Heitor de Oliveira Braga

Fishers' local ecological knowledge (LEK) in the Atlantic Ocean (Brazil and Portugal): The case study of the Brazilian sardine and the European pilchard

Tese de doutoramento em Biociências, ramo de especialização em Ecologia Marinha,
orientada pelo Professor Doutor Miguel Ângelo do Carmo Pardal e pelo Professor Doutor Ulisses Miranda Azeiteiro
e apresentada ao Departamento de Ciências da Vida da Faculdade de Ciências e Tecnologia da Universidade de Coimbra

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FCTUC FACULDADE DE CIÊNCIAS E TECNOLOGIA
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Doctoral thesis in Biosciences, scientific area of Marine Ecology, supervised by Professor Miguel Ângelo do Carmo Pardal and Professor Ulisses Miranda Azeiteiro, presented to the Faculty of Sciences and Technology of the University of Coimbra

Tese de doutoramento em Biociências, ramo de especialização em Ecologia Marinha, orientada pelo Professor Doutor Miguel Ângelo do Carmo Pardal e pelo Professor Doutor Ulisses Miranda Azeiteiro, apresentada à Faculdade de Ciências e Tecnologia da Universidade de Coimbra

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"O passado também se inventa. O nosso e o dos outros. É uma das funções do presente, que não se vive à espera que o futuro nos caia dos céus, conquistado e imaginado por outros"

Eduardo Lourenço

Thesis Outline

The thesis is structured in seven chapters: the first corresponds to the general introduction that presents the topic to be discussed in the later sections (adapted from a published book chapter), and the objectives of the thesis; four chapters with correlated themes (published or submitted for publication in scientific journals in the fields of biological sciences, marine ecology, and human ecology); a general discussion of all the findings (chapter 6) of the developed chapters; and a final chapter with the conclusion of the present investigation. The publications that support this thesis are listed below:

General Introduction

Braga HO, Pardal MA, Azeiteiro UM (2018) 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. In: Leal Filho W., Manolas E., Azul A., Azeiteiro U., McGhie H. (eds) Handbook of Climate Change Communication Climate Change Management. Springer, Cham, 2:237-262. doi: 10.1007/978-3-319-70066-3_16.

Chapter 1

Braga HO, Azeiteiro UM, Oliveira HM, Pardal, MA (2017) Evaluating fishermen's conservation attitudes and local ecological knowledge of the European sardine (*Sardina pilchardus*), Peniche, Portugal. Journal of Ethnobiology and Ethnomedicine, 13:25. doi: 10.1186/s13002-017-0154-y.

Chapter 2

Braga HO, Pardal MA, Azeiteiro UM (2017) Sharing fishers´ ethnoecological knowledge of the European pilchard (*Sardina pilchardus*) in the westernmost fishing community in Europe. Journal of Ethnobiology and Ethnomedicine, 13:52. doi: 10.1186/s13002-017-0181-8.

Chapter 3

Braga, HO, Azeiteiro, UM, Oliveira, HM, Pardal MA Using the fisher´s Local Ecological Knowledge (LEK) and their attitudes to assist in the management of the Brazilian sardinella (*Sardinella brasiliensis*) in the Southwestern Atlantic. Submitted for publication in Human Ecology.

Chapter 4

Braga HO, Pardal MA, Cruz RCM, Alvarenga TC, Azeiteiro UM Local ecological knowledge (LEK) of the Brazilian sardine, *Sardinella brasiliensis* (Steindachner, 1879): a synthesis of the ethnoecology a Bio-Resource in a typical fishing village of Rio de Janeiro State, Brazil. Submitted for publication in Ocean & Coastal Management.

Thesis should be cited as:

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Contents

Summary

In the face of the current non-linear and abrupt changes in ecosystems around the world, a systematic impact has arisen to the environmental dynamics of the coastal systems. At their essential intermediate trophic level in the marine system, sardines are recognized for being highly susceptible to the deregulation of their stocks when subjected to intensive exploitation. Given this, there are significant difficulties of management and participatory coastal management of the species of sardines in the Atlantic Ocean. In this way, local ecological knowledge (LEK) emerges as an auxiliary tool that seeks to extract specific information about an individual about the environment as well as to understand the attitudes of local individuals regarding a resource as a way to improve biodiversity conservation practices. Therefore, the present thesis sought to evaluate and share local ecological knowledge (LEK) and attitudes for the conservation of European pilchard (*Sardina pilchardus*) and Brazilian sardine (*Sardinella brasiliensis*) in two fishing villages (Peniche, District of Leiria, Portugal and Arraial do Cabo, State of Rio de Janeiro, Brazil). This study was based on 221 semi-structured interviews conducted with fishermen from Peniche (N = 87) about European sardines, and with fishers from Arraial do Cabo (N = 134) about Brazilian sardine. The data extracted from the interviews were qualitatively and quantitatively analysed, and the LEK made available was compared with the literature following an emic-etic approach. Additives knowledge indicators and attitudes about sardines were created for comparison purposes. The classification adopted to evaluate the LEK, and the attitudes respected the premises of the three-point Likert scale. It was also sought to investigate possible correlations between LEK, attitudes and the profile of fishers from both communities. The statistical treatments performed were calculated using program R version 3.3.2. The profiles of the interviewees of the studied communities were investigated and measured succinctly. Informants shared detailed informal knowledge of the significant biological and ecological aspects of the clupeoids in question. Taboos and food aversions were present inexpressively and were not related to conservation measures. Fishers from both Atlantic communities presented moderate local ecological knowledge about sardines when compared to the biological data already published of this small pelagic species. Attitudes towards conservation of sardines were classified as positive in Peniche, while in the Brazilian community analyzed, they were

moderate. In Peniche, attitudes showed to be a predictor of LEK, age and educational level of informants. Otherwise, in Arraial do Cabo the variables of the fisher´s profile (source of income, educational level, boat ownership, association with fishing colony and occupation) showed a correlation with LEK and with conservationist attitudes. Encouraging the continuation of regular educational training of informants and the inclusion of environmental education programs with the sharing of information on sardine conservation. This ethnobiological study reported comparable results with other studies examining LEK and local community attitudes about a natural resource, which reaffirms the importance of this socio-ecological tool for environmental management. Informal knowledge not compatible with the literature should not be discarded. This type of information can be further analysed and used in the formulation of testable hypotheses for future investigations of the species studied. The next step would be to include the LEK provided by the surveyed communities for analysis at meetings between all actors directly involved with the fishing resource. This procedure can collaborate and promote greater social inclusion of the less favored in the fisheries management decision-making in the Portuguese and Brazilian communities verified. A discussion with the participation of all the interested parties, without preconceived privileges to any of those involved, becomes of extreme importance because it enables reliability among the participants of these assemblies. This process, if well conducted, still can generate a better understanding of the predisposition of these communities to conserve the environmental resource. Also, this participatory management strategy may also provide an opportunity for local populations to acquire reliable and more scientific knowledge about this depleting fishing resource. Finally, a continuous exchange of information between ecologists and ethnobiologists is suggested on possible gaps in knowledge that may arise about fish stocks in both Atlantic systems.

Keywords: Attitudes; Local ecological knowledge; Ethnobiology; Ethnoecology; Peniche; European pilchard; Arraial do Cabo; Brazilian sardine; Artisanal fisheries.

Resumo

Em virtude das actuais mudanças não-lineares e abruptas nos ecossistemas em todo o planeta, a dinâmica ambiental dos sistemas costeiros tem sido bastante modificada. Por ocuparem o nível trófico intermediário essencial no sistema marinho, as sardinhas são reconhecidas por serem altamente susceptíveis a grandes alterações dos seus efectivos populacionais quando submetidas à exploração intensiva. Diante de tal cenário, observam-se grandes dificuldades na gestão costeira (que se quer participativa) das espécies de sardinhas no oceano Atlântico. Desse modo, o conhecimento ecológico local (CEL) surge como uma ferramenta auxiliar que busca extrair informações específicas de um indivíduo em relação ao meio ambiente como também compreender as atitudes de indivíduos locais no que tange a um recurso em particular, como forma de melhorar as práticas de conservação da biodiversidade. Por conseguinte, a presente tese tentou avaliar o conhecimento ecológico local (CEL), bem como as atitudes para a conservação da sardinha europeia (*Sardina pilchardus*) e da sardinha brasileira (*Sardinella brasiliensis*) em duas aldeias piscatórias (Peniche, Distrito de Leiria, Portugal; e Arraial do Cabo, Estado do Rio de Janeiro, Brasil). Este estudo baseou-se em 221 entrevistas semiestruturadas realizadas aleatoriamente com pescadores de Peniche (N = 87) acerca da sardinha europeia, e com pescadores de Arraial do Cabo (N = 134) sobre a sardinha brasileira. Os dados extraídos das entrevistas foram analisados de modo qualitativo e quantitativo e o CEL disponibilizado foi comparado com a literatura através da utilização das abordagens êmica e ética. Foram criados índices para medir o CEL e as atitudes dos pescadores em relação à conservação das espécies de sardinhas. A classificação adotada para avaliar o CEL e as atitudes respeitou as premissas da escala de três pontos de Likert. Por último, também foram investigadas as possíveis correlações entre CEL, atitudes e o perfil dos pescadores de ambas as comunidades. Os tratamentos estatísticos realizados foram calculados por meio do programa R versão 3.3.2. Os perfis dos entrevistados das comunidades estudadas foram investigados e analisados sucintamente. Os entrevistados compartilharam conhecimentos informais detalhados dos principais aspectos biológicos e ecológicos dos clupeóides em questão. Os tabus e aversões alimentares estiveram presentes de forma inexpressiva e não foram relacionados com medidas conservacionistas. Os pescadores de ambas as comunidades Atlânticas apresentaram um conhecimento ecológico local moderado acerca das sardinhas quando comparados aos

dados biológicos já publicados dessas pequenas espécies pelágicas. Em Peniche, houve a correlação entre as atitudes e o CEL, a idade e o nível educacional dos informantes respectivamente. Por outro lado, em Arraial do Cabo as variáveis do perfil dos pescadores (fonte de renda, nível educacional, propriedade de embarcação, associação à colónia de pescadores e ocupação) mostraram correlação com o CEL e com as atitudes conservacionistas. O incentivo à continuação da formação educacional convencional dos informantes (pescadores) e a inserção de programas de educação ambiental acompanhados de informações acerca da conservação da sardinha nas aldeias de pescadores investigadas são essenciais para estabelecer e melhorar as atitudes conservacionistas. Este estudo etnobiológico reportou resultados comparáveis com outros estudos que investigam o LEK e atitudes de comunidades locais acerca de um determinado recurso natural, o que reafirma a importância desta ferramenta sócio-ecológica para a gestão ambiental. O conhecimento informal não compatível com a literatura não deve ser totalmente descartado. Esse tipo de informação pode ainda ser analisado minuciosamente e utilizado na formulação de hipóteses para futuras investigações acerca da espécie estudada. O próximo passo seria incluir o CEL fornecido pelas comunidades estudadas para análises em reuniões entre todos os atores envolvidos directamente com o recurso pesqueiro. Esse procedimento pode promover uma maior inclusão social dos menos favorecidos nas decisões relativas à gestão dos stocks pesqueiros nas comunidades portuguesa e brasileira. Uma discussão com a participação de todos os interessados, sem privilégios preconcebidos a nenhum dos envolvidos, torna-se de extrema importância pois aumenta a confiança entre todos os envolvidos. Este processo, se bem conduzido, ainda tem a capacidade de gerar um melhor entendimento da predisposição dessas comunidades em conservar o recurso ambiental. Além disso, esta estratégia de gestão participativa também pode proporcionar uma oportunidade das populações locais adquirirem conhecimentos mais científicos sobre esse recurso pesqueiro em questão. Por fim, sugere-se ainda uma contínua troca de informações entre ecólogos e etnobiólogos sobre as possíveis lacunas de informações que possam surgir relativamente aos stocks pesqueiros em ambos os sistemas Atlânticos.

Palavra-chave: Atitudes; Conhecimento ecológico local; Etnobiologia; Etnoecologia; Peniche; Sardinha europeia; Arraial do Cabo; Sardinha brasileira; Pesca artesanal.

1. General Introduction

"Ethnobiology is the scientific study of dynamic relationships among people, biota, and environments. The diversity of perspectives in ethnobiology is our greatest strength. It allows us to examine complex, dynamic interactions between human and natural systems, and enhances our intellectual merit and broader impacts"

International Society of Ethnobiology (ISE)

1.1 Introduction

As there is no sufficient knowledge on the capacity of 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; Pardo-de-Santayana and Macía 2015). 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). Biocultural approaches in conservation studies, management and 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, 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 (Olsson and Folke 2001; 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 and for conservation purposes (Gómez-Baggethun et al. 2010; Bender et al. 2014; Mmassy and Røskaft 2014; Macdonald et al. 2014; Leeney and Poncelet 2015; Bevilacqua et al. 2016; Frans and Augé 2016; Silvano and Begossi 2016; Zhang and Vincent 2017). 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. 2012a).

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 folk taxonomy 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). Artisanal fishers can be a valid source of information in situations where there is insufficient data available on fishery resources (Johannes 1998; Silvano et al. 2006). 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).

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. 2012b; Viegas et al. 2016). Brazil, solutions to conservation issues are often shadowed by a rapid economic growth and political short-term agendas. The resulting management decisions may sometimes 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.

1.2 Local Ecological Knowledge in Brazil

Ethnobiology exhibits evident growth as a science in Latin America, especially Brazil and Mexico (Albuquerque et al. 2013). This line of recent research in Brazil had a boost in scientific production since the beginning of the 21st century, being more prominent over the past years (Alves and Souto 2011). Brazil due to its peculiarities proved to be a site of great potential for studies of this scientific nature, with the ecologist José Marques as a precursor in the development of ethnoecology in this country (Albuquerque and Alves 2016).

There is great interest in scientific research based on fishers' local ecological knowledge (LEK) on coastal and estuary sites in Brazil (Alves and Souto 2011). Fisher's LEK in Brazil includes detailed knowledge of the conservation of reef fish (Bender et al. 2013, 2014; Zapelini et al. 2017), on the relative abundance and aggregation of fish (Gerhardinger et al. 2009b) 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), and on closed season of fishing (Musiello-Fernandes et al. 2017).

This tool also includes studies 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), on fish trophic levels (Silvano and Begossi 2016), and about the life cycles of fish 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 a marine protected area (MPA) evaluation. Fishermen report that the MPA was only effective for reef species but was not efficient for the recovery of target species. This approach by using 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*) along the Bahia coast, generated refined data on the ecological characteristics of a critically endangered species (Ferreira et al. 2014). This initial study of the species based on LEK of expert fishers 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). In the same Brazilian State, expert fishers exhibited a detailed ethnoecological knowledge about the abundance, places of occurrence, fishing and conservation of *E. Itajara* in Abrolhos Bank (Zapelini et al. 2017).

Similarly, Herbst and Hanazaki (2014) highlighted the LEK regarding the life cycle of mullets (*Mugil liza*) 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 extensive 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). The LEK of local inhabitants in the Amazon and Atlantic Forest coast also extended the relationship between beliefs, food taboos and fish food chain (Begossi et al. 2004).

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). Nonetheless, studies that investigate the local ecological knowledge and the attitudes for the conservation of the Brazilian sardinella, *Sardinella brasiliensis* (Steindacher, 1879), and particularly in Arraial do Cabo, Rio de Janeiro, do not yet exist.

Given the high economic and social importance of this fishing resource in the Southwest Atlantic (Coelho-Souza et al. 2012), this small pelagic species becomes a potential subject of the LEK study. We highlight fishing villages in Rio de Janeiro where there is a considerable landing of this species (FIPERJ 2015). The Brazilian sardine LEK under these circumstances presents itself with an imminent possibility of providing information on the attitudes of fishers regarding conservation and practical knowledge of ecology and biology for overall small-scale fisheries records in Arraial do Cabo.

1.3 Local Ecological Knowledge in Portugal

There is still a huge gap in the scientific literature about ethnobiology in Portugal, with most local ecological knowledge (LEK) papers targeting ethnobotany. Research that seek to exploit the fisher´s LEK about a fishing resource through accurate methodologies are almost nonexistent in this country. There is only one study in Portugal that can fit this theme. The researchers in this work sought to associate fish-dependent data with the ecological knowledge of fishers to identify essential fish habitats (EFH) for seven species of skates (Rajidae) in Peniche (Serra-Pereira et al. 2014). Another study based on the traditional ecological knowledge (TEK) along the southwest coast of Portugal confirmed the importance of the local community with its traditions and ancestral character in the activity about the gooseneck barnacle (*Pollicipes pollicipes*) (Carvalho et al. 2017).

Other findings of an ethnobiological nature involving fishers in Portugal were more focused on TEK and folkloric aspects of reptiles in urban areas (Ceríaco et al. 2011; Ceríaco 2012). In the literature, there is also a study of LEK of fishers related to climate change, coastal issues and the factors that influence these two thematic areas in three

zones along the Portuguese coast (Delicado et al. 2012). Viegas et al. (2016) on the same line sought to explore the relationship between fishers and climate change in the community of Peniche, on the center-west coast of Portugal. However, there are no records of ethnobiological research involving pelagic fish in Europe, and particularly about the European pilchard, *Sardina pilchardus* (Walbaum, 1792).

There is a lack of social and cultural interest in fisheries policy on the European continent, especially in small-scale fishing communities (Urquhart et al. 2011). However, it is known that coastal fisheries in general strongly influence these social values of local communities and form an indispensable pillar of sustainable development (Symes and Phillipson 2009). Thus, fishermen's knowledge and practice emerge at this point as part of this social and cultural dimension, which shows the possible interrelationships between local communities and coastal ecosystems as a way of generating conservationist practices that are more interdisciplinary and adaptive (Poe et al. 2014).

