sea (Parrish et al. 1989). Sardine has an important ecological role in the ecosystem and is also commercially important (ICES 2013; Correia et al. 2014). *S. pilchardus* is heavily fished in Portugal (Tacon and Metian 2009) and Spain (ICES 2013). This taxon has not yet been assessed for the IUCN Red List (IUCN 2016).

The Atlantic horse mackerel (*Trachurus trachurus*) is a very important species in the Atlantic-Iberian region (Murta 2000). This species has a high nutritional value, primarily because it is rich in minerals (Özden 2010). This species is distributed in the Mediterranean Sea and the northeast Atlantic from Norway to the Cape Verde Islands (Abaunza et al. 2008). *T. trachurus* is the second mostly commonly targeted species on the Portuguese coast, with more than 15,000 tons landed per annum and is well appreciated in smaller sizes by the Portuguese population (Bandarra et al. 2001). The IUCN Red List status of this species has not been evaluated (IUCN 2016).

The gilthead seabream (*Sparus aurata*) is a subtropical Sparidae that is quite important in the Mediterranean region (Boulton et al. 2011). *S. aurata* can also be found on the east coast of the Atlantic (from Great Britain to Senegal) and in the Black Sea (FAO 2015a). In Portugal, this species has a high market value and is very important for Portuguese marine aquaculture, primarily in the Algarve (Andrade et al. 1996). This species is targeted using traditional fishing gear such as trawl nets, bottom set longlines and hand lines (Crosetti et al. 2014). The IUCN Red List status of this species has not been assessed (IUCN 2016).

The European seabass (*Dicentrarchus labrax*) is a member of the Moronidae family and is quite widespread along the European coast, primarily in the Eastern Atlantic, Mediterranean Sea and Black Sea (Kottelat and Freyhof 2007). Vasco-Rodrigues et al. (2011) observed a decrease of 14.8% in the occurrence of this species in the Berlenga MNR. The lack of effective control over spearfishing in the Berlengas

Archipelago caused a decline in abundance of this target species in the Berlenga MNR (Inglês 2010). European seabass is listed under Least Concern (LC) in the IUCN Red List Category and Criteria (Freyhof and Kottelat 2008; IUCN 2016).

The white seabream (*Diplodus sargus*) is a teleost from the family Sparidae and is very abundant in the coastal waters of the Persian Gulf and Mediterranean Sea and in the Indian and Atlantic Oceans (González-Wangüemert and Pérez-Ruzafa 2012). *D. sargus* is considered a species of great importance in artisanal fisheries that use fixed gear, such as trammels and gillnets (Benchalel and Kara 2013). In Portugal, white seabream have potential for cultivation due to its high economic value (Rigos and Katharios 2010). This species has not been evaluated by the IUCN Red List for conservation status (IUCN 2016).

3.2. Important aspects of local ecological knowledge (LEK) for the management of fisheries in Marine Protected Areas (MPAs)

3.2.1. LEK and its role within Marine Protected Areas (MPAs)

Environmental quality is affected by several types of human exploitation and organizations. (Lubchenco et al. 2003). Amid the recognition of the enormous influence of humans on marine environments, marine reserves arise as a strategy to protect these critical areas from overfishing and other destructive and extractive activities (Lubchenco et al. 2003).

Overfishing and side effects from fishing directly influence the population structure of different species of fish in marine protected areas, often by mismanagement that was not effective in their sustainability objectives (Botsford et al. 1997). In this perspective, new conservation tools that respond to environmental changes, particularly the effects from climate change, are suggested to assist biodiversity conservation strategies (Hannah et al. 2002). In addition to biological points, other additional factors, such as local participation and political viability, are key features to the success of a marine reserve (Allison et al. 1998). The link between ecosystems and humans is crucial for the recovery strategy of biota on a planet that has been changed by various anthropogenic activities (Novacek and Cleland 2001).