Small-scale fisheries practices in Portugal are threatened in many local communities largely because of their low profitability and the impositions and limitations imposed by the European Union in general activity (Santos et al. 2012a). In Peniche, in particular, the life of the local community remains linked to fishing activities in the region, even with all the competition from other development centers, such as tourism (Santos et al. 2012b).

Thus, the knowledge of these fishermen acquired from years of practice and from generations to generations of fishing resources available in the region may be vulnerable to this current situation. Fishers from these areas (e.g., Peniche) can present information on the beliefs, food taboos and LEK of biology and ecology about various natural resources vulnerable to oceanographic conditions, such as European pilchard. Moreover, this ethnoscience also can contribute to the understanding of the predisposition of the fisherman to protect this important biological resource. Investigating the LEK becomes necessary so that this knowledge is not lost (Frans and Augé 2016), once we see the exodus of the young workforce and the aging of the current members (Santos et al. 2012b). Finally, Peniche offers a spatial context, with relevant conservation concerns, for the development of the use of fishers' local ecological knowledge in Portugal (and Europe).

1.4 Objectives

1.4.1 General Objective

The general objective of this thesis was to evaluate and share local ecological knowledge (LEK) and attitudes towards the conservation of European pilchard (*Sardina pilchardus*) and Brazilian sardine (*Sardinella brasiliensis*) in two fishing villages in different hemispheres in the Atlantic Ocean (Peniche, District of Leiria, Portugal and Arraial do Cabo, State of Rio de Janeiro, Brazil).

1.4.2 Specific Objectives

Chapter 1

In this first chapter of the thesis the objective was to evaluate the local ecological knowledge (LEK) and the attitudes regarding the conservation of the European pilchard (also known as the Atlantic sardine or European sardine), *Sardina pilchardus* (Walbaum, 1792) in the typical fishing village of Peniche, Portugal. Through social science tools sought to evaluate the LEK of the fisherman about the ecology and biology of sardines. It was also investigated the tendency of the interviewees to assume a positive, moderate, or negative attitude towards the conservation of the sardine population in small-scale fishing in Peniche. In this ethnoichthyology research, we also sought to explore the possible correlations between LEK and fishers' attitudes, as well as fisherman profile and LEK and attitudes.

Chapter 2

The objective of this chapter was to point out the local ecological knowledge (LEK) of the ecology and biology of the European pilchard (*Sardina pilchardus*) in the traditional fishing community of Peniche, Portugal. The profile of fishers and the likely human uses, beliefs, and taboos related to European pilchard were also explored. The main LEK data provided were also interpreted, discussed, and compared with published biological data of this species.

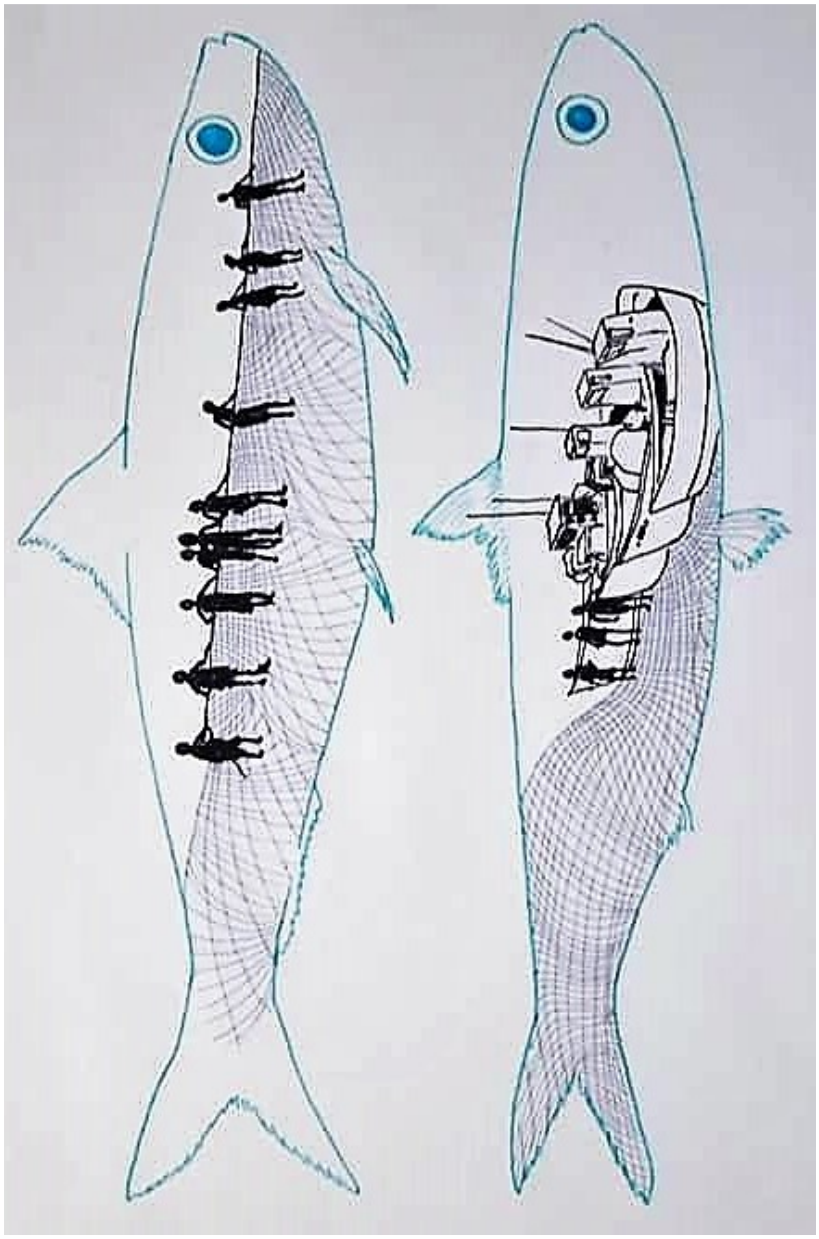
Chapter 3

This chapter aims to evaluate the local ecological knowledge (LEK), and the attitudes regarding the conservation of Brazilian sardinella (also known as Brazilian sardine), *Sardinella brasiliensis* (Steindacher, 1879) in the fishing village of the Marine Extractive Reserve of Arraial do Cabo, State of Rio de Janeiro, Brazil. This research also

aimed at reporting the significant relationships between the knowledge and attitudes indexes and the fishermen profile.

Chapter 4

The objective of the last chapter of this thesis was to document and share local ecological knowledge (LEK) and data on biology and ecology of *Sardinella brasiliensis* from the fishing village of Arraial do Cabo, Rio de Janeiro. It was also investigated the unwritten social rules and human uses of Brazilian sardine through ethnobiological tools of data collection. The present chapter also aimed to show and compare the leading LEK data of fishers with the literature on sardines.



2. Chapter I

Evaluating fishermen's conservation attitudes and local ecological knowledge of the European sardine (*Sardina pilchardus*), Peniche, Portugal

2.1 Abstract

2.1.1 Background

European sardines are an important fishing resource in the North Atlantic. Recognized for its great commercial and economic value in southern Europe, this resource currently has low stock indices. From this perspective, fishers' local ecological knowledge (LEK) is appreciated as an auxiliary tool in the management of sardines in this region. Our goal is to evaluate the LEK and attitudes towards the conservation of *Sardina pilchardus* in the typical fishing village of Peniche, Portugal.

2.1.2 Methods

From June to September 2016, we carried out 87 semi-structured interviews. The four main points of the interviews were interviewee profile, fishing structure, fishermen's LEK and attitudes towards sardine conservation. The interviews were qualitatively and quantitatively analyzed using a 3-point Likert scale. An LEK index and an attitude index were generated. Comparison analyses and correlations were made between the indices and variables of the interviewee profile and the fishing structure.

2.1.3 Results

The mean LEK index was 0.55 and was classified as moderate. The attitudes index in relation to conservation was 0.76 and was classified as positive. This index had a positive and significant correlation with the LEK index and a significant negative correlation with the fishermen's age. When the LEK index was compared with the educational level, significant differences were observed only between class A and class C. The result showed that the differences in the attitudes index were statistically significant when the three educational classes were compared.

2.1.4 Conclusions

The fishermen of Peniche in Portugal present moderate informal knowledge about the biology and ecology of sardines. Attitudes towards conservation were predominantly positive. Fishermen with greater LEK, with a higher educational level and at a younger age presented more positive attitudes in relation to environmental conservation issues in the present case of the sardine population. Nevertheless, the LEK is not necessarily related to the educational level of the fishermen. We suggest environmental education programs for the communities that depend on this resource. The use of LEK and fishermen's perceptions can help in the management of the European sardine fishery in Portugal.

2.2 Keywords

Attitudes; local ecological knowledge; European sardine; fishermen; conservation, Portugal.

2.3 Background

The European sardine *Sardina pilchardus* (Walbaum, 1792) is a small pelagic fish species from the family Clupeidae that is widely distributed in the northeast Atlantic Ocean, from Iceland and the North Sea to Mauritania and Senegal, and in the Mediterranean Sea, Sea of Marmara and Black Sea (Parrish et al. 1989). This species is a schooling and oceanodromous fish that occurs in several environments in the world's oceans (Parrish et al. 1989), mainly at depths between 10 and 100 m (often above 25 m) (Whitehead 1990; Tous et al. 2015). It is a warmer-water fish (Alheit et al. 2012), and it is usually found between the coastline and up to 100 km offshore (Tous et al. 2015).

The European sardine is a relatively short-lived species that exhibits rapid growth and high fertilization capacity (Jemaa et al. 2015). The main components of the sardine's diet are zooplankton and phytoplankton (Bode et al. 2004; Garrido et al. 2008a). Sardines are an important food item for marine mammals, predominantly the common dolphin (*Delphinus delphis*, Linnaeus, 1758), as well as seabirds and other, larger fish species (Garrido et al. 2008a; Preciado et al. 2008; Begoña Santos et al. 2014). Sardines allocate energy resources to grow predominantly during spring and summer (Nunes et al. 2011). The spawning season occurs over a broad spectrum between October and April (García-García et al. 2016) and is more pronounced in the months of December and February (Nunes et al. 2011).

Sardines support an important fishery in Atlantic Iberian waters (Correia et al. 2014). This important species of the North Atlantic is captured through purse-seine fisheries by Portuguese vessels (ICES 2013). It is recognized for its high commercial value and is responsible for a large part of the volume of fish discharged in these coastal waters (ICES 2013; INE, 2016; Teixeira et al. 2016). In Portugal, the sardine has great socioeconomic importance and is associated with recognized traditions for the Portuguese population (Teixeira et al. 2016). This fishing resource can be used for fresh food, bait for other fisheries and the canning industry (Vázquez-Rowe et al. 2014a; González-García et al. 2015).

The northwestern part of Portugal is the main area of recruitment for this pelagic species (ICES 2013). However, the level of recruitment in recent years has not been sufficient to recover the abundance of the species in coastal areas (INE, 2016). In 2012, 38% of the catches of sardines in European waters were carried out by Portugal, indicating a decrease compared to the previous year (ICES 2013). Regarding stock development over time, despite a decrease in observed fishing pressure in 2016, the recruitment of the species has been below the long-term average since 2005, and the biomass of fish aged 1 and older is at a low level (ICES 2016). Although fishing limits imposed since 2011 have contributed to the reduction of fishing pressure, stocks remain at very low levels (ICES 2016).

Effects of climate variability may also lead to changes in the sardine populations (Alheit et al. 2012). As a pelagic species, the sardine plays a prominent intermediary ecological role within the marine ecosystem (Cury et al. 2000). Moreover, with other pelagic species, it may contribute to the modification of the structure and functioning of the marine ecosystem as a result of eutrophication, overfishing and climate change (Daskalov 2002; Costalago et al. 2012). Due to all these factors, this pelagic fish, which represents the most abundant catch of the Portuguese fleet, is an important but difficult challenge for defining management goals (Nunes et al. 2011).

The current international policy of environmental resources management requires a change of paradigms through the inclusion of more delineated human perspectives on the environment (Folke 2006). In practice, the applicability of the knowledge of local actors about changes in the ecosystem being managed is based on processes that generate their knowledge, experience and concept of the dynamics of the environment (Folke et al. 2005). The combination of this institutional and organizational background with the ecological scale can make co-management more robust against external environmental

adversities (Olsson et al. 2004). Thus, socio-ecological approaches must be integrated into a wide spectrum and actively conducted and strengthened to improve a more participatory and adaptive governance of coastal systems (Adger et al. 2005).

Ethnozoology science studies are increasingly used in zoological and ecological research programs (Alves and Souto 2015). Specifically ethnoichthyological studies have been increasingly highlighted in recent years as an auxiliary tool in the management of fishery resources (Silvano and Begossi 2005; Silvano et al. 2006; Pinto et al. 2013, 2015). In this perspective, local ecological knowledge (LEK), meaning the specific knowledge of an individual about the environment (Yli-Pelkonen and Kohl 2005), can be used as a complementary way to conduct a more equitable and culturally sensitive approach to new conservation programs (Drew 2005). Additionally, it becomes useful to understand people's attitudes towards a particular resource to determine the effectiveness of management programs by showing their successes and failures (Malleret-King et al. 2006). Therefore, the main goal of the present study was to evaluate fishermen's local ecological knowledge and conservation attitudes to help understand and collaborate in better management of the European sardine in Portugal.

2.4 Methods

2.4.1 Study Area

This study was conducted in Peniche on the western coast of Portugal (39° 21' 32" N, 9° 22' 40" W; Figure 2.1), approximately 10 km from the Berlenga Marine Natural Reserve (Category Ia: IUCN Strict Nature Reserve). The westernmost fishing city of the European continent (Viegas et al. 2016) has an area of 77.55 km^2 and has a resident population of 27,628 (INE, 2015). The climate of Peniche is Csb (Mediterranean), according to the Köppen-Geiger climate classification: temperate with dry, mild summers (INE, 2015). The mean annual temperature in Peniche is 16.6°C with an annual rainfall of 873.8 mm (INE, 2015; IPMA 2016a).

The Peniche fishing port is the most important in the central region of Portugal and the second-most important of the country when accounting for the amounts of nominal fish catches (Santos et al. 2012a). The fishing community of Peniche is one of the oldest communities with the largest number of active fishermen in the central region of Portugal (Santos et al. 2012a). Maritime authorities have registered approximately 1105 fishermen (996 in marine fishing), and fishing continues to have a significant and symbolic role in the economic and social activity of Peniche (INE, 2015).

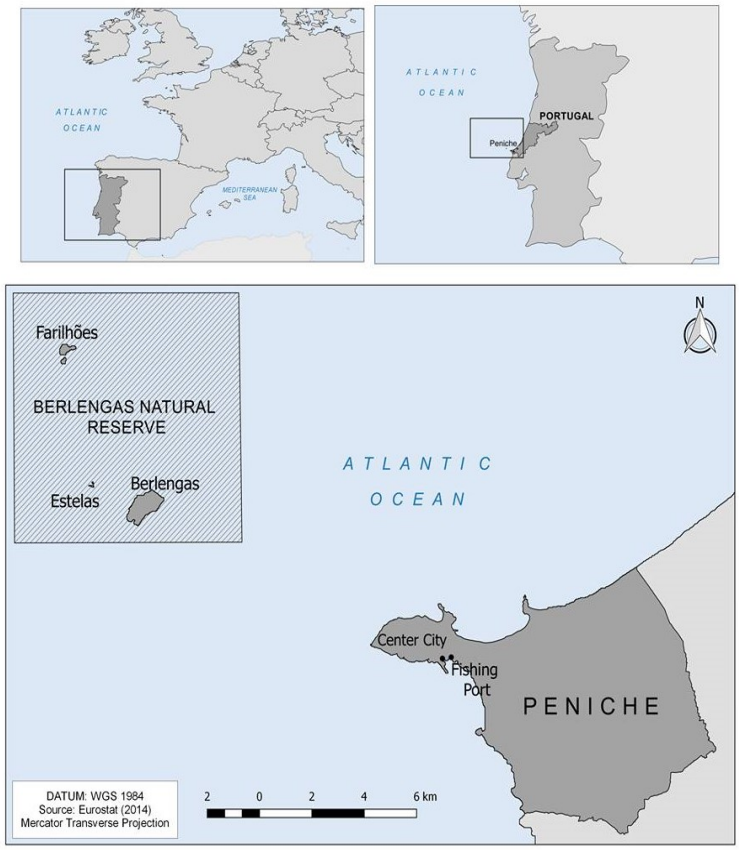


Figure 2.1 Study area of the fishery community (Peniche) on the western coast of Portugal, Iberian Peninsula. Source: Zucherato, B.

2.4.2 Ethical considerations

The state-owned company Docapesca – Portos e Lotas, SA, which is responsible for the first sale of fish and supports the fishing ports sector in Portugal, granted permission for the researcher to have free access to the fishing port facilities in Peniche. Before each interview, the respondents became aware of the objectives of the project, and the researcher requested permission to conduct the interviews. A "Statement of Informed Consent (IC)" was given to the interviewees, providing information about the researcher and the institution to which the researchers belong [see Additional File 1].

2.4.3 Data collection

To evaluate the fishermen's LEK and attitudes concerning the European sardine (*Sardina pilchardus*), individual interviews were conducted from June to September 2016 in the fishing community of Peniche. Successive visits were made to the Port of Peniche and places most frequented by fishermen in the region as a way of establishing a friendly and trustworthy ambience for interviewees. Interviews in the local community were

conducted randomly, and the approach to the fishermen occurred mainly during the arrivals and departures of the fishing boats in the port of Peniche.

Data collection was done through a semi-structured interview script (Table 2.1) (Newing 2010; Albuquerque et al. 2014). Interviews were recorded through notes and eventually through the use of tape recorders (Albuquerque et al. 2014). The questionnaire was applied and pre-tested with fishermen from the fishing port of Aveiro, Portugal, in order to improve the criteria of validity and reliability of the interview script structure (Dijkstra and Goedhart 2012).

The four guiding points of the interview were 1) interviewee profile (age, level of education, income source, stay in Peniche); (2) fishing structure (fishing currently, fishing experience, fishing effort); (3) the fisherman's LEK about the European pilchard (projective test, habitat, migration patterns, fish depth, schooling behavior, reproduction and spawning, growth and development, predators and prey, and fishing periods); (4) attitudes towards sardine conservation. (The fourth part of the questionnaire investigated the tendency of the respondents to take a positive, moderate, or negative attitude towards the conservation of the sardine population.) Attitudes were defined in this evaluation as "a psychological tendency that is expressed by evaluating a particular entity with some degree of favor or disfavor" (Eagly and Chaiken 1993).

At the beginning of the third part of the questionnaire, the respondents were shown two images (a drawing and a photograph on an electronic device; Figure 2.2) of the European pilchard so that they could visually identify the species and confirm the possible variations of European pilchard names. The images were presented in the same order to the respondents in this projective test (Silvano et al. 2006).

Table 2.1 Interview schedule applied in the community of Peniche, Portugal

Key points of interview	Topics
1 – Interviewee profile	Age? Level of education? Income source? Time of residence in Peniche?
2 – Fishing	Fishing experience? Fishing effort? Fishing currently?
3 – Fisherman's LEK	Projective test (identification of the species)
	Habitat? Migration pattern? Most found depth?
	Are schooling fish?
	Age of reproduction / maturation?
	Time of spawning and breeding?
	Rapid or short growth?
	Do they have eggs, larvae in their growth phase?
	Accumulation of fat (months or season)?
	Lifetime: long or short?
	Predators? What does sardine eat?
	Time of the last biological closure?
4 – Attitudes towards conservation	
Topics	
Do you think it is necessary to stop fishing the sardines for a few months every year to preserve them?	
What do you do when fishing very small sardines?	
During sardine fishing, fish of various sizes can come. Should sardines of all sizes be harvested?	
Are there any natural predators of sardines in the sea?	
Can and should all kinds of fishing gear be used in sardine fishing?	
Do you catch sardines at the beginning of the year? Would you catch them this time?	
Do you fish juvenile sardines?	

Figure 2.2 Images used in the projective test of European sardine (*Sardina pilchardus*, Walbaum, 1792). Sources: A: Gervais, H.; B: GICIM Database of the Muséum National d'Histoire Naturelle – Froese, R. and D. Pauly. Editors. 2016. FishBase.

2.4.4 Data analyses

This ethnoichthyology research was based on an emic-etic approach between the community (local knowledge/insider view) and the researchers (scientific knowledge/outsider view) (Harris 1976). The model of integrating various individual competencies was used in the analysis of interview data, taking into account all information provided by the respondents (Marques 1991). The level of education was classified in the following classes of the Portuguese education system: primary education, A = 1st Cycle (1-4 years); B = 2nd Cycle (5-6 years); C = 3rd Cycle (7-9 years); and secondary education (10-12 years). The illiterate and higher education (more than 12 years) classes were not included in the analysis because representatives of these classes were absent from the sample.

Data on the fishermen's LEK and attitudes towards conservation of sardines (points 3 and 4 of the questionnaire) were extracted and analyzed qualitatively and quantitatively. This analysis was performed by using a three-point Likert scale (values between 0 and 1) (Likert 1932). To analyze the levels of LEK, the correct scientific answers were scored with a value equal to 1, the answers with part of the correct answer were scored with 0.5, and the wrong answers or no response were scored with 0. For attitudes towards conservation of sardines, favorable conservation attitudes received scores with a value of 1; responses with moderate attitudes, 0.5; and responses with negative attitudes or no attitude, 0.

LEK and the attitudes of interviewees were compared quantitatively through additive indicators (Castilho et al. 2013; Braga and Schiavetti 2013). Indicators were obtained by summing the individual score of each respondent, and this score was divided by the maximum possible score. The value obtained from each subject was calculated by afterwards by the average of all these values. The indicators of LEK and attitudes were classified in three categories (0-0.33, 0.34-0.66, and 0.67-1). LEK was classified as below average, within average or above average by comparison with the scientific literature. Attitudes were classified as negative, moderate, and positive. All analyses (a one-way ANOVA parametric test, Kruskal-Wallis (H) non-parametric test and correlation analyses (r) were performed using the R Project for Statistical Computing version 3.3.2 (Team and others 2016).

2.5 Results

2.5.1 Fishermen's Interviews Profile

Fieldwork was conducted with 87 fishermen in Peniche, Portugal, through the semi-structured questionnaire. This sample represents approximately 9% of the registered fishermen by the maritime authorities (registered activity). In this fishing community, 68% of the interviewees were born in Peniche, 17% lived in Peniche since childhood, 8% since teenagers, 6% since the age of majority, and only one fisherman does not live in Peniche, but belongs to Port of Peniche (56% in activity). Their ages ranged from 25 to 76, with a mean age of 58.3 (sd = 10.7). The years of fishing experience varied from 3 to 60, with a mean of 39.1 years (sd = 11.0). The minimum monthly income was 208 € (Euros) and the maximum 3000 €, with an average of 810.5 € (sd = 452.0 €). The average offshore fishing time was 133.83 hours (sd = 498.5 h), with a minimum time of 3 hours and a maximum effort of 2922 hours (Table 2.2).

Table 2.2 Fishermen's profile in Peniche, Portugal (N = 87).

	Minimum	Median	Mean	Maximum	Standard Deviation (sd)
Age (years)	25.0	60.0	58.3	76.0	10.7
Fishing experience (years)	3.0	40.0	39.0	60.0	11.0
Income source (EUR)	208.0	700.0	810.5	3000.0	452.0
Fishing effort (hours)	3.0	11.0	133.8	2922.0	498.5

2.5.2 Index of LEK and attitudes towards the conservation of the European sardine

Most the fishermen (N = 86) correctly identified the image of the European sardine in the projective test. Only one interviewee was not sure how to identify the species. The average indicator of the LEK about European sardines for the fishermen in the fishing community of Peniche was 0.55. The median of the knowledge indicator was 0.58. The minimum indicator registered was 0.31, and the maximum was 0.77. Based on the knowledge indicator obtained, the LEK of the fishermen was classified as moderate. Only one interviewee was scored within the range of the low knowledge class, 85% were classified with moderate knowledge and 13.8% had high knowledge, when this knowledge was compared with the scientific literature.

Regarding attitudes towards the conservation of European sardines, the average indicator value was 0.76, with a minimum observed index of 0.5 and a maximum of 1. The median of the indicator was 0.78. Attitudes towards sardine conservation were classified as positive. None of the respondents registered in the range of negative attitudes, 20.7% had moderate attitudes and 79.3% had positive attitudes. Seven fishermen were scored within the maximum attitude indicator in relation to the conservation of sardines.

2.5.3 LEK and Attitudes: Correlation and Comparison Analysis

Spearman's correlation was made between the LEK and attitudes indices and between the indices and the socio-demographic variables collected in the fieldwork (ages of fishermen, fishing experience, income source and fishing time). A comparison between the indices of LEK and attitudes and the educational classes was also performed. Only significant correlations were explored in this work.

The index of LEK had a positive and significant correlation ($N = 87$, $S = 79399.5$, $p = 0.0095$) with the index of conservation attitudes. In this study, fishermen with a more accurate knowledge of the species tended to have more positive attitudes towards the conservation of sardines. To compare the LEK index with the differences in educational classes, the ANOVA test was performed ($F = 3.1$; $p = 0.05$; Figure 2.3). The result showed that the differences in knowledge indices are statistically significant when comparing class A with class C but not when comparing class A with class B and class B with class C.

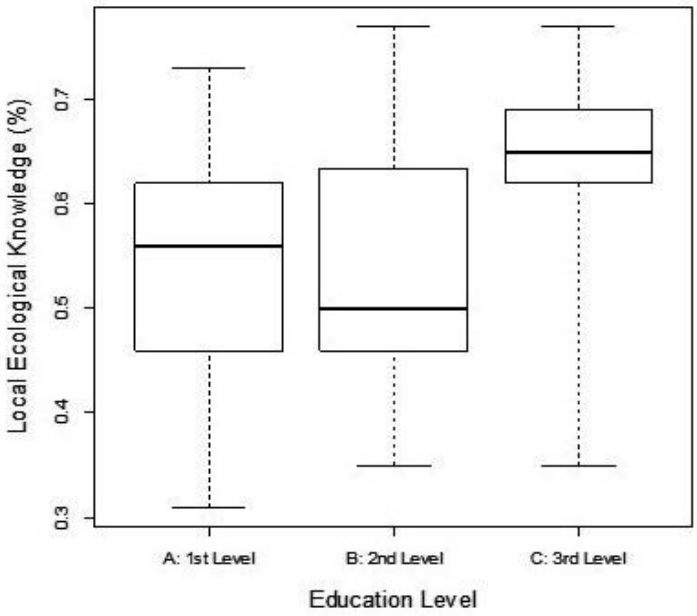


Figure 2.3 Comparison of the LEK index with the educational classes (A = 1-4 years); B = (5-6 years); C = (7-12 years); F = 3.1; p = 0.05; N = 87).

In this sample, there was a negative and significant correlation (N = 87, S = 137894.9, p = 0.016) between the age of the fishermen interviewed and the index of attitudes regarding the conservation of European sardines. It can be said that older fishermen tended to have negative attitudes towards species conservation. The Kruskal-Wallis test was performed to compare the index of attitudes in the different classes of education (N = 87, K = 124.74; $p < 0.01$, Figure 2.4). The result showed that the differences in attitude indices are statistically significant when comparing the three educational classes. Although the medians are very close, the variation is gradually lower from class A to class C. overall, it was observed that class C is more homogeneous.

To verify in a more detailed way the behavior of the correlation of LEK index with the index of conservationist attitudes, each educational class was analyzed separately. In the first class of educational level, the results showed a positive and significant correlation (S = 23627.01, p = 0.037). When the two indices were compared within the second educational-level class, a positive and significant correlation was also noted (t = 2.112, df = 17, p = 0.04979). For the third class of education, the results showed a non-significant difference (t = -0.9558, df = 8, p = 0.3671).

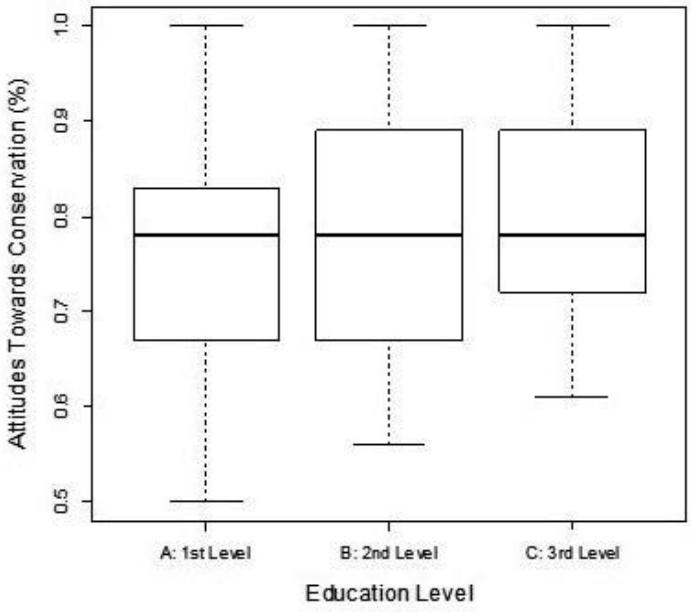


Figure 2.4 Comparison of the index of attitudes in the different classes of education (K = 124.74; p < 0.01; N = 87).

2.6 Discussion

2.6.1 Fishermen´s LEK about the European sardine

The fishermen's LEK in the fishing community of Peniche was moderate when compared with the scientific literature (Parrish et al. 1989; Whitehead 1990; Bode et al. 2004; Garrido et al. 2008a; Preciado et al. 2008; Nunes et al. 2011; Alheit et al. 2012; ICES 2013; Begoña Santos et al. 2014; Tous et al. 2015; Jemaa et al. 2015; IPMA 2016b). In the northern North Sea (International Council for the Exploration of the Sea – ICES Division IVa), the fishermen's knowledge of megrim (*Lepidorhombus whiffiagonis*, Walbaum, 1792) was also potentially high and was also indicated to contribute to the evaluation and management of this species (Silvano et al. 2006). Fishermen on the Murray River, Australia, had considerable LEK about Murray crayfish (*Euastacus armatus*, von Martens, 1866) when their knowledge was compared to scientific research and fisher catch cards (Zukowski et al. 2011). Ethnoecologists have observed that fishermen from Australia (North Stradbroke Island, Queensland) and Brazil (Búzios Island, Rio de Janeiro) also presented a local ecological knowledge about (*Pomatomus saltatrix*, Linnaeus, 1766) comparable to the available literature and collaborated on new hypotheses for investigation (Silvano and Begossi 2005). The considerable informal knowledge of pelagic fish found in the present work indicates that fishermen in Peniche seek to better understand the biology and ecology of the species, allowing them to better

understand its behavior patterns and possibly to improve the quality of their fishing efforts in adverse circumstances.

The capture of sardines occurs mainly through the purse-seine fisheries along the Portuguese coast (Anderson et al. 2012). It is known that purse-seine fisheries in Portugal have sardines and other small pelagic fish as their main target (ICES 2013; IPMA 2016b). In the port of Peniche, the sardine plays a prominent role in the local fishing community (Santos et al. 2012a). Thus, the importance of this resource in general may have contributed to local fishermen seeking to better understand the species during the fishing effort through practical observation and dialogues with the master of the vessel. This LEK has probably been complemented by other sources of information (brochures available in the fishing warehouses, the media, and the Internet).

It is known that this ethnoichthyological knowledge of fishermen provides important information for fishery managers. Fishermen livelihoods depend directly on the marine bioresources that supports their economic, social and cultural development (Pinto et al. 2015). Traditional knowledge contributes to conservation, management and cultural sustainable practices (The Role of Culture in a Sustainable Environment) providing information about overfished species in order to a better management of natural resources (Pinto et al. 2013). Given the current uncertainties in the evaluation of the stock and the exploitation status of the sardine (ICES 2016), our study supports the idea that this available and low-cost knowledge can help contribute to an adaptive management of species with scarce data sources in the integration of managers, politicians, ecologists and fishermen (Aylesworth et al. 2016). Moreover, a detailed analysis of the LEK available here can be used to complement pre-existing ecological data (Rist et al. 2010) as well as to understand the dynamics of the decline in fish stocks of marine species (Dulvy and Polunin 2004). LEK data that do not correspond to the scientific literature should not necessarily be discarded. According to Drew (2005), these data can be tested as new hypotheses for new investigations.

2.6.2 Attitudes towards conservation of sardines

In the fishing community of Peniche, fishermen's attitudes about the conservation of the sardine population were predominantly positive. The same trend was observed in the Fanjingshan National Nature Reserve, southwest China, where informants had positive and supportive attitudes towards the conservation of primate species (Ellwanger et al. 2015). Fishermen experts belonging to two fishermen's colonies in Ilhéus, southern

Bahia State, Brazil, also had positive attitudes regarding the conservation of sea turtles (Braga and Schiavetti 2013). Household members from the local community in the Maputo Elephant Reserve (MER) in southern Mozambique showed predominantly positive attitudes towards wildlife and conservation in that area (de Boer and Baquete 1998).

Even though most of the fishermen in Peniche presented favorable attitudes towards conservation of the sardine population, the sardine stock in the Iberian Peninsula is still quite unstable with low recruitment levels (ICES 2016). It can be said that these positive attitudes are still recent in the fishing community of Peniche. The most negative attitudes, carried out in the past through fishing pressure along with changing environmental factors, may have contributed to the current depletion of this fishing resource.

Commonly, a system with more enforced monitoring and enforced rules has an abundance of more predictable resources, being able to economically and socially privilege the local community (Stevens et al. 2015). The imposition by the government of rules for managing a biological resource can modify the fishermen's behavior due to the possibility of punishment (Braga and Schiavetti 2013). However, it is known that co-management that encompasses social, economic and ecological attributes is better suited to more sustainable fishing worldwide (Gutiérrez et al. 2011). Thus, this positive attitude towards the conservation of sardines in Peniche can also be justified by the rules imposed by the Directorate General for Natural Resources, Safety and Maritime Services of the Ministry of Agriculture and the Sea (MAS) of Portugal. The fear of possible penalties may have contributed to the presentation of more positive attitudes regarding the conservation of this biological resource in exhaustion.

Another hypothesis is that even if the fishermen of the fishing community of Peniche have a propensity to have positive attitudes towards the conservation of sardines, in practice, this attitude may not be realized. Failure to understand and manage fisheries, rather than being an important part of fisheries management, may be hindering the management of the biological resource (Hilborn 1985).

Understanding how a local community interacts with the available biological resources in the ecosystem, based on the people's attitudes towards and perceptions of the resource, has been increasingly used as a conservation tool (Kideghesho et al. 2007). The success of a management strategy should take into account the social dimension and the social acceptance of public policies and conservation strategies (Treves and Karanth

2003; Røskaft et al. 2007). The inclusion of this social context in the formulation of conservation measures for fish management is extremely important for its effectiveness (Pinto et al. 2015). There is an urgent need to understand how fishermen behave in regard to a biological resource and the substantial efforts that act on them (Richardson et al. 2005). This type of attitude research can help to provide a better orientation in management decisions as well as collaboration in the implementation of new policies (Fiallo and Jacobson 1995).