Berkes et al. (2007) showed that the aggregation of participatory management, where all stakeholders are involved, can facilitate better assessments and understanding of the marine environment. In a biodiversity hotspot in Papua New Guinea, for example, the local community was involved in a successful planning process for the management of a marine protected area (Green et al. 2009).

For more effective conservation in a system in which a few resources are limited, it is advisable to use management regimes where the interests of the communities are also taken into consideration

(McClanahan et al. 2006). Imposing restrictions on limited fishery resources in a protected area could trigger instability of social and economic factors within coastal communities and generate future conflict over resources. All parties should be supported for effective management (Agardy et al. 2003; Dietz et al. 2003).

"Traditional ecological knowledge" (TEK) has emerged as a means to assist in the management of complex systems by using local information to help understand local dynamics and ensure greater chances of survival of a particular traditional dependent community (Berkes et al. 2000). TEK reflects the experience of humans with the environment, which has been acquired for thousands of years (Berkes 1993), and is presently a useful tool in modern conservation programs (Drew 2005). TEK can be defined as, "a cumulative body of knowledge, practice and belief evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment " (Berkes 2012).

Similarly to TEK, local ecological knowledge (LEK) is the cumulative knowledge derived from the interaction of individuals in a population with the environment acquired by living with the biological resources they use (Yli-Pelkonen and Kohl 2005). It is important to clarify that TEK can be observed in most cases as a synonym for ethno-ecological knowledge, indigenous knowledge or local ecological knowledge (Berkes 2012). We have chosen to use the term LEK in this work as it is more commonly used in fisheries management (Wilson et al. 2003).

There is growing interest in the use of LEK as a complementary tool that can be used in adaptive management of protected areas (Berkes et al. 2007; Gómez-Baggethun et al. 2010; Bender et al. 2013; Mmassy and Røskaft 2014). Studies of local ecological knowledge may provide some biological information regarding a feature of the fish fauna that fishermen have explored at some point. However, for this knowledge to be used in biodiversity management and to be validated and shared appropriately within the scientific literature, its confidentiality must be maintained (Hamilton et al. 2012).

The information generated by a community, such as observations of fish behavior in the local habitat and the knowledge of fisherman regarding the ecology and biology of a species (ethnoecology, ethnobiology and ethnotaxonomy of fish species), are highly relevant to fisheries management (Begossi 2008). Another goal of the LEK approach is to analyze and understand the description of local physical and biological characteristics within a social context and with regard to other productive activities of these communities (Ruddle 2000).

The use of LEK can complement scientific studies and replace some types of scientific research; LEK may even be recognized as a new source of scientific information with proven quality (Le Fur et al. 2011). LEK contributes to better discussions among stakeholders, thereby facilitating the management of funds by fishermen, exposing existing conflicts and highlighting the necessary measures to be considered in decision making (Mellado et al. 2014).

In areas where biological data are scarce, LEK can be useful for formulating testable hypotheses and providing auxiliary information to guide further investigation (Silvano and Valbo-Jørgensen 2008). Specialized artisanal fishermen can be a valid source of information in situations where there is no available long-term data for an ecosystem. Focusing on LEK of fisheries and the biology of key species becomes the most effective and functional way of gathering local information (Begossi and Silvano 2008).

Understanding the attitudes towards conservation from LEK studies and sharing the socio-economic information of communities is extremely important for improving the management and biophysical health of coastal marine systems (Malleret-King et al. 2006). Thus, comprehensive studies involving continuous interactions between fishermen, scientists and other stakeholders are key to the effective contribution of LEK to resource management (Wilson et al. 2006). The inclusion of LEK is presented as an alternative to traditional management aimed at preserving biodiversity, especially for fisheries management systems in MPAs (Ruddle and Hickey 2008; Silvano and Begossi 2012).