Thus, to include fishermen from the fishing fleet of Peniche in a more active and participatory way, seeking to understand their attitudes in practice about the sardine population is indispensable at this moment. This first step may be the beginning of a new trend of participatory management in the Iberian Peninsula so that this resource can be properly managed, and the approach applied in other coastal areas of Portugal.

2.6.3 Knowledge, Attitudes and other socio-economic variables

In the present study, there was a tendency for fishermen with more LEK about sardines to have more positive attitudes regarding conservation of the species. The knowledge of boaters in Tampa Bay in Florida has been positively correlated with attitudes supporting the conservation of the Florida manatee (Aipanjiguly et al. 2003). In Braga & Schiavetti (2013), the trend was the opposite of that found in our work. In that case, expert fishermen with more LEK about sea turtle species tended to have more negative attitudes regarding the conservation of this species (Braga and Schiavetti 2013). In the present work, the more educated fishermen of Peniche tended to have more positive attitudes towards the conservation of sardines. Members of a rural community in a conservation area in Natal, South Africa, who were asked about conservationist attitudes about fauna and flora in this area had a propensity to have more positive attitudes with the increase of the respondent's level of education (Infield 1988). The attitudes of the local community of Machalilla National Park in Ecuador towards the conservation and management of natural resources also had the same pattern as our study (Fiallo and Jacobson 1995). In the conservation area of Bhitarkanika, on the east coast of India, respondents with higher education showed more positive attitudes towards mangrove forest conservation, suggesting that increasing educational infrastructure is a way to improve conservationist attitudes of populations dependent on natural resources (Badola et al. 2012). In the case of residents of the Fanjingshan National Nature Reserve in China,

the educational level of the respondents had no significant effect on the attitudes (Ellwanger et al. 2015).

The higher level of education is noted as one of the factors for the improvement of people´s attitudes in relation to conservation (Fiallo and Jacobson 1995). Gelcich and collaborators (2005) suggest that the long-term educational approach can improve fishermen's behavioral attitudes towards a biological resource (Gelcich et al. 2005). Even though the Peniche fishermen have more positive attitudes towards sardine population conservation, educational and information programs can be implemented at the Port of Peniche as a way of consolidating this attitude in the local fishing community. Economic and environmental interests should be considered in these conservation programs (Daoutopoulos and Pyrovetsi 1990).

There is need for government to invest more in education. Programs that either fund education or technical assistance and knowledge transfer tend to improve attitudes towards conservation. The propensity for more sustainable behavior among fishermen is most likely when there is a sense between the environment and natural resources (Chen 2010). In this perspective, the local fishermen can better understand the importance of the catch limits and closed seasons established by the European Government and thus improve their commitment to the conservation of this resource. According to Chen (2010), if fishermen are more knowledgeable about the marine environment they may be more aware and more likely to act according to the fisheries policy norms established by the imposed fishing management (Chen 2010). Thus, the introduction of monthly meetings with the participation of all involved with the natural resources in an open and participatory manner should increase positive attitudes over time (Viegas et al. 2016). At these discussion meetings, we also suggest providing information on possible changes in the behavior of species seen by both stakeholders to improve the management of this fishery resource.

Comparing the local ecological knowledge index with the different education classes, significant differences were observed only between class A and class C, although the correlation was significant ($F = 3.1$; $p = 0.05$). As the interviews were limited to only 3 levels of education, the pattern of relationship between the attitudes index and the educational levels was not clear. Most likely, if there was a greater variation in education, this relationship could be better explained.

We can therefore say that the local ecological knowledge about sardines in Peniche is not necessarily related to the formal education of the respondents. Because it

is an active knowledge capable of responding to the presented circumstances, it can be expanded and incorporated into the generations (Hill et al. 2010), not necessarily with the increase of the education of the individual. Perhaps the second educational class of fishermen analyzed may contain individuals who have a more generalist focus on fishing. Therefore, they do not seek to better understand the behavior, ecology and biology of the species.

The older fishermen of our sample tended to have more negative attitudes regarding the conservation of the sardine population along the Portuguese Coast. The farmers' attitudes towards the conservation of Environmentally Sensitive Areas (ESA) in the Cambrian Mountains in the southwest of England are also explained by the age of the interviewees (Wilson 1996). In a local community in the District of Kuching in Malaysia, attitudes towards conservation of the deltaic mangrove forest areas were also correlated with the respondents' ages (Shuib et al. 2012). Rural landowners in the Cape Floral Kingdom in South Africa did not show a significant relationship between age and conservation attitudes towards Overberg Coastal Renosterveld (OCR) (Winter et al. 2005).

The older fishermen in the present case may have had this negative attitude because they were more active in the past when the catches were more abundant, government restrictions and species conservation were not priorities and the income source was not committed. Once the stock reduction began to change the success of the catches (ICES 2016), it became important to seek to understand the species as well as to respect its biological cycle.

2.7 Conclusions

This is the first study in Europe regarding the evaluation of the local ecological knowledge about *Sardina pilchardus*. The fishermen of Peniche in Portugal presented moderate informal knowledge about the biology and ecology of this species when compared to the scientific literature. Attitudes towards the conservation of European sardines were predominantly positive. Fishermen belonging to the fishing fleet of Peniche with greater LEK, with a higher level of education and younger in age were more likely to bear positive attitudes involving conservation of the sardine population. The LEK is not necessarily related to the educational level of the fishermen. Nevertheless, the results showed that the differences in the knowledge indices are statistically significant when comparing class A with class C.

This study from ethnoichthyology reports comparable results with other studies that investigate the attitudes of local communities towards the conservation of natural resources (Infield 1988; Fiallo and Jacobson 1995; Aipanjiguly et al. 2003; Badola et al. 2012) reaffirming the importance the ethnozoology and LEK as auxiliary tools in the management of natural resources (Silvano and Begossi 2005; Silvano et al. 2006; Pinto et al. 2013, 2015).

In view of this difference, we suggest environmental education programs with the entire fishing community of Peniche to stabilize positive attitudes towards the conservation of this natural resource. Fishermen with less educational instruction and older fishermen should have priority in the suggested conservation program. Dialogue between stakeholders (local actors, managers of local fishermen's associations, scientists and lawmakers), without privileging any parties, is advised for a better conservation strategy (Wilson 1996; Mellado et al. 2014).

Due to the large gap in the scientific literature on LEK in the Iberian Peninsula, and especially in Portugal (Braga et al. 2018), we suggest new studies of the same scientific nature in the Iberian Coast as a way of comparing our findings. The local ecological knowledge about European sardines that was considered incompatible with the scientific literature should not be completely discarded. This LEK can be used to formulate new hypotheses for future scientific research (Drew 2005; Silvano and Valbo-Jørgensen 2008). Such research, if well conducted, can help in better understanding the natural resource in question and assist in the recovery, management, action, and adjustment of the European sardine fishery on the Portuguese Coast.

2.8 Acknowledgements

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3. Chapter II

Sharing fishers´ ethnoecological knowledge of the European pilchard (*Sardina pilchardus*) in the westernmost fishing community in Europe

3.1 Abstract

3.1.1 Background

With the present difficulties in the conservation of sardines in the North Atlantic, it is important to investigate the local ecological knowledge (LEK) of fishermen about the biology and ecology of these fish. The ethnoecological data of European pilchard provided by local fishermen can be of importance for the management and conservation of this fishery resource. Thus, the present study recorded the ethnoecological knowledge of *S. pilchardus* in the traditional fishing community of Peniche, Portugal.

3.1.2 Methods

This study was based on 87 semi-structured interviews conducted randomly from June to September 2016 in Peniche. The interview script contained two main points: Profile of fishermen and LEK on European pilchard. The ethnoecological data of sardines were compared with the scientific literature following an emic-etic approach. Data collected also were also analysed following the union model of the different individual competences and carefully explored to guarantee the objectivity of the study.

3.1.3 Results

The profile of the fishermen was investigated and measured. Respondents provided detailed informal data on the taxonomy, habitat, behaviour, migration, development, spawning and fat accumulation season of sardines that showed agreements with the biological data already published on the species. The main uses of sardines by fishermen, as well as beliefs and food taboos have also been mentioned by the local community.

3.1.4 Conclusions

The generated ethnoecological data can be used to improve the management of this fishery resource through an adaptive framework among the actors involved, in addition to providing data that can be tested in further ecological studies. Therefore, this local knowledge may have the capacity to contribute to more effective conservation actions for sardines in Portugal.

3.2 Keywords

Ethnoecology; folk knowledge; fishermen; European pilchard; participatory management.

3.3 Background

Human populations have forced marine coastal ecosystems to differ from their historical states, which were characterized by diversified and productive communities (Lotze et al. 2006). One of the biggest human impacts has been overfishing, which has progressively reduced stocks, geographically expanded its range and disguises itself through new and improved technologies (Pauly et al. 2002).

In marine ecosystems, pelagic fish are recognized as abundant in productive fishing areas, both on a large scale and on a small scale (Teixeira et al. 2016), and are characterized by a history of large fluctuations in their populations, both due to overfishing as well as environmental factors (Cury et al. 2000). Within this group of fish, we have small pelagic species, such as sardines and anchovies, which are abundant in several productive regions of the ocean and are found mainly in areas of coastal and oceanic upwelling (Checkley et al. 2009). These clupeoid fishes are recognized mainly as having a low trophic level in the food web, early reproduction age and rapid growth, all of which make them more vulnerable to different environmental factors and climate change (Checkley et al. 2009).

In the central, eastern, and northeastern Atlantic, the European pilchard *Sardina pilchardus* (Walbaum, 1792) stands out among the pelagic fish for fisheries (Atarhouch et al. 2006). At the moment in Iberian waters, this species exhibits low biomass stocks at age 1 and a decrease in the stock of old fish and low recruitment rates (INE, 2015). In Portugal, European pilchard are one of the most important species to fishing fleets using purse seines and are recognized for their socio-economic values and traditional uses among the Portuguese (Teixeira et al. 2016).

With all these processes occurring, it is important to understand both the perceptions of local fishery managers and users of local resources and to provide strategies for avoiding conflicting shared perceptions among the stakeholders involved in fisheries management (McClanahan et al. 2005). In small-scale fisheries, for example, local fishermen are in many cases disadvantaged in relation to the actors belonging to large-scale fisheries due to their marginal political power, lack of infrastructure and their typical remoteness (Jacquet and Pauly 2008).

However, it is known that support from the general public for the management of natural resources is fundamental for long-term sustainability (Fiallo and Jacobson 1995). Discussions should be initiated with these local communities as a way of transferring responsibility and regulatory power over available environmental resources (de Boer and Baquete 1998).

The local ecological knowledge (LEK) in this context serves as an effective tool for monitoring and assisting in the planning of depleted resources, for the conservation of biodiversity (Pitt et al. 2012), and for conducting more reasonable and culturally sensitive research and management plans (Drew 2005). This knowledge can be understood as the lay or experiential knowledge of an individual about the environment based on daily observations, practical experiences in nature and learned scientific knowledge (Yli-Pelkonen and Kohl 2005).

To better understand recent history of artisanal fishing and the deterioration of the standard of living of the dependents of this resource (Pinto et al. 2013), we can employ ethnoecology, which according to Marques (2001) can be understood as the scientific study of traditional ecological knowledge (knowledge, behaviour, feelings, and beliefs that influence all interactions between humans and the ecosystem) (Marques 2001). More specifically within ethnozoology, we have ethnoichthyology (Alves and Souto 2015), which aims to report the knowledge that fishermen have about fish biology and ecology (Begossi et al. 2016), and the understanding of interactions between humans and ichthyological resources encompassing the cognitive and behavioural aspects supported by conservation (Marques 1995).

From this perspective, extracting ethnoecological data about European pilchard from the fishing community of Peniche, as well as the knowledge passed from generation to generation by the more experienced fishermen, can be important strategies for the conservation of this fishing resource. This type of ethnoecological survey emphasizes the cultural knowledge of fishermen, favours their dialogue with environmental managers

and researchers, and contributes to the improvement of participatory management of natural resources by increasing the acceptance of management rules (Silvano and Begossi 2005).

Thus, the aim of this study was to record the ethnoecological knowledge of the fishing village of Peniche, Portugal, about the ecology and biology of *S. pilchardus. T*he fishermen's profiles and the likely human uses, beliefs and taboos related to European pilchard (also known as the Atlantic sardine, European sardine, or sardine) were also explored. The ethnoecological data provided by the fishermen who are in agreement with the published biological data were interpreted and discussed in the present study.

3.4 Materials and Methods

3.4.1 Study area

This study was based on interviews with artisanal fishermen from the fishing community of Peniche, on the coast of the western sub-region of Portugal (39° 21' 32" N, 9° 22' 40" W; Figure 3.1). This city has 27,628 inhabitants with an area of approximately 77,55 km2 (INE, 2015). The climate is temperate with rainy winters and dry and somewhat hot summers (Köppen type Csb) (INE, 2015).

Figure 3.1 Map of the study area, highlighting the fishing port and the city center of Peniche where the interviews were conducted in Portugal. Credits: B Zucherato.

One of the world's first Portuguese protected areas (Monteiro et al. 2016) is located approximately 5.7 miles from Peniche (Cape Carvoeiro) in the Atlantic Ocean (Mendes et al. 2011). Formed by an archipelago of islands (Berlenga Grande, Estela and Farilhões), this marine protected area is located in the transition zone between the Mediterranean and European sub-regions, specifically at the top of the escarpment of the Nazaré Canyon (Mendes et al. 2011). The Berlengas Marine Natural Reserve (MNR) is renowned for its great marine biological diversity, archaeological features, insular ecosystem specificities and is importance in the life cycle of the marine avifauna (Jacinto et al. 2011).

3.4.2 Fishing community

The fishing port of Peniche is recognized as one of the main ports of the country (Viegas et al. 2016) according to fishing indicators for the average value of fish unloaded in this area (Santos et al. 2012a; INE, 2015). The economic and social development of the city is directly linked to the fishing activity of this port, which is one of the busiest in Portugal (Queiroga et al. 2008).

This fishing community is considered a local symbol with remarkable prestige throughout the municipality (Santos et al. 2012a). In the maritime captaincy of Peniche, there are approximately 1105 registered fishermen, with 996 conducting marine fishing (INE, 2015). Polyvalent and seine fishing are predominant in this area, with sardines being one of the three main target species for fishing according to the data on the nominal catch landed in Portugal (INE, 2015).

3.4.3 Fishermen's interviews

Semi-structured interviews (Newing 2010; Albuquerque et al. 2014) were conducted from June to September 2016 to obtain data on LEK about the European pilchard. The state-owned company Docapesca - Portos e Lotas granted permission for administering the interviews to the fishermen of Porto de Peniche. Fishermen were interviewed over successive visits in the fishing warehouses of the Port of Peniche and at the main meeting points of the fishing community. Brook and McLachlan (2008) sees this type of involvement with the community as indispensable (Brook and McLachlan 2008). The objectives of the work and the statement of informed consent to participate in the research were provided to the fishermen through the Statement of Informed Consent (IC) [see Additional file 1].

The interviews were mainly conducted through manual transcription and occasionally with a digital audio recorder. The interviews with fishermen were conducted randomly - always before or after the arrivals and departures of the fishing teams and when they were doing net and fishing gear repairs. The interview script [see Additional file 2] was structured in 2 parts: Profile of fisherman (age, schooling, fishing time, time of residence in Peniche, income source, type and length of boat, fishing time at sea and time to catch sardines) and LEK of European pilchard (folk taxonomy, habitat, behaviour and migration, development of sardines, spawning, fat accumulation season and uses, beliefs and food taboos). The educational profile of the interviewees followed the Portuguese educational classification: A (1st Cycle: 1-4 years of study), B (2nd Cycle: 5-6 years of study), C (3rd Cycle: 7-9 years of study) and D: (Secondary Education: 10-12 years of study).

3.4.4 Data analyses

A respect for the stakeholders and communities, the clarification of data collection objectives, the interactive approach and the recognition of information limitations were used as a basis for analysing the data acquired (Bunce et al. 2000). All the information provided through the surveys was analysed following the union model of the different individual competences (Marques 1991). The LEK about sardine was analysed through an emic-etic approach (Harris 1976), and the data generated by the community were compared with the scientific literature (Marques 2001). The wealth of information and depth of perceptions in the data collected were analysed through careful coding and cross-checking to ensure the objectivity of the study (Newing 2010). Species nomenclature data were analysed following the Food and Agriculture Organization of the United Nations (FAO) (FAO 2017), the International Union for Conservation of Nature (IUCN) (IUCN 2014), and Fish Base (Fishbase 2014). The data obtained in the interviews were stored and standardized in EXCEL and analysed (descriptive statistics) in the R Project for Statistical Computing version 3.3.2 (Team and others 2016).

3.5 Results

3.5.1 Descriptive statistics of fishermen's profiles

A total of 87 interviews were conducted in the fishing community of Peniche. The interview sites were predominantly in the Port of Peniche (Figure 3.2) (N = 71) followed by the city centre (N = 16). The average age of the respondents was 58.25 years, with a

minimum of 25 years and a maximum of 76 years. More than half of the interviewees (N = 59) were born in Peniche and are active (N = 49) in the fishing currently. According to the Portuguese educational classification, 58 individuals belonged to the 1st Cycle, 19 to the 2nd Cycle, 5 to the 3rd Cycle and 5 to Secondary Education. There were no illiterates or individuals with higher education in the sample. The fishing experience varied from 3 to 60 years, but fishing experience average was 39.08 years. The average monthly income source related to fishing, including retirees, is 810.5 Euros, ranging from 208.0 to 3000.0 Euros. A total of 50 fishermen interviewed supplement their income with income from other activities. Of these fishermen, 31 informants do so through work related to fishing (maintenance of fishing nets) and the rest in other autonomous activities.

Figure 3.2 A: Main area of the fishing port of Peniche, Portugal where the interviews with the fishermen were carried out. B: A fisherman doing maintenance of purse seine nets. Credits: HO Braga. (Images published under previous consent of the participants).

The main types of boats mentioned by the fishermen were: trawlers, artisanal fishing boats, trawl nets, coastal boats, and sports boats. Trawlers were further sub-classified by fishermen into trawlers (larger boats) and "rapa" (smaller boats). Boats were measured 93 times during the interviews. Of these, the boats mentioned were as follows: trawlers (35), artisanal fishing boats (38), “rapa” (14), trawl nets (3), coastal boats (2) and sport boats (1). Six Fishermen have said they have fished in more than one type of boat, those being 3 in both artisanal fishing boats and trawlers and 3 in artisanal fishing boats and trawl nets. Only 17 of the fishermen interviewed are boat owners.

The fishermen interviewed were questioned about their preferred schedule of sardine capture during the fishing campaigns. A cycle called "It is six in the morning and six in the afternoon" was the most cited by fishermen (N = 27). Other respondents

mentioned both sunrise and sunset (N = 17), day and night (N = 16), preferably day (N = 16), preferably night (N = 9), and only at sunset (N = 2).

Local ecological knowledge of sardines

3.5.2 Folk taxonomy

In Peniche, besides the name sardine, the artisanal fishermen attributed popular names to small sardines. A total of 82 fishermen attributed the name "petinga" or "esquilha" to juvenile sardines. One fishermen mentioned the name "real" sardine and another fishermen "sueste" fish. In this community, only two fishermen mentioned the scientific name (Linnaean).

3.5.3 Habitat, behaviour and migration

When questioned about the preferential habitat of sardines, 40 of the fishermen indicated coasts and high sea, 39 only on the coast, 6 more often on the coast, one only on the high sea and one did not answer this question. The informants highlighted some specific habitats (rocky seabeds, areas where the river empties into the sea carrying food, clean seabeds, more temperate waters, and sandy seabed to escape from common dolphin (*Delphinus delphis* Linnaeus, 1758) attacks.

In relation to the most common depth of the sardine in the sea, 32 informants indicate a forage interval of 0-50 m, 40 between 0-100 m and 11 between 0-200 m. Two fishermen did not know how to answer this question and two others just said they were deep-sea fish.

The locomotion of sardines in the sea, according to all fishermen, is carried out in shoals. Some fishermen (N = 15) specified that the schools are enormous. Two other fishermen referred to a phenomenon that makes sardines stick together. One informant said that sardines usually come together to protect themselves from common dolphins, and the other informant said that common dolphins make them stay together to feed.

The following types and patterns of sardine migration have been mentioned by fishermen in the fishing community of Peniche: the migration comes from the South (13 times), comes from the North (18 times), comes from the South and North (32 times), occurs with the tides (3 times), occurs according to the seasons of the year - summer and winter (15 times) and migrant/pelagic/moving fish (14 times). Only 7 respondents did not respond to this part of the interview.

Local fishermen also mentioned the probable areas of sardine displacement along the Portuguese Coast that passes through Peniche (Table 3.1). The areas most cited by respondents were Figueira da Foz (27 times), Algarve (25 times), Nazaré (19 times), Ericeira (15 times), Sesimbra (12 times) and Sines (11 times). Other areas of Portugal, such as Aveiro, Setúbal and Portimão (8 times), Cape Roca (7 times), São Pedro de Moel and Matosinhos (4 times), Viana de Castelo, Póvoa de Varzim, Olhão and Santa Cruz (3 times) and Cascaiz and Leixões (2 times). Foz do Minho Beach, Vila do Conde, Caparica Coast, Porto Beach, Mira Beach, Tocha Beach, Sagres and Lisbon were mentioned only once in the interviews.

3.5.4 Development of sardines

In the development section, the fisherman was asked about the time of sardine growth. According to 57 of respondents, sardines showed rapid growth, 16 said they were slow growing, 3 indicated intermediate growth (neither slow nor fast) and 11 did not know how to answer this question. The vast majority of respondents (N = 85) said that the sardine exhibit only the roe phase during their development. One fisherman mentioned both the larval stage and the roe phase, and another fisherman did not know how to answer this question.

Only 19 of respondents said that sardine mature after 1 year of age, and 24 did not know how to respond. The rest of the interviewees (N = 44) said that the sardine is able to reproduce within a range of 3-7 months old.

3.5.5 Spawning and fat accumulation season

The answers about the spawning time of sardines varied among fishermen. Most informants cited the spawning months as the answer to this question. The spawning time ranged from one to 8 months (72 citations). There was 1 response for 8 months, 2 for 4 months, 3 for 6 months and 3 for 7 months, 7 responses for 5 months, 16 for 4 months, 17 for 3 months and 20 for 2 months. The rest of the respondents (N = 3) did not report any months.

According to respondents, spawning occurs mainly in the months of January and February (20 times). December was quoted 19 times, November and March 15 times and October 12 times. The months of April (9 times), May and September (6 times), June (5 times), July and August (4 times) were the least mentioned by fishermen in Peniche (Table 3.2).

Other fishermen still specified the occurrence of spawning seasons. Along these lines, there were citations only for winter (N = 12) and summer (N = 8). There were also fishermen who reported the number of times (2x a year = 4 citations, 2-3x = 4 citations, 3x = 3 citations and 3-4x = 1 citation) that they spawn each year (Table 3.2).

Table 3.1 Probable areas of sardines displacement along the Portuguese Coast according to the fishermen of Peniche.

Fishing spots in Portugal	Number of times cited by fishermen
Figueira da Foz	27
Algarve	25
Nazaré	19
Ericeira	15
Sesimbra	12
Sines	11
Aveiro, Setúbal and Portimão	8
Cape Roca	7
São Pedro de Moel and Matosinhos	4
Viana de Castelo, Póvoa de Varzim, Olhão and Santa Cruz	3
Cascaiz and Leixões	2
Foz do Minho Beach, Vila do Conde, Caparica Coast, Porto Beach, Mira Beach, Tocha Beach, Sagres and Lisbon	1

The fishermen interviewed in Peniche provided some information from this part of the questionnaire below:

1. *“The water becomes creamy and milky when the sardine spawns”.*
2. *"From 100% of the spawn, 90% live and 10% die".*
3. *“The sardine buries itself in the sand to spawn and escape predators”.*
4. *“The sardine goes to the rocks to scratch its belly when it is pregnant".*

5. *"Outside the summer, the sardines are thin and run away".*
6. *"The sardine passes its belly through the sand to spawn and leaves the eggs for the sea to take later".*

Table 3.2 The sardines spawning period according to the fishermen interviewed.

Sardines spawning period	Number of times cited by fishermen
Months	
January and February	20
December	19
November and March	15
October	12
April	9
May and September	6
June	5
July and August	4
Seasons	
Winter	12
Summer	8
Time per year	
2 times	4
2-3 times	4
3 times	3
3-4 times	1

The informants mentioned the months of the years when the sardines accumulate (April to December). The months of June (56 times), July (75 times), August (68 times), September (47 times) and October (34 times) are the most remembered by the fishermen. (Table 3.3). Some local sayings were recorded in the interview as:

1. *"In July, the sardine already drips on bread".*
2. *"The sardine grows earlier in the Algarve (Portugal) because of the warm waters".*
3. *"The more rain, the more the sardine gets fat".*
4. *"In June and July, they are fatter, just like the Christmas sardine".*

Table 3.3 The period of fat accumulation of sardines according to the respondents.

Sardines accumulation season	Number of times cited by fishermen
Months	
June	56
July	75
August	68
September	47
October	34

3.5.6 Trophic ecology: Predators and prey

The LEK of the fishermen of the Port of Peniche showed important aspects of the sardine food chain, indicating the main predators and prey according to fishing experiences along the Portuguese coast. The main predators according to the fishermen (Table 3.4) are dolphins (*atuninha or toninha*), sharks and whales (generally), conger eel (*safio*) and yellowfin tuna (*atum-albacora*).

The fishermen also mentioned the following: sea bass (*robalo*), wreckfish (*cherne-legítimo*), red porgy (*pargo-legítimo*), chub mackerel (*cavala*), black scabbardfish (*espada-preto*), common octopus (*polvo-comum*), blackspot seabream (*goraz*), European hake (*pescada-branca*), forkbeard (*abrótea*), Atlantic "bonito" (*sarrajão or serrajão*), raja rays nei (*raias*), blackbelly rosefish (*cantarilho*), monkfish (*tamboril branco*) and swordfish (*espadarte*).

The following species were cited only once in the interviews: horse mackerel (*carapau*), meagre (*corvina*), white seabream (*sargo-legítimo*), Atlantic mackerel (*sarda*), pouting (*faneca*), black moray eels (*moréia-preta*) and ocean sunfish (*peixe-lua*). The "*tainha*" was also mentioned in the study in a generalized way. Birds were generally

cited as sardine predators. The yellow-legged gull (*gaivota-de-patas-amarelas*) and albatross (*albatroz*) and were also mentioned within this group.

According to the ethnoecological data obtained from the fishing community have a diet (Figure 3.3) based on plankton (N = 56), algae called “limo” (N = 30), small shrimp (N = 13), “comedias” or “comedorias” (N =12), the spawn of other fish species (N = 8) their own spawn (N = 6). The fishermen also said that the sardine feed on krill (N = 5), sediments accumulated after rainfall (N = 5), sea impurities (N = 1), and remnants of other fish species (N = 1). “Comedorias" or "Comedias" in this study was defined by fishermen as a mixture of small fish, small prawns, the roe of other species of fish and sardine roe.

3.5.7 Human uses, beliefs, and food taboos about European pilchard

The sardine is greatly important to the fishermen interviewed. According to the majority of the interviewees (N = 81), sardines have a high economic importance in the region of Peniche. Another 4 fishermen said that the importance of it is average and 2 other respondents have said that the importance is low. The summer (N = 21) is cited as the time when the sardine is more important to the population of Peniche. The main uses of this pelagic species are as bait for another species (N = 85 fishermen), in the canning industry (N = 53), for one’s own food (N = 50) and the fish meal industries (N =10). Local commerce (N = 2) and tourism (N = 2) were also identified by Fishermen.

Some informants (N = 6) from this community mentioned sardine food taboos. Fish that are restricted were locally termed “raimoso”. A change in the restriction of this fish was observed over time. Twenty-three percent of fishermen said that the sardine was once "raimosa" in the past and sixty-one percent of the fishermen said it was not "raimosa”. Two informants said that the sardine was little "raimosa" and that sick people could not eat it. There were 3 respondents who said that if the joint between the sardine skins is removed, it is no longer a restricted food. The fat found in sardines was recognized as a source of omega 3 by fishermen (N = 9), aiding in the medical treatment of people with problems with cholesterol or in the treatment of heart disease patients.

Table 3.4 The correspondence between the Portuguese folk names of the *S. pilchardus* predators and the scientific classification (Linnaean).

Folk taxonomy	Scientific names (Linnaean)
Atuninha or toninha	*Delphinus delphis* Linnaeus, 1758
Sharkes	Generally
Whales	Generally
Safio	*Conger conger* (Linnaeus, 1758)
Albacora	*Thunnus albacares* (Bonnaterre, 1788)
Robalo	*Dicentrarchus labrax* (Linnaeus, 1758)
Cherne	*Polyprion americanus* (Bloch & Schneider, 1801)
Pargo	*Pagrus pagrus* (Linnaeus, 1758)
Cavala	*Scomber japonicus* Houttuyn, 1782
Espada-preto	*Aphanopus carbo* Lowe, 1839
Polvo-comum	*Octopus vulgaris* Cuvier, 1797
Goraz	*Pagellus bogaraveo* (Brünnich, 1768)
Pescada-branca	*Merluccius merluccius* (Linneaus, 1758)
Abrótea	*Phycis phycis* (Linnaeus, 1766)
Sarrajão or serrajão	*Sarda sarda* (Bloch, 1793)
Raias	*Raja* spp.
Cantarilho	*Helicolenus dactylopterus* (Delaroche, 1809)
Tamboril branco	*Lophius piscatorius* Linnaeus, 1758
Espadarte	*Xiphias gladius* Linnaeus, 1758
Carapau	*Trachurus trachurus* (Linnaeus, 1758)
Corvina	*Argyrosomus regius* (Asso, 1801)
Sargo-legítimo	*Diplodus sargus* (Linnaeus, 1758)
Sarda	*Scomber scombrus* Linnaeus, 1758
Faneca	*Trisopterus luscus* (Linnaeus, 1758)
Moréia-preta	*Muraena augusti* (Kaup, 1856)
Peixe-lua	*Mola mola* (Linnaeus, 1758)
Tainhas	*Mugil* spp.
Gaivota	*Larus michahellis* J. F. Naumann, 1840
Albatroz	Generally
Birds	Generally

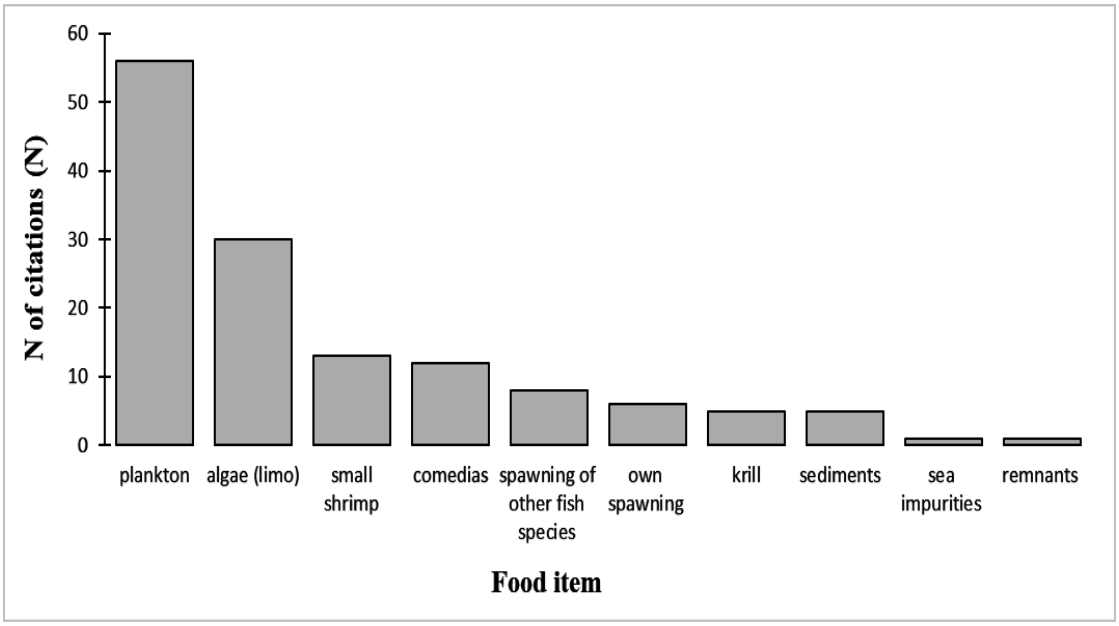

Figure 3.3 Number of citations of *S. pilchardus* food items by fishermen in the fishing community of Peniche, Portugal.

3.6 Discussion

3.6.1 Folk taxonomy

Local knowledge related to the naming of fish species is an inherent part of fishermen's trade and can be considered as proof of ability in these communities (Masski and Ait Hammou 2016). In Ericeira, Portugal, the local community also calls the juveniles of this species "petinga" (Vale and Sampayo 2001). In the Autonomous Region of the Azores in Portugal, the sardine is also called by the same vernacular name (Fishbase 2014). The designation of sardines as "esquilha" (small fish), "sueste" and "real" are new to the scientific literature.

3.6.2 Habitat, behaviour and migration

According to the ethnoecological data extracted from the interviews, sardine is a predominantly coastal species and prefers sites near river mouths in the sea. The fishermen reported that sardines are distributed vertically, predominantly between the depths between 0 to 100 m. In the scientific literature, similar information was found indicating that this species is predominantly found in coastal shelf waters (Brito 1991; Zwolinski et al. 2010; Di Natale et al. 2011; Silva et al. 2015; IPMA 2016b) and prefers areas of great productivity near the mouths of rivers and estuaries (IPMA 2016b). In a study on the modelling of habitat suitability for juveniles of *S. pilchardus*, the results showed that sardines in the growth phase, in search of food and in the spawning process

can be closely linked to sites that provide nutrient sources that increase productivity, such as local upwelling or river runoff (Giannoulaki et al. 2011). Di Natale and collaborators (2011) report in the IUCN Red List of Threatened Species 2011 that European pilchard can usually be found at depths of up to 100 m, reaching a lower depth limit of 180 m (Di Natale et al. 2011). The PECH Committee of the European Parliament for the sardine fishery shows that this species can range down to 150 m (Silva et al. 2015), and in a study of sardine habitat to the west of Portugal showed that this species has a preference for waters with depths of up to 100 m (Zwolinski et al. 2010) (Table 3.5).

European pilchard show migratory behaviour, a high dispersal capacity and schooling behaviour similar to other pelagic fish (Jemaa et al. 2015). In the present study, respondents exclusively reported this type of behaviour pattern. There was an account of a fisherman who referred to this ability to school as a way to ward off predators. Neilson and Perry (1990) show that the presence of competitors or predators may change the direction or influence the intensity of these migrations in schooling (Neilson and Perry 1990) (Table 3.5).

In Portugal, the geographic distribution of this pelagic fish covers the entire coastline, Madeira Island and the Azores (Parrish et al. 1989). However, sardine migration patterns are not yet well understood (IPMA 2016b). There are indications of seasonal migrations along the Portuguese Coast (Monteiro 2017), and fifteen interviewees mentioned this information.