3.2.2. Fisher´s local ecological knowledge in Brazil

There is great interest in scientific research based on fishers' local ecological knowledge (LEK) of the Brazilian coast (Begossi and Silvano 2008; Caló et al. 2009; Gerhardinger et al. 2009; Silvano and Begossi 2012; Bender et al. 2013; Bender et al. 2014; Ferreira et al. 2014; Herbst and Hanazaki 2014; Martins et al. 2014; Giglio and Bornatowski 2016, Barbosa-Filho et al. 2016, Pinto et al. 2016, Begossi et al. 2016).

Fisher's LEK in Brazil includes detailed knowledge of the conservation status of reef fish (Bender et al. 2013; Bender et al. 2014), on the relative abundance and aggregation of fish (Gerhardinger et al. 2009), on reproduction, diet and areas of risks (Begossi and Silvano 2008), on temporal and spatial distribution of both prey and predators (Caló et al. 2009), on various aspects of fisheries, such as temporal changes in catches and biology (Giglio and Bornatowski 2016), on fish diets and habitat use (Begossi et al. 2016), on species interactions (Barbosa-Filho et al. 2016), on ethnotaxonomic classification systems (Pinto et al. 2016), and about the life cycles of these species, which is generally consistent with the ichthyological scientific literature (Lima and Batista 2012).

Through the collection of data in standardized interviews, with calculated precision and reliability, LEK was found to exhibit a considerable amount of alternative information for nine coastal fishes in Búzios Island in the State of Rio de Janeiro, Brazil (Silvano and Begossi 2012). These data were considered to be the only available source of information on some species and thus could contribute positively to local fisheries management initiatives (Silvano and Begossi 2012). In a fishing community near the Arvoredo Biological Reserve in southern Brazil, studies showed that the accurate LEK of fishermen pertaining to different species around the reserve could support an MPA evaluation. Fishermen report that the MPA was only effective for reef species but was not efficient for the recovery of target species; this type of ethnobiological research suggests that LEK can contribute to the monitoring of marine protected areas (Martins et al. 2014).

The results of the work involving the LEK of artisanal fishermen regarding the goliath grouper (*Epinephelus itajara* Lichtenstein, 1822) along the Bahia coast, which generated refined data on ecological and biological characteristics of a critically endangered species. The initial study of the species based on LEK of expert fishermen along the Ilhéus coast suggests an important starting point encouraging new studies on the behavior, reproduction and ecology of *E. itajara* in the region (Ferreira et al. 2014).

Similarly, Herbst and Hanazaki (2014) highlighted the detailed LEK regarding the life cycle of mullets (*Mugil liza* Valenciennes, 1836) along the coast of Santa Catarina State. Furthermore, the authors noted the importance of conservation measures taken based on the information provided by the fishermen of the variations in migration routes as an attribute to the species natural life cycle.

Interactions with whale sharks (*Rhincodon types*) reported by fishermen along the Brazilian coast provided important data to support the government plans to regulate fishing activities (Barbosa-Filho et al. 2016). In a small-scale fishery on the northeast coast of Brazil, use of local ecological knowledge was suggested as a complement to scientific data and may improve modeling efforts for research and management of fishery resources (Bevilacqua et al. 2016).

Diegues (2003) recognized that the artisanal fishermen of Arraial do Cabo, Rio de Janeiro, Brazil have a vast local knowledge on the ecology, behavior and distribution of fish species. In the same region, the combination of local ecological knowledge with scientific data indicates a decline of different fish species, suggesting the importance of LEK as an auxiliary tool in marine biodiversity maintenance strategies (Bender et al. 2014). Moreover, other studies investigating the beliefs, customs, food taboos, and attitudes towards the conservation of local biological resources can aid the conservation of marine ecosystems.

However, in Brazil MPA management is guided mainly by traditional science, which cannot provide all the information necessary for making management decisions. Thus, the population must be a partner in all phases of research and management. However, local knowledge should be subjected to a filtering process to remove sensitive information that might otherwise benefit competing interests (Gerhardinger et al. 2009).