According to acoustic campaigns performed in April and May of 2015 by the Portuguese Sea and Atmosphere Institute (IPMA), the abundance of sardines decreased from the north to the south of Portugal (Albuquerque et al. 2014. Regarding sardine migrations, it is known that they occur during the growth phase and towards the north coast of Spain (Jacinto et al. 2011). During the collection of ethnoecological data in this part of the interview, it was observed that there was a variation in the responses among the interviewees. There were 18 fishermen who said that the sardines come from the north of Portugal and another 32 fishermen who say that they come from the north and the south of Portugal. This pattern of responses among fishermen reinforces the need to investigate and explore the studies on the migratory behaviour of sardines in the Iberian Peninsula.

The European pilchard show migratory behaviour, a high dispersal capacity and schooling behaviour similar to other pelagic fish is distributed mainly near Póvoa de Varzim and Figueira da Foz in the northwestern region of Portugal and near Peniche and Lisbon in the southwestern region (IPMA 2015). In the Algarve (Southern Portion of

Portugal), this pelagic fish is found in greater quantities in Lagos, Portimão and between Faro and Vila Real de Santo António (IPMA 2015). According to the fishermen of Peniche's LEK, the Figueira da Foz region and the Algarve were cited the most frequently when asked about where the sardine is on the coast after passing through Peniche (Table 3.5). The regions of Portimão, São Pedro de Manoel, Olhão, Tocha Beach and Sagres were identified by the fishermen in the southern portion of Portugal, which are included in or near the range of greater distribution found during the last acoustic campaign by the IPMA. None of the respondents specifically mentioned V. Real de Santo Antônio.

3.6.3 Development of sardines

The sardines show a very fast growth rate (Silva et al. 2008; Jemaa et al. 2015; IPMA 2016b), growing to approximately 90% of their full size in 2 years (IPMA 2016b). Most fishermen in the community of Peniche (N = 57) corroborate the scientific research in relation to rapid growth (Table 3.5). In relation to the stages of development of this species, the fishermen only mentioned the egg phase as constituting the whole sardine life history. However, it is known that the larval stage is one of the development stages of this pelagic fish (Fogarty and Moksness 2016).

The European pilchard matures early (Blaxter and Hunter 1982; Silva et al. 2006). Individuals are largely mature at 1 year of age, and all individuals are reproductively mature at 2 years of age (Silva et al. 2006, 2015). In the present study, only 19 of fishermen said that sardine reach sexual maturity at 1 year of age and 44 of respondents mentioned that they are ready to reproduce from 3 to 7 months of age (Table 3.5).

3.6.4 Spawning and fat accumulation season

Regarding reproduction, spawning of sardines occurs in batches of eggs (Zwolinski et al. 2001; Ganias et al. 2004). The spawning of the Atlantic sardines occurs mainly on the western coast of Portugal between the Nazaré Canyon and the Minho river and in the Cantabrian Sea (García-García et al. 2016). Along the western Iberian coast, the spawning season of this pelagic species ranges from September to May, with spawning peaking in November to the north of Portugal from October to April (García-García et al. 2016). Nunes and collaborators (2011) showed that the spawning peak occurs mainly between December and February along the Portuguese coast. According to fishermen from Peniche, the main months of spawning are also December, January and

February. This period as a whole (from October to April) included the months most cited by the respondents (Table 3.5).

There is a variation in the duration of spawning times in the European waters of the North-East Atlantic, ranging from 3 months per year up to 8 months to the south and west of the Iberian Peninsula for large fish (Zwolinski et al. 2010). A similar pattern was found in responses of our interviewees from Peniche, in which 72 fishermen said that the Atlantic sardine spawn time can range from one to 8 months (Table 3.5).

The winter was cited by 12 fishermen as being the season during which sardine spawn the most along the Portuguese Coast, and others (N = 12) said that the spawning occurs 2 to 4 times a year. This point aligns with the scientific information that Atlantic sardines exhibit a prolonged spawning period during the year, with more pronounced spawning mainly in the colder months of the year (Zwolinski et al. 2010) (Table 3.5).

S. pilchardus begins to store fat reserves before the breeding season between late summer and autumn (Garrido et al. 2008b). However, sardines can also accumulate fat from late spring to autumn (IPMA 2016b). Most months cited by fishermen (June through October) fit the range of months for the accumulation of fat found in the scientific literature (Table 3.5).

3.6.5 Trophic ecology: Predator and prey

The sardine is one of the main prey species of the common dolphin (*D. delphis*) (Silva 1999; Cañadas and Hammond 2008; Certain et al. 2011; Santos et al. 2014). It also serves as a food base for several species of demersal fish, seabirds and marine mammals (Garrido et al. 2008a; Preciado et al. 2008; Santos et al. 2014; Silva et al. 2015; IPMA 2016b). These animals were also cited by fishermen during the interviews (Table 3.5). The common dolphin stood out among all the other predators (Silva 1999; Cañadas and Hammond 2008; Certain et al. 2011; Santos et al. 2014). Along the Portuguese Coast specifically, *S. pilchardus* was the most important species in the common dolphin diet in a study in which the stomach contents of this animal were examined during accidental catch and when they were stranded (Silva 1999). It is also known that the common dolphin is an opportunistic predator of small epipelagic fish (Cañadas and Hammond 2008), usually in places with moderate or high productivity (Jefferson et al. 2009) where sardines seek their energy sources (Giannoulaki et al. 2011). Given the current population decline in the sardine population on the Iberian coast (ICES 2016), attention should be

given to the conservation of the common dolphin along the Portuguese coast, as this is one of the main predators of this clupeoid fish (Moura et al. 2012).

Sardines primarily seek zooplankton as their energy source (Garrido et al. 2008b; Garrido and Van der Lingen 2014). Phytoplankton are also an integral part of the diet of this species (Garrido et al. 2008b; Costalago et al. 2015). Among the zooplankton, we should highlight copepods, decapods and cirripeds (Garrido et al. 2008b; Costalago et al. 2015), fish eggs and crustaceans (Garrido et al. 2008b). During the winter spawning months, sardines may exhibit cannibalistic behaviour in which they predate on their own eggs (Costalago et al. 2015). Respondents describe a foraging behaviour similar to that reported in the investigative work on European sardine prey (Table 3.5). In general, it is also observed that fishermen in the fishing village of Peniche show sardines with migratory behaviour, high dispersal capacity, prey and school behaviour similar to other pelagic fish.

3.6.6 Human uses, beliefs and food taboos about European pilchard

The great majority of fishermen (N = 81) in our ethnoecological study indicated the great economic importance of Iberian sardines, *S. pilchardus,* to the local community of Peniche. According to data from the Statistics Yearbook of the Central Region of 2015 made by Portugal's National Statistical Institute (INE), sardine fisheries officially yielded approximately 1223 tons of fish and 3517 thousand Euros for the municipality of Peniche in 2015 (INE, 2015). This fact proves the strength of this economic activity for this region.

The summer was highlighted among the respondents as being the most important season for sardine fishing, local commerce and tourism. In this season, the sardines are in the fattening stage (Garrido et al. 2008b; IPMA 2016b), and their fat content is high (Mendes et al. 2000). The sardine in this period has a flavour and aroma that is more appreciated by the consumers (Zlatanos and Laskaridis 2007), which makes this species more economically profitable. When the fat content is low (2-5%), this fish is less preferred by consumers and is normally sent to the canning and fish meal industries (Mendes et al. 2000). In other seasons, sardines are primarily used as baitfish for demersal fishing or for the canning industry (Vázquez-Rowe et al. 2014b). All sardine uses known to the scientific literature were also mentioned by the fishermen during the interviews.

Taboos are unwritten social rules that regulate human behaviour and can both govern and affect human social life and serve to manage a local biological resource (Colding and Folke 1997). In the local community of Peniche, there were no significant

taboos or food aversions regarding sardines by fishermen (N = 6). In local communities of the Amazon and in the Atlantic Forest in Brazil, taboos and aversions were also not associated with herbivorous fish or invertebrate eaters (Begossi et al. 2004). According to Begossi et al. (2004), this can be an adaptive strategy of local inhabitants to fish of higher trophic levels that can more easily accumulate toxins by eating a variety of prey (plants, invertebrates and other fish. This may be one of the reasons that there are few fishermen with taboos or sardine aversions. Another hypothesis is that these social rules may be losing strength over the years due to the exodus of fishermen to other economic activities, many of whom leave due to the low economic profitability of this profession and the difficulties imposed by European Union legislation on Portuguese artisanal fisheries (Santos et al. 2012b).

Regarding medicinal purposes, 9 fishermen indicated that sardine can treat high cholesterol levels and patients with cardiac problems. In a study about the fauna and the role of taboos in the conservation of animals in a forest reserve in southeastern Cameroon (Bobo et al. 2015), sardine (*Sardina sp.*) are used medicinally to treat cardiovascular diseases, which was also indicated in our survey by some fishermen (N = 9). In the Sierra de Segura (Albacete, Spain), *S. pilchardus* is used for medicinal purposes in the treatment of sore feet and blisters in modern times and is marketed in the fish markets as food (Vallejo and González 2014).

Table 3.5 Matrix cognition compared between the fishers` LEK and the scientific literature on the biology and ecology of European pilchard in Peniche, Portugal.

Topics	Fisherman's citation	Scientific literature
Habitat	"Coastal species and prefers sites near river mouths in the sea".	Coastal shelf waters (Brito 1991; Zwolinski et al. 2010; Di Natale et al. 2011; Silva et al. 2015; IPMA 2016); Areas of great productivity near the mouths of rivers and estuaries (IPMA 2016); Area of local upwelling or river runoff (Giannoulaki et al. 2011).
	"Depths between 0 to 100 m".	Depths of up to 100 m, reaching a lower depth limit of 180 m (Di Natale et al. 2011); Preference for waters with depths of up to 100 m (Zwolinski et al. 2010).
Behaviour	"Migration carried out in shoals". "Ability to school as a way to ward off predators".	Migratory behaviour, a high dispersal capacity and schooling behaviour similar to other pelagic fish (Jemaa et al. 2015). Competitors or predators may change the direction or influence the intensity of these migrations in schooling (Neilson and Perry 1990).
Migration	"Mainly Figueira da Foz and Algarve". "Póvoa de Varzim, Lisbon...".	Póvoa de Varzim, Figueira da Foz and Lisbon (IPMA 2015); Algarve (Southern Portion of Portugal), this pelagic fish is found in greater quantities (IPMA 2015).
Development	"Rapid growth". "Sardine reach sexual maturity at 1 year"; "from 3 to 7 months of age".	Very fast growth rate (Silva et al. 2008; Jemaa et al. 2015; IPMA 2016). Matures early (Blaxter and Hunter 1982; Silva et al. 2006).
Spawning	"The main months of spawning are also December, January and February".	October to April (García-García et al. 2016); mainly between December and February along the Portuguese coast (Nunes et al. 2011).
	"Spawn time can range from one to 8 months".	Ranging from 3 months per year up to 8 months (Zwolinski et al. 2010).
	"In the winter, the sardine spawns more"; "The spawning occurs 2 to 4 times a year".	Sardines exhibit a prolonged spawning period during the year, with more pronounced spawning mainly in the colder months of the year (Zwolinski et al. 2010).

Fat accumulation season	"June through October".	Late summer and autumn (Garrido et al. 2008b). Late spring to autumn (IPMA 2016).
Predator	"Mainly dolphins (atuninha or toninha), "sharks, whales, conger eel (safio) and yellowfin tuna (albacora)"; "yellow-legged gull (gaivota), "albatross and other birds".	Common dolphin (*D. delphis*) (Silva 1999; Cañadas and Hammond 2008; Certain et al. 2011; Santos et al. 2014); species of demersal fish, seabirds and marine mammals (Garrido et al. 2008a; Preciado et al. 2008; Santos et al. 2014; Silva et al. 2015; IPMA 2016).
Prey	"Plankton, algae called "limo", small shrimp, krill, the spawn of other fish species and their own spawn".	Zooplankton as their energy source (Garrido et al. 2008b; Garrido and Van der Lingen 2014); Phytoplankton (Garrido et al. 2008b; Costalago et al. 2015); fish eggs and crustaceans (Garrido et al. 2008b). Sardines may predate on their own eggs in winter (Costalago et al. 2015).

3.6.7 Conservation concerns and co-management

There is a growing interest in LEK research in order to provide complementary data for several small-scale fishery species (Silvano and Valbo-Jørgensen 2008). With the difficulties and vulnerability of the marine ecosystem, LEK correctly acquired and aggregated at appropriate spatial-temporal scales becomes an important marine species conservation tool (Beaudreau and Levin 2014). The management of these coastal resources in fishing villages can also be better achieved by exploring data of this nature, which provide information on the ecology, behaviour and presence of these species in the environment (Rasalato et al. 2010).

In the present work, we present LEK data on the ecology of sardines that corroborated scientific research. Other data generated in the interviews that were not validated by the scientific literature can be tested and incorporated into new hypotheses before carrying out a scientific study. According to Drew (2005), an analysis of the components of traditional ecological knowledge can reveal new information and thus contribute to the formulation of testable hypotheses in order to improve scientific infrastructure. Silva et al. (2014) also reveal the importance of generating new scientific questions through ethnoecological data (Silva et al. 2014). The LEK about sardines acquired here may complement pre-existing scientific data. Due to the high cost and lack of resources for investments in traditional samplings, data of this nature become important for conservation practices and development (Anadón et al. 2009).

Given the low stock levels of the sardine population in the Iberian Region (ICES 2016), participation among the actors involved in fishing regulations should be carried out in an interactive manner (Heck et al. 2011). Ecological knowledge data on spawning and the time of fat accumulation may provide researchers an additional source of data to better understand the reproductive behaviour of this species from the fishermen's point of view. Analysing this knowledge can contribute to a better understanding and reduction of internal conflicts between fishing managers, politicians and the community about the correct time for harvesting this species. In addition, LEK data acquired from these traditional communities are important because it reveals the most recent changes in environmental processes (Cosham et al. 2016).

The new data (trophic ecology, habitat and behaviour) that emerged during the interviews can serve as a starting point for research on the population structure of sardines. On a larger spatial scale, this kind of data, with adequate treatment, becomes

important in the construction of management and conservation plans for sardines. Finally, we can note that the LEK of the sardines in Peniche should (and did) treat all stakeholders as being within a continuously adaptive framework (Wilson et al. 2006).

3.7 Conclusions

The socioeconomic profile of the fishermen of Peniche was described in this ethnoecological research. Respondents provided detailed informal data on the taxonomy, ecology and biology of *Sardina pilchardus*. This informal knowledge showed agreements with the scientific literature. We suggest the use of non-corresponding data with formal knowledge to aid in the construction of testable hypotheses for new investigative work on sardines. The data generated here can be used to try to improve the understanding of the fishermen's knowledge of the European pilchard by managers and conservationists. This approach requires the use of an adaptive framework, which contributes to an improvement in the relations between the actors involved with the resource. The food taboos and social rules about European pilchard were not relevant to conservation in this community. This species, which is mainly used as baitfish for other fishes and in the canning and fish meal industries, provides a great economic value for the fishing community studied here.

Finally, our results highlighted that artisanal fishermen from Peniche show ethnoecological data about European pilchard that can support scientific knowledge, as well as collaborate with future initiatives in pursuit of viable conservation goals for sardines on the coast of Portugal.

3.8 Acknowledgements

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4. Chapter III

Using the fisher's Local Ecological Knowledge (LEK) and their attitudes to assist in the management of the Brazilian sardinella (*Sardinella brasiliensis*) in the Southwestern Atlantic

4.1 Abstract

Due to the socioeconomic importance of sardines in the South Atlantic, the aim of this study was to evaluate the fishers´ LEK and the attitudes towards conservation of *S. brasiliensis* in the fishing village of the Arraial do Cabo, Rio de Janeiro, Brazil. A total of 134 semi-structured interviews were conducted from April to July 2016. The LEK was classified as moderate (0.56) as well as the conservation attitudes (0.60). It was shown that there was a correlation between LEK and income source of fishers. The LEK and the attitudes also show highly significant association with education, boat ownership, occupation and if the fisherman belonged to the local fishing association. As a way to improve fishers´ attitudes in practice, we encouraged the promotion of education among youth and adults is recommended so that the behavior of fishers becomes more favorable to the conservation of sardines in this fishing community.

4.2 Keywords

Attitudes; Local ecological knowledge; Artisanal fisheries; *Sardinella brasiliensis*; Fishing management.

4.3 Introduction

Biodiversity is facing an irrefutable crisis due to human population growth, which increasingly seeks biological resources, namely for energy demands and food requirements (Pacheco-Cobos et al. 2015). Presently, marine ecosystems exhibit a widespread environmental decline and a collapse of the unit fish stocks mainly due to overfishing (Myers and Worm 2003). Moreover, the consequent possibility of ecological changes at all levels make coastal ecosystems even more susceptible to climatic and environmental changes and human impacts (Jackson et al. 2001; McCauley et al. 2015).

In many marine environments, at an essential intermediate trophic level, the small pelagic fish species are more susceptible to the deregulation of their stocks when subjected to intensive exploitation (Cury et al. 2000). This group of fish is recognized as the most caught species and landed in capture fisheries worldwide (Metian 2009). In the southwestern Atlantic, the Brazilian sardinella, *Sardinella brasiliensis* (Steindacher, 1879) does not escape this pattern, being recognized as one of the most overfished clupeoids by commercial fleets on the Brazilian coast (Cergole et al. 2002).

The Brazilian sardinella is distributed in the southeastern Brazilian bight (SBB) between Cape São Tomé, Region of Campos dos Goytacazes, Rio de Janeiro State (22º S) to Cape Santa Marta, State of Santa Catarina (29º S) (Jablonski 2007). This small pelagic fish species is highly dependent on recruitment because it has a short life cycle (up to 3 years) and rapid growth and high mortality rates (Cergole and Dias-Neto 2011; Dias et al. 2014). Due to these biological features, sardine stocks are exposed and vulnerable to intense overfishing, to environmental variations and to inadequate management of this fishery resource in a sustainable way (Cergole and Dias-Neto 2011).

The history of sardine catches in the last decades is marked by a series of fluctuations and declines (Cergole et al. 2002; Dias et al. 2014). In 2000, there was a decreasing trend of minimum catches of approximately 20,000 tons at the Brazilian ports of Rio de Janeiro, Santos (State of São Paulo) and Itajaí (State of Santa Catarina) (Soares et al. 2011). In 2006, there was a slow and gradual recovery in the catches, reaching 83,917 tons landed in 2009 (Cergole and Dias-Neto 2011; Dias-Neto et al. 2011). However, in 2010 there was an indication of fluctuation with a decrease in catches to 62,133 tons and a slight recovery to 75,122 tons in 2011 (MPA 2011).

The *S. brasiliensis* in 2015 represented about 77,8% of the fish catches (47,204 tons) of the State of Rio de Janeiro (FIPERJ 2015), which reinforces the importance of this teleost to the commerce of this Brazilian state. In the municipality of Cabo Frio, for example, this fishing resource is the most landed in the fishing port (FIPERJ 2015). In addition, it is recognized by the local population as a fish of great socioeconomic importance for the region (Coelho-Souza et al. 2012).

With all these difficulties of managing this biological resource, the survey of users' knowledge becomes of extreme importance since it recognizes and legitimizes traditional or informal ecosystem management (da Silva 2004). The incorporation of a framework that includes the fishermen and their knowledge in the decision making also can

contribute decisively to increasing the success of marine ecosystem management (Lopes et al. 2013).

It is known that the LEK also plays an extremely useful role specifically in the management of marine protected areas (MPAs), especially when small-scale fisheries are involved (Gerhardinger et al. 2009a). Fishermen involved in this type of marine area collaborate mainly in the part related to the regulation of fishing and its application (Heck et al. 2011). Populations of species with some degree of vulnerability, for example, can be aided by combining this local knowledge with marine and fisheries science (Hamilton et al., 2012b). However, there is a tendency to consider not relevant the interests of these local communities, which creates a lack of communication between the actors involved, which can contribute to the emergence of new conflicts, skepticism and difficulties in resource management (Daw and Gray 2005; Mellado et al. 2014).

This local ecological knowledge (LEK) in question may be understood as the knowledge acquired through the experiences and observations of the local communities about natural resources (Olsson and Folke 2001). The LEK can still be very useful in providing information on changes in marine resources, as well as complementing information provided on the evolution of fishing activity (Coll et al. 2014). This socio-ecological tool also makes it possible to extract local residents' attitudes on a particular resource as a way to improve conservation practices and determine their impacts on coastal management (Fiallo and Jacobson 1995; Braga and Schiavetti 2013). Therefore, the present work aimed to evaluate the local ecological knowledge (LEK) and the attitudes towards conservation of the Brazilian sardinella (*Sardinella brasiliensis*) in the fishing village of the Marine Extractive Reserve of Arraial do Cabo, Rio de Janeiro State, Brazil with the purpose of assisting in the management and conservation of this biological resource.

4.4 Material and methods

4.4.1 Description of the study site

The study was conducted in the city of Arraial do Cabo (22° 57' 57" S, 42° 01' 41" W, Figure 4.1), Lagos microregion, Rio de Janeiro State, Brazil. This city has a resident population of 29,304 inhabitants with a territorial area of 158,952 km² (IBGE 2017). The climate in Arraial do Cabo is classified as semi-arid hot (BSh in Köppen's classification), presenting five months of drought (Duarte 1998). The mean annual temperature in this region is 23°C and the mean annual rainfall is about 823 mm/year (Godoy et al. 2013).

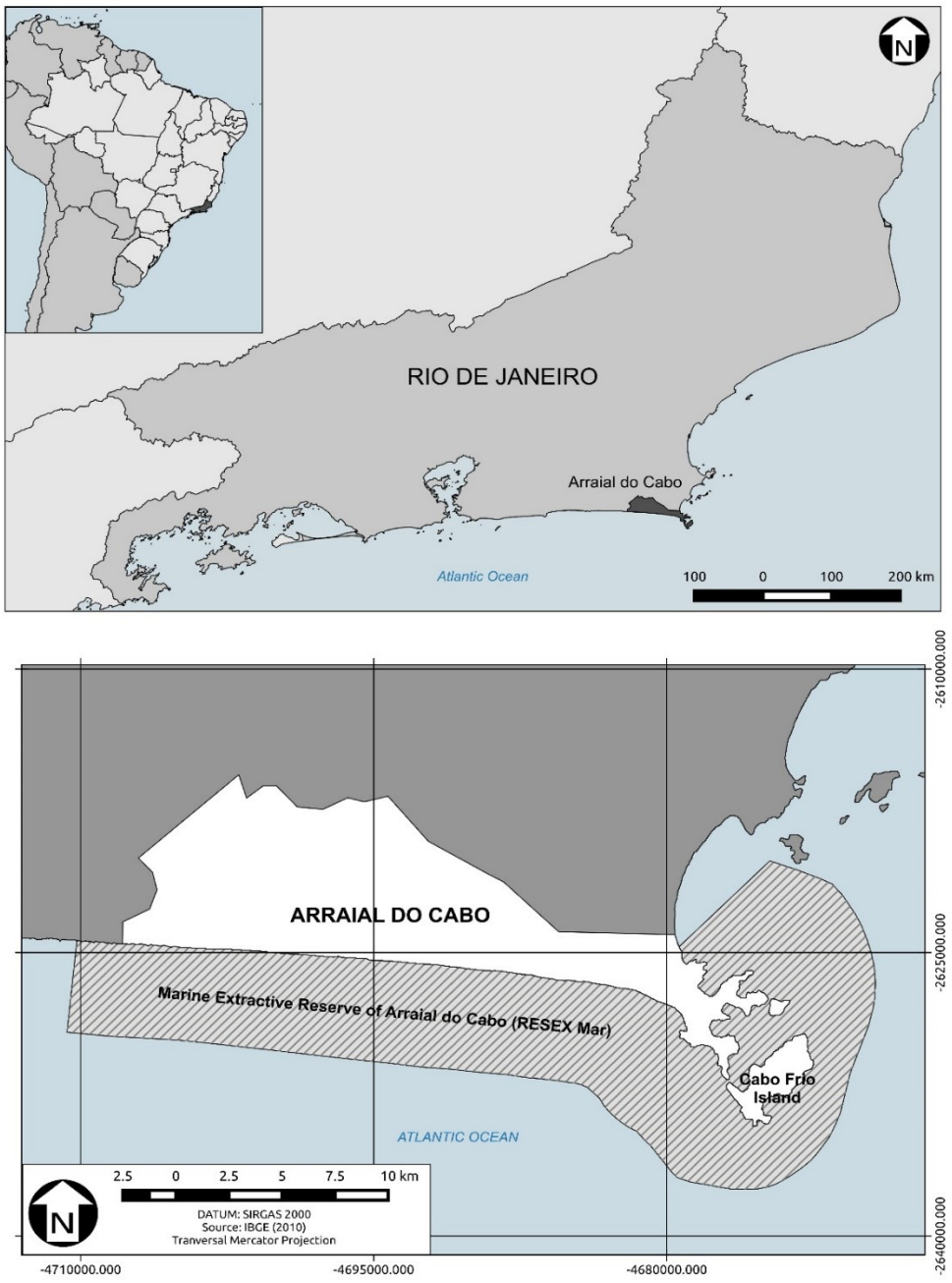

Figure 4.1 Location of the municipality of Arraial do Cabo and the Extractive Marine Reserve of Arraial do Cabo, State of Rio de Janeiro, Brazil. Source: Zucherato, B.

Arraial do Cabo has attracted fishermen over the years due to the marine biological diversity supported by the upwelling of Arctic deep waters (da Silva 2004). This region has a traditional fishing village with about 1,000 active fishermen (Giglio et al. 2017), mainly concentrated in *Anjos* Beach (due to the presence of the Z-5 fishing association, fishing port, marine and jetty), *Grande* Beach, *Prainha* Beach and *Pontal* Beach.

This study site is located in the Marine Biome in the Southern Atlantic system, specifically in the Marine Extractive Reserve of Arraial do Cabo with approximately

56.601ha (ICMBio 2017a). This Brazilian Marine Conservation Unit was created on January 3, 1997 and stands out for its ecological and social interests in the Southwestern Atlantic (ICMBio 2017a). This territorial space has the characteristic of enabling self-sustainable exploitation by extractive populations without damage to the conservation of renewable biological resources (ICMBio 2017a).

4.4.2 Data collection

Fisher´s interviews

The questionnaire was randomly applied to fishermen from April to July 2016 in four beaches (*Anjos* Beach, *Grande* Beach, *Prainha* Beach and *Pontal* Beach) with the highest fishing activity in the village of Arraial do Cabo. A trustworthy atmosphere with fishermen was established prior (Brook and McLachlan 2008), to the application of the semi-structured interview script (Albuquerque et al. 2014). The approach to the fishermen was carried out mainly after the arrivals and before the departure of the fishing boats in these beaches. A short pilot study was conducted in Arraial do Cabo on a subsample of participants in order to better adapt this instrument of data collection (White et al. 2005). According to Huntington (2000), a well-designed questionnaire is needed to obtain accurate quantitative data.

The interviews took place only after the consent of the respondent and the explanation of the objectives of the work. The decision-making power to interrupt the interview was always respected by the researcher. The fieldwork researchers used notes and eventually electronic recorders to collect information during interviews (Albuquerque et al. 2014). The agreement to participate in the interview was made through the Statement of Informed Consent (IC) [see Additional File 1]. The interviews applied in the present study were approved by the Ethics Committee of the Federal University of the State of Rio de Janeiro, Brazil (CAAE: 53819116.6.0000.5285). This study also was authorized by the Biodiversity Authorization and Information System (Sisbio-ICMBio/IBAMA/Brazil nr. 52333-1).

Questionnaire Design

The questionnaire applied to fishermen contained three sections [see Additional File 3]. The first section contains information about socio-demographic variables of fishermen (age, level of education, monthly income, duration of stay in Arraial do Cabo, fishermen in activity or not, fishing experience, fishing effort, member on local fishing colony association and boat ownership).

In the second section, 12 statements were constructed in order to measure the local ecological knowledge about the Brazilian sardinella (*Sardinella brasiliensis*). The questionnaire contained questions about the biology and ecology of Brazilian sardinella (species identification, habitat, spatial and temporal distribution, schooling behavior, growth and maturation, reproduction and spawning, prey and predators and correct fishing periods). In the identification part of the species, the fishermen observed a colored image of the sardine through an electronic device for recognition purposes (Figure 4.2). At this interview point, the image was always shown to the fishermen in the same order at the beginning of the interview (Silvano et al. 2006).

Figure 4.2 Image used for the identification of Brazilian sardine - *Sardinella brasiliensis*. Source: Carvalho Filho, A. FishBase.

In the last part of this instrument of data collection 10 statements were elaborate to measure the attitudes towards sardine conservation. The attitude in the present study was defined as the feeling of favor or disfavor of the individual in relation to this concept (Ajzen and Fishbein 1980; Eagly and Chaiken 1993). The questions in this section aimed to identify the fishers' tendency to conserve and/or protect this biological resource (sardines).

4.4.3 Analytical methods

The data extracted from the semi-structural interviews were analyzed quantitatively and qualitatively considering all the information available (Marques 1991), through an emic-etic point of view in which the local ecological knowledge was compared with the scientific literature (Harris 1976). The level of education was classified into three groups: A: Low level (illiterate and Elementary School 1 - up to 5 years of schooling); B: Basic level (Elementary School 2 - 6 to 9 years), and C: Intermediate level (Secondary

school - 10 to 12 years). The local monthly income source was converted into Euro currency (1 Brazilian Real - BRL = 0.29 Euro – € or EUR).

The section of the questionnaire about fisher´s LEK and attitudes towards the conservation of sardines was measured using the 3-point Likert scale (Likert 1932). The knowledge and attitudes interval-level data varied between 0 and 1. To quantify the local ecological knowledge and attitudes towards sardine conservation of the fishermen, the questions were analyzed individually. The answers according to the scientific literature were assigned the score 1, partially correct the score 0.5 and incorrect the score 0. For the statements about the favorable attitudes towards sardines conservation were assigned the score 1, for to moderate attitudes, 0.5; and unfavorable attitudes, 0.

Additive indicators of knowledge and attitudes were created for comparison purposes (Braga et al. 2017b; Castilho et al. 2013; Braga and Schiavetti 2013). They were classified into three interval-levels (0-0.33: knowledge below average, unfavorable attitudes; 0.34-0.66; knowledge within average, moderate attitudes; and 0.67-1: knowledge above the average, favorable attitudes).

We conducted analysis of the data generated by the interviews through Project R for Statistical Computing version 3.3.2. (Team and others 2016). The descriptive statistics of fishermen's profile included the standard deviation, mean and median of the analyzed variables. The Normality (Shapiro-Wilks test), correlations (Spearman's rank test) and non-parametric (Kruskal-Wallis test) were also performed.

4.5 Results

4.5.1 Fishers´ socioeconomic characteristics

In total 134 semi-structured interviews were conducted with fishermen from the village of Arraial do Cabo. This sample represents 13.4% of the total fishermen currently on this important typical fishing village of the Southwest Atlantic. All fishermen were male, with an average age of 48.6 years (sd = 13.6). The minimum age was 20 years and the maximum was 87 years. The average fishing experience time was 27.1 years (sd = 12.2), ranged from 5 to 62 years. The average monthly income source of the local fisherman was 420.5 € (sd = 256.8 €), with a minimum of 87 € and a maximum of 2030 €. The average fishing effort per trip was 22.1 hours (sd = 66.8 h) and the highest recorded fishing effort per trip was 720 hours and the lowest fishing effort was 3.5 hours (Table 4.1).

Table 4.1 Fishers´ socioeconomic profile from the village of Arraial do Cabo in the Southwestern Atlantic (N = 134 – 100% male).

Variables	Minimum	Median	Mean	Maximum	Standard Deviation (sd)
Age (years)	20.0	48	48.6	87.0	13.6
Fishing experience (years)	5.0	27	27.1	62.0	12.2
Income source (EUR)	87.0	420.5	420.5	2030.0	256.8
Fishing effort (hours)	3.5	12	22.1	720.0	66.8

A total of 94 of respondents (70.1%) had low educational level, 25 fishermen (18.7%) had basic level and 15 fishermen (11.2%) had intermediate level of schooling. About sixty percent (N = 81) of the interviewees are natives of the city of Arraial do Cabo and almost forty percent (N = 52) are residents from some stage of life (since childhood: 21.6%, N = 29; since teenagers: 8.2%, N = 11; and since the age of majority: 9.0 %, N = 12). Only one respondent is not resident in this fishing village. Of the informants approached, 60.4% (N = 81) were members of the Z-5 fishing association of Arraial do Cabo and only 27.6% (N = 37) owned their boat (Table 4.2).

4.5.2 Fishers' knowledge

The average index of local ecological knowledge of fishermen was 0.56. The median of the indicator was 0.58. The lowest index was 0.29 and the highest was 0.79. Of these fishermen, 3.7% have below average knowledge, 82.1% have average knowledge and 14,2% have above average knowledge when compared to the scientific literature. According to the scale adopted, the fisher´s local ecological knowledge of Arraial do Cabo on sardines was considered moderate.

4.5.3 Attitudes towards biological conservation

The average index of attitudes of fishermen scored 0.60. The median of the index was also 0.60. There was only one informant who obtained the average index equal to 0 and one that obtained the maximum index equal to 1. According to the established classes, 3.7% had non-favorable attitudes, 63.5% moderate attitudes and 32.8% had favorable attitudes towards the conservation of sardines. Data obtained allow us to classify the

attitudes of this fishing village regarding the conservation of Brazilian sardinella as moderate.

Table 4.2 Characteristics of the profile of respondents from the fishing village of Arraial do Cabo (N of fishermen = 134 - 100% male).

Education Level (years of schooling)	**N**	**%**
Low (0-5 years)	94	70.1
Basic (6-9 years)	25	18.7
Intermediate (10-12 years)	15	11.2
Time of residence		
Native	81	60.4
Since childhood	29	21.6
Since teenagers	11	8.2
Since the age of majority	12	9.0
Not Resident	1	0.8
Members of the Z-5 fishing colony	81	60.4
Boat owners	37	27.6

4.5.4 Ecological knowledge, attitudes, and fishers´ socioeconomic characteristics

The normality test (Shapiro-Wilks) was applied to all variables explored in this study. Only the age of the fishermen presented a normal distribution. Spearman's (r) rank tests showed a positive and significant correlation between the index of local ecological knowledge and the income source of the fishermen ($N = 134$, $S = 266090.0$, p-value < 0.001; Figure 4.3). There was no correlation between index of local ecological knowledge and conservationist attitudes ($N = 134$, $S = 371894$, p-value $= 0.28$).