3.2.3. Fishers´ local ecological knowledge in Portugal

There is still a huge gap in the scientific literature pertaining to ethnobiology in Portugal, with most LEK papers targeting ethnobotany. There is one study that addresses LEK of fishermen in three zones along the Portuguese coast. This study focuses on LEK pertaining to climate change, coastal issues and the factors that influence these two topic areas (Delicado et al. 2012). A study of Peniche, a community on the central-western coast of Portugal, also focused on exploring the relationship between fisherman and climate change (Viegas et al. 2016). However, no studies to date have focused on LEK regarding the ecology, behavior, spatial distribution, feed, population, reproduction or conservation of target species for artisanal fisheries along the Portuguese coast. In this perspective, this knowledge may be an alternative to study emerging changes in fish diversity due to the unexpected effects of global change (Azurro et al. 2011).

Understanding LEK and attitudes towards conservation of critical artisanal fisheries species in the Peniche region could provide important information and collaboration in the management of the ichthyofauna of the Berlenga MNR. It is possible that food taboos and beliefs about some species may improve resource conservation (Begossi et al. 2002; Braga and Schiavetti 2013). Also, it is still necessary to conduct a detailed investigation into the real participation of local people in decision making within the Berlenga MNR and its current impact on the preservation of the ecosystem.

Even with all the potential of artisanal fisheries in Portugal, the current situation indicates the likely influence of tourism and other various pressures on fisheries resources (Santos et al. 2012). Although it is known that the oceanographic conditions within the Berlenga MNR and its submarine archaeological heritage permit the presence of a large biodiversity of fish fauna (Queiroga et al. 2008; Inglês 2010), the possibility of the extinction of beliefs, customs, taboos and fishing gear used by artisanal fishermen of Peniche is imminent.

4. Global Change Communication

Fishing Communities (close ties with and reliance on ecosystem goods and services) have benefitted from the application of LEK in natural and cultural resource management and there is increasing recognition of the value of LEK as it applies to climate change assessment and adaptation efforts (Setti et al., 2016 a,b). Traditional ecological knowledge can help build an understanding of climate impacts on ecological processes and climate phenomena (Setti et al. 2016 a,b; Alexander et al. 2011; Ford et al. 2010; Nabhan 2010; Berkes 2009; Salick and Ross 2009; Riedlinger and Berkes 2001). The applicability of LEK, associated with socioeconomic and adaptive human responses to environmental change and climate change strategies can make an important contribution to understanding the impacts from climate change adaptation. Similarly, despite community-based approaches to climate change adaptation and disaster risk reduction increasing there is very limited guidance on how to effectively communicate climate change in a way that enhances people's resilience (Dumaru 2010; Berkes, F. and D. Jolly. 2001; Berkes et al., 1995). This document shows the experiences of LEK in Brazil and proposes LEK scenarios in the AMP of Peniche and Arraial do Cabo in coastal zones and in fishing communities, as well as scenarios for LEK studies to analyze the perceptions of fishermen of climate change in the fauna of fish in both areas. Three key climate change communication challenges are being prepared for the future studies: interviews, focus group discussions and online discussion site with the purpose of drawing recommendations for good practice guidance in climate change communication that is empowering and culturally relevant. Effectively communicate this Climate Change Challenge is critical (Moser 2010), Climate researchers must improve their ability to explain uncertainties and risks (Ward 2010) and raising awareness about climate change remains crucial, importantly and essential for communities to make local sense of climate change, particularly in an ever-changing world where knowledge is continuously expanding and changing (McNamara 2013) .

5. Conclusions

This work attempts to demonstrate the importance of fisher´s local ecological knowledge (LEK) and communication strategies as a source of additional information for use in the conservation and management of fishery resources and climate change adaptation of fishing communities. The geographic regions discussed are representative of different socio-environmental and jurisdictional contexts; ongoing research will provide new insights to this scientific and environmental field. The inclusion of fishers´ LEK can contribute greatly to the construction and improvement of management plans for the sustainable use of a particular resource within these areas. However, the use of local ecological knowledge is not a guarantee that a fishery will be sustainable, but rather offers an alternative knowledge source as fishermen manage resources, especially when scientific biological data are scarce.

The Berlenga MNR offers a spatial context, with relevant conservation concerns, for the development of the use of fishers' local ecological knowledge in Portugal (and Europe). LEK has been identified as a potential contributor to conservation practices in Europe within communities where the local livelihood depends on ecosystem resources and services (Hernández-Morcillo et al. 2014). On the Iberian Peninsula, especially in Portugal, studies could utilize ethnobiology methodologies for developing the National Network of Protected Areas (RNAP) with a focus on local ecological knowledge of biological resources, especially ichthyofauna for which no assessment of conservation status has been made.

Despite neglect in European research (Svanberg et al. 2011), ethnobiology exhibits evident growth as a science in Latin America (Albuquerque et al. 2013). With this approach, new data will help elucidate emerging changes in marine ecosystems as a result of inherent current overexploitation and climate change. Like many studies highlighted here, the use of LEK can be an important tool in fisheries management, and thus could be more used in climate change management and mitigation along with the affected resources. Therefore, ethnobiological studies in Portugal can promote a better understanding of climate change (Byg and Salick 2009), as well as provide and predict new local information for fisheries management along the European Atlantic coast. In this context climate researchers must improve their ability to explain uncertainties and risks (Ward 2010) particularly in an ever-changing world where knowledge is continuously expanding and changing (McNamara 2013) and particularly to most vulnerable when it comes to preparing for and adapting to change in resource-dependent communities (Joshua et al. 2015) like the Coastal communities that are particularly at risk from the impacts of a changing climate (Islam et al.2014).

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Figure 1. Location of the city of Arraial do Cabo and the Marine Extractive Reserve of Arraial do Cabo, State of Rio de Janeiro, Brazil.

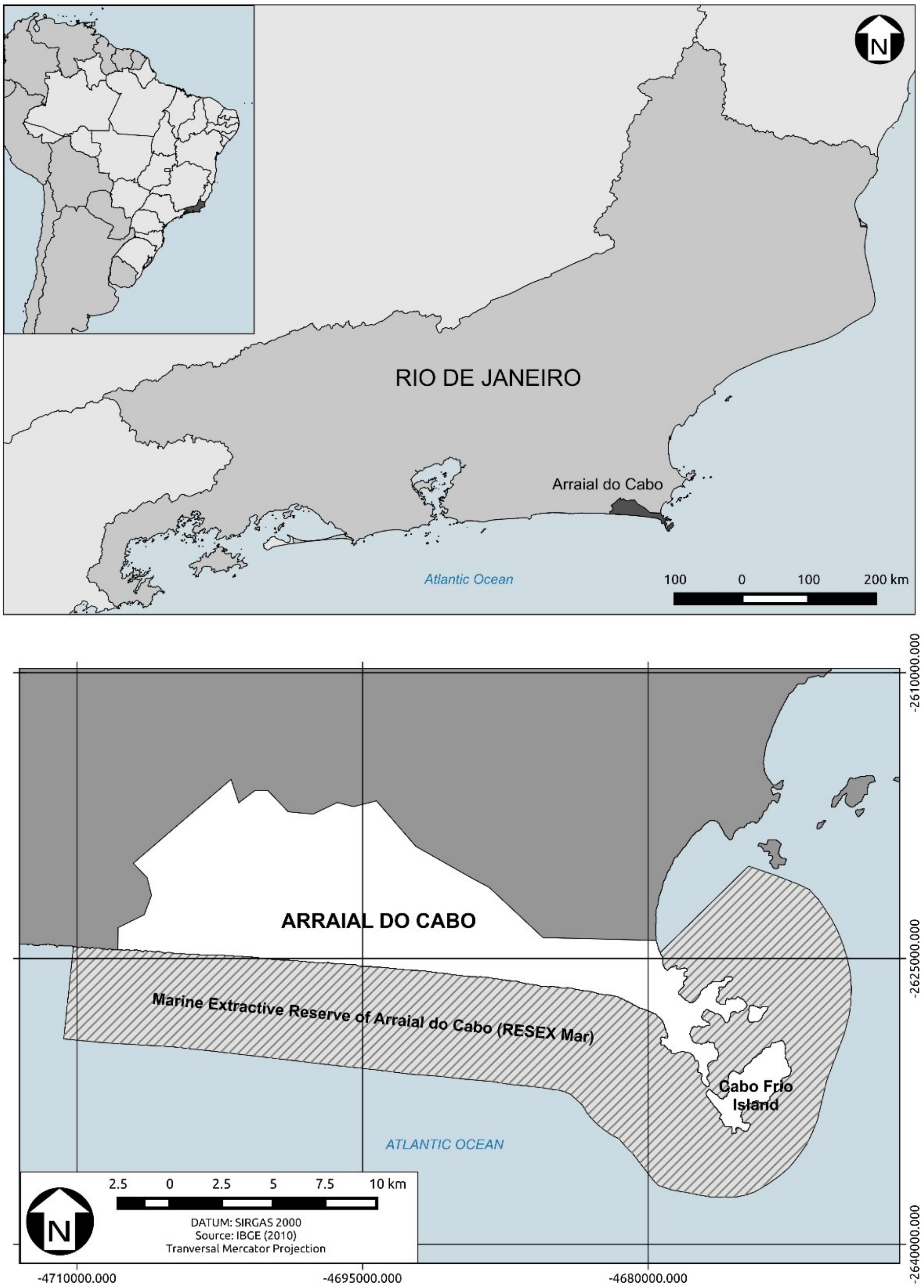
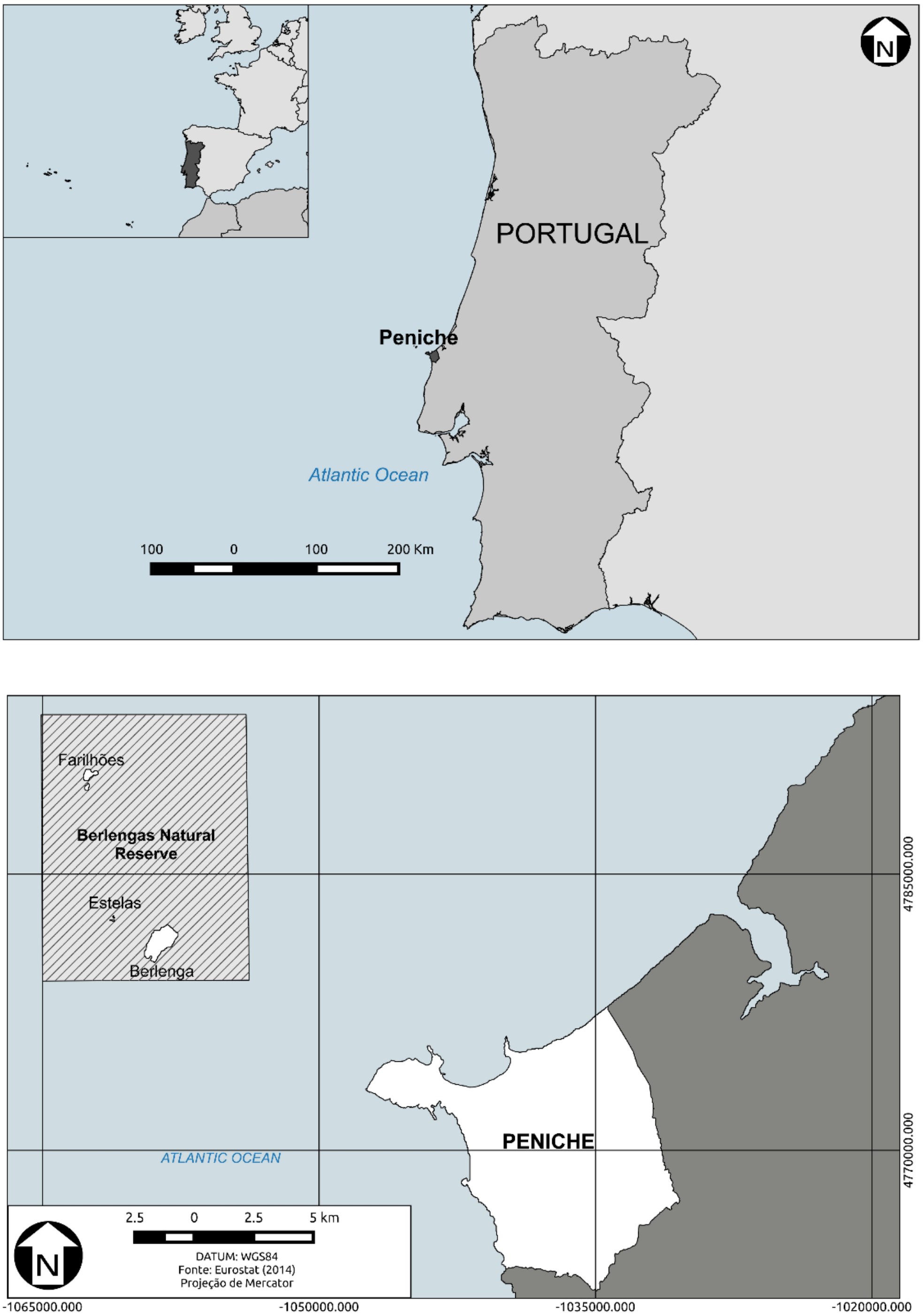


Figure 2. Location of the city of Peniche and the Marine Nature Reserve of Berlengas, Peniche, Portugal.



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Heitor de Oliveira Braga - PhD Student in Marine Ecology at the Centre For Functional Ecology (CFE), University of Coimbra, Portugal. It has experience in Ecology, with an emphasis on local ecological knowledge (LEK), fishing communities, human ecology, ethnobiology, ethnoecology, ethnozoology and environmental education. It works with local ecological knowledge (LEK) in two marine reserves, Portugal / Brazil.

Miguel Pardal is an Associate Professor at the Life Sciences Department of the University of Coimbra and the coordinator of the Marine Coastal Processes Research Line of the Centre for Functional Ecology (CFE). In the last twenty years supervised over 20 PhD students and 40 MSc students. So far has already published over 250 ISI papers and 15 book chapters as co-author.

Ulisses M Azeiteiro is a Senior Professor (Associate Professor with Habilitation and Tenure) and Coordinator of the Climate Change and Biodiversity Assets Unit from the Biology Department and Integrated Member/Senior Researcher of the Centre for Environmental and Marine Studies (CESAM) at University of Aveiro in Portugal. His main interests are the Impacts of Climate Change in the Marine Environment (Biology and Ecology of Global Change) and Adaptation to Climate Change in the Context of Sustainable Development (Social and Environmental Sustainability and Climate Change). Research Coordinator since 2008 (Research Line Long Term Ecological Response to Global Changes at IMAR-CMA – Marine and Environmental Research from 2008 to 2010 and Research Group Social-Economic Governance and Sustainability from the Centre for Functional Ecology, hosted by the Faculty of Sciences and Technology at University of Coimbra from 2010 to 2016) was member of several evaluation panels from research projects and grants (International, European and National - Portuguese and outside Portugal), member of the organizing and scientific committees of more than 100 international and national congresses, member of more than 150 exam panels for viva voice examinations (for PhD and MSc) and carer assessment and supervised over 50 Postgraduate students (MSc and PhD students). Professor Ulisses M Azeiteiro has written, co-written, edited or co-edited more than 200 publications, including books (> 20), book chapters (> 50), Special Issues of Scientific Journals and papers in refereed journals (> 75 ISI and > 50 peer reviewed).

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