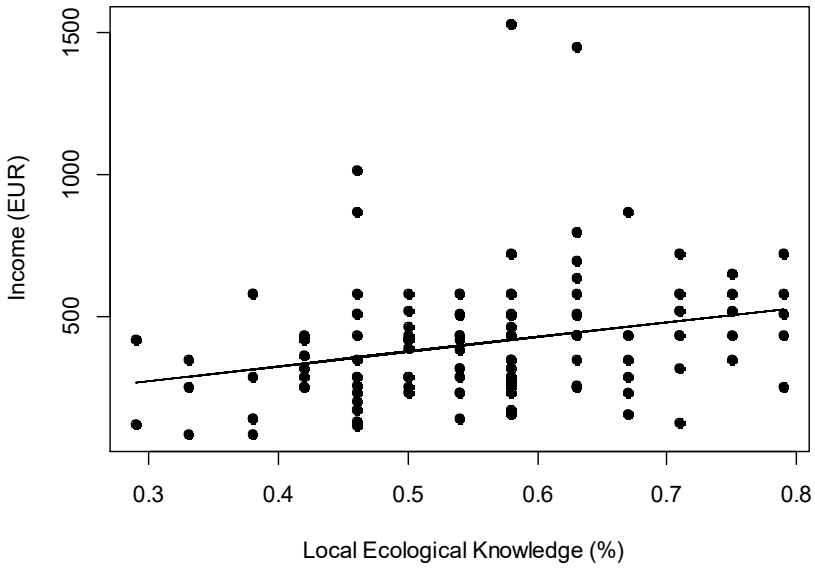

Figure 4.3 The correlation between the income source of fishermen (EUROS) and the index of local ecological knowledge about Brazilian sardine.

Kruskal and Wallis (H) tests showed a highly significant association between educational level and index of local ecological knowledge (K = 211.2483, df = 1, p-value < 0.001; Figure 4.4a) and index of attitudes regarding conservation of sardines (K = 209.351, df = 1, p-value < 0.001; Fig. Figure 4.4b). There was a significant difference between the associated and non-associated fishermen of the Fishing Association Z-5, and the index of LEK (K = 209.5753, df = 1, p-value < 0.001; Figure 4.4c), and the index of attitudes (K = 208.4307, df = 1, p-value < 0.001; Figure 4.4d). There was also significant statistical differences between the fishermen owners and non-owners, in relation to the index of LEK (K = 209.5753, df = 1, p-value < 0.001; Figure 4.5a), and the index of attitudes (K = 210.8745, df = 1, p-value < 0.001; Figure 4.5b). Finally, our results showed that there was also a significant difference between those who live exclusively on fishing and the others that have another source of income in relation to index of LEK (K = 208.7276, df = 1, p-value < 0.001; Figure 4.5c) and the index of attitudes (K = 207.2318, df = 1, p-value < 0.001; Figure 4.5d).

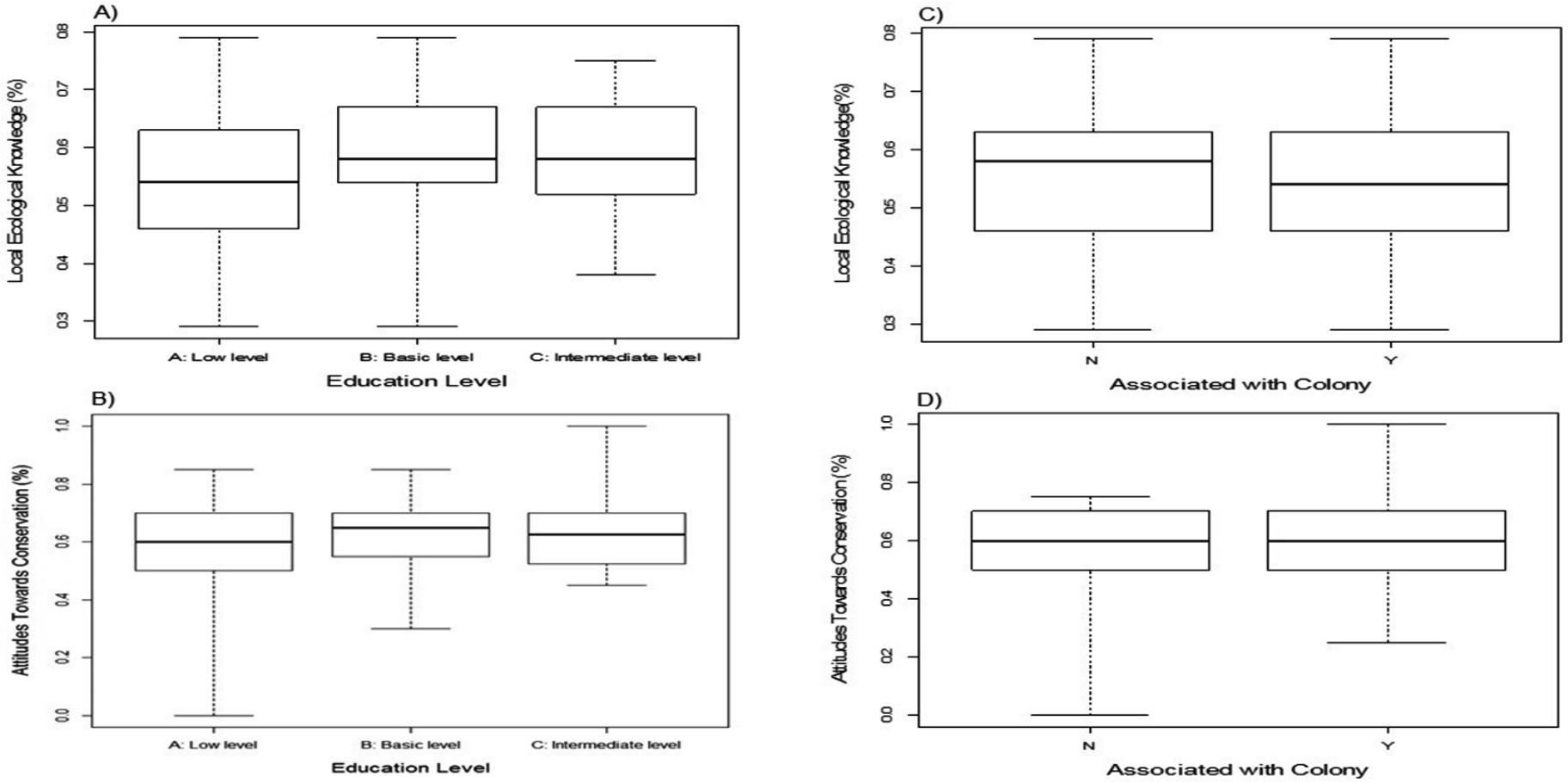

Figure 4.4 A) The correlation between the index of LEK and the education level; B) The correlation between the index of attitudes and the education level; C) The correlation between the index of LEK and the fishermen associated with Fishing Colony Z-5 D) The correlation between the index of attitudes and the fishermen associated with Fishing Colony Z-5. (N: not associated, Y: associated).

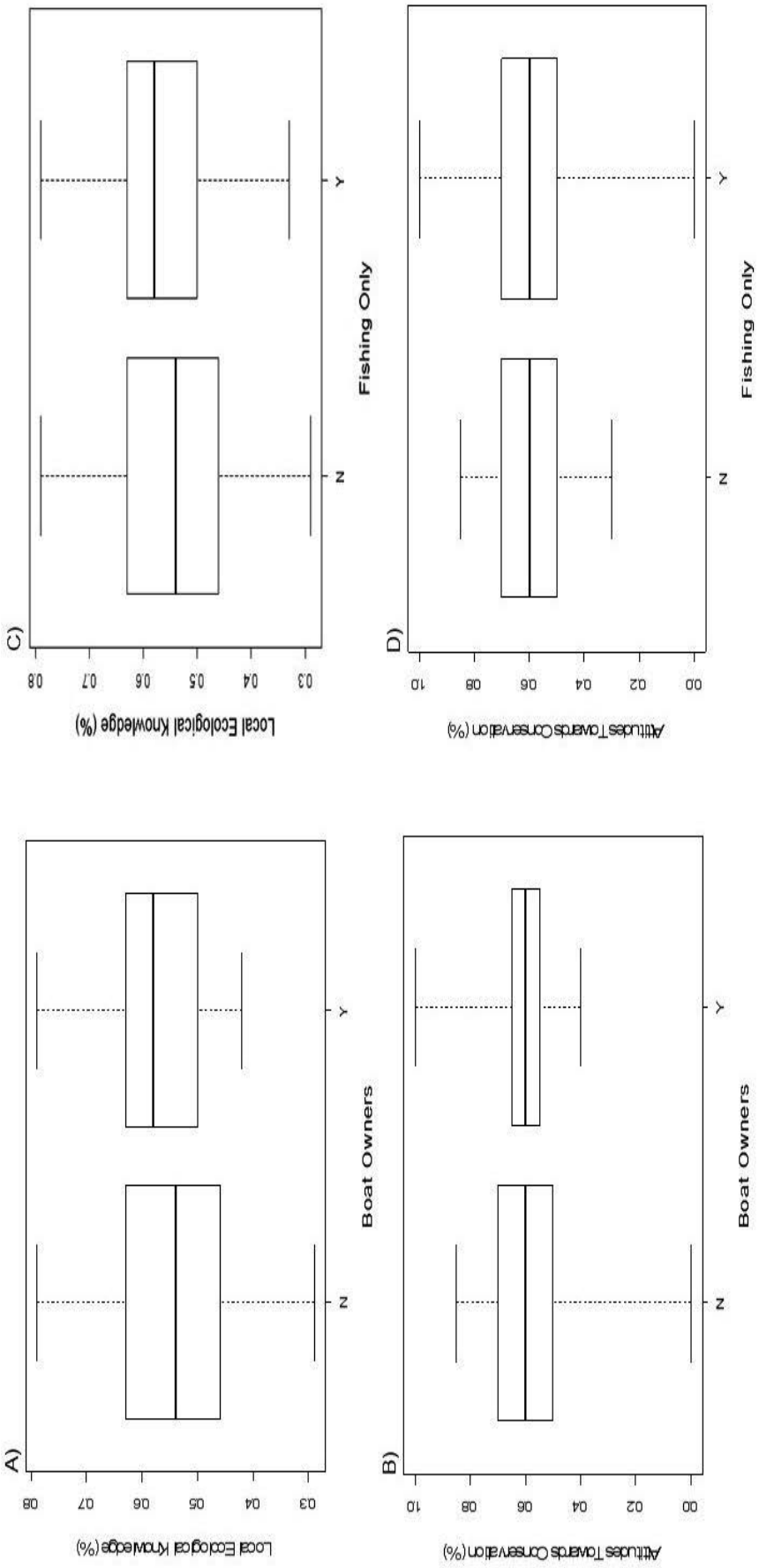

Figure 4.5 A) The correlation between the index of LEK and the owners and non-owners of boats; B) The correlation between the index of attitudes and the owners and non-owners of boats. (N: fishermen not owners of boats, Y: fishermen owners of boats); C) The correlation between the index of the LEK and fishermen who live exclusively from fishing or not. D) The correlation between the index of attitudes fishermen who live exclusively from fishing or not. (N: not fishing only, Y: fishing only).

4.6 Discussion

4.6.1 Fishers' knowledge

The search for evaluating the ecological knowledge of local communities has shown that this auxiliary tool can provide important insights for the conservation of biodiversity (Braga et al. 2017b; Braga and Schiavetti 2013). The ecological index created to evaluate the knowledge of fishermen about the ecology and biology of Brazilian sardinella showed that their knowledge was moderate (0.56) when compared to the scientific literature. The same pattern (0.55) occurred with fishermen from the westernmost fishing community of Europe (with the species *Sardina pilchardus,* Walbaum, 1792) specifically located in the city of Peniche, Portugal and near the Berlengas Marine Nature Reserve (Braga et al. 2017b). In a study that sought to evaluate the knowledge of chelonians in the South of Bahia, Brazil, fishermen presented also an average knowledge (0.43) (Braga and Schiavetti 2013).

In a neotropical ecosystem in northeastern Brazil, fishermen's knowledge provided evidence as a scientific complement to what is said about fish biodiversity and structures in each food chain (Rosa et al. 2014). In two other marine and freshwater ecosystems, in Brazil, the small-scale local fisher´s provided important data on fish ecotoxicology, with results that stimulate the expected cooperation between researchers and artisanal fishers (Silvano and Begossi 2016). In situations where there is a lack of scientific data, local knowledge can also be a reliable source of data, as demonstrated by fishermen in the northern Irish Sea, where spatial extraction data were available (Shepperson et al. 2014). Using qualitative-quantitative interview techniques, Olsson and Folke (2001) observed that members of a community in western Sweden had a considerable local ecological knowledge of crayfish population, as well as their resource dynamics at the ecosystem level. Data from fishermen from the Spanish Mediterranean Sea and the Gulf of Cadiz on abundance, size composition and catches of fish species were correlated with available scientific evidence (Coll et al. 2014). Finally, the same study also demonstrated that the local ecological knowledge of these fishers can also be useful to complement quantitative information generated from fishing activity as a means of monitoring the effects of fishing and climate change on the Mediterranean (Coll et al. 2014).

4.6.2 Attitudes towards biological conservation

It is known that the attitudes that a local community presents about a biological resource is of great importance for its conservation (Alexander 2000). On occasions where self-interest and livelihoods are in some degree of threat, conservation support is almost always facilitated (Kideghesho et al. 2007). In this way, understanding attitudes becomes crucial to better understand why people choose certain choices and behave the way they do (Winter et al. 2005). Thus, we calculate the index of attitudes towards conservation of sardines that had an average value of 0.60. According to the Likert scale, the fishermen´s attitudes from the village of Arraial do Cabo was predominantly moderate. Negative attitudes towards sardine conservation were witnessed in only 3.7% of fishermen in this local community. All these individuals were not boat owners and only one fisherman had the monthly income lower than the average of all respondents (145 €). In the evaluation of fishermen's attitudes in five species of sea turtles in the south of Bahia, Brazil, no fishermen with negative attitudes were registered and the average attitudes indicator was 0.69 (Braga and Schiavetti 2013). In a fishing community on the west coast of Portugal, the average indicator of attitudes was 0.76 and none of the respondents also showed negative attitudes towards the conservation of European sardines (Braga et al. 2017b). The attitudes of rural landowners have also been generally favorable to the conservation of Overberg Coastal Renosterveld (OCR), a highly-endangered vegetation grassy-shrubland of Cape Floral Region (CFR) in South Africa. In this case, the average index of attitudes to conservation was 0.6 (Winter et al. 2005).

In the Pacific Ocean, 89% of local Costa Rican fishermen support shark conservation when their fishing practices are not affected (O'Bryhim et al. 2016). An assessment of local attitudes towards forest elephant conservation in four villages in a protected area around the northern Congo showed general positive attitudes (Nsonsi et al. 2017). In the Kalakad-Mundanthurai Tiger Reserve (KMTR) in South India, 61% of respondents from the local community presented positive attitudes towards tiger conservation (Arjunan et al. 2006). In addition, Arjunan et al. (2006) indicates this type of conservationist perception assessment as a good indicator of the interests of resource used by the community around the Tiger Reserve. In contrast to our study, the conservationist attitudes of ranchers about wild dogs in South Africa were generally negative where there is hunting around the farms (Lindsey et al. 2005). However, the author makes clear that even with this negative trend of attitudes

towards this local community, there are still possibilities to improve the conservation of these animals on ranchland in southern Africa (Lindsey et al. 2005). In Finland, fishermen from Lake Pihlajavesi also followed this negative trend and were not in favor of the conservation of the only endemic mammal in this country - Saimaa ringed seal (Tonder and Jurvelius 2004). In this case, a conflict of interest between conservationists, local owners, summer cottage owners and commercial fishermen was elucidated. The latter, for example, shared the idea that it was unnecessary to use financial resources for the protection of this animal (Tonder and Jurvelius 2004). This makes clear how local knowledge and social learning may be important for a better understanding of the local situation for more successful co-management of resources (Berkes 2009).

4.6.3 Ethnoecological knowledge, attitudes, and fishers´ socioeconomic characteristics

The current study showed that fishermen with higher income source tended to have more local ecological knowledge (Fig. 4.3). In contrast to the present study, in Braga et al. (2017b) there was no significant correlation between income source and index of LEK on European sardines. The variation in attitudes regarding the conservation of Brazilian sardinella among fishermen in the fishing community in question was not explained by LEK. However, in another tropical community in Brazil, the fishermen have shown more favorable attitudes towards conservation of sea turtles when LEK was lower (Braga and Schiavetti 2013). In Peniche, Portugal, when Fisher´s LEK of European sardines was greater, the more positive were the attitudes towards conservation of this clupeoid (Braga et al. 2017b). In the case of Tampa Bay boaters, along the Gulf of Mexico on the west coast of Florida, United States, knowledge about Florida manatees was highly associated with attitudes towards conservation of this marine mammal (Aipanjiguly et al. 2003).

In the present study, the results showed that there was a significant difference in LEK between the schooling classes. In this case (Figure 4.4a), it is possible to conclude that there was a higher LEK among individuals with higher level of schooling. The same pattern was observed in a study of another specie of sardine in the Iberian Peninsula (Braga et al. 2017b). Differently from our study, there was no relationship between knowledge and educational level in Aipanjiguly et al (2003). However, these researchers reinforce the idea of the need to educate boaters and the general public as a way to avoid harassment of the manatee, thus contributing to a greater incorporation of knowledge by this local community. Thus, this

educational recommendation can provide a better basis for the management of manatee conservation in Tamp Bay, United States (U.S) (Aipanjiguly et al. 2003). This trend can also be applied to the local community of Arraial do Cabo as a way to support the conservation of sardines in the region.

Factors influencing conservationist attitudes may help to improve conservation objectives (Kideghesho et al. 2007). One variable that stands out in relation to environmental awareness is education, since it usually explains environmental causalities as well as pro-environmental behavior (Zsóka et al. 2013). In the present study, the fishers´ level of education influenced the extent of their conservationist attitudes about Brazilian sardinella. The highest values of the attitudes index were observed in the most advanced level of education. This pattern of behavior may be an indication that more educated fishermen may have a more favorable conservation of sardines.

Level of education was also an important predictor of the relationship between six villages and protected areas in the Western Serengeti, Tanzania (Kideghesho et al. 2007). Members of these local communities with a higher level of education supported the conservation of these protected areas (Kideghesho et al. 2007). The attitudes of local residents about the conservation and management of natural resources in one of the largest protected areas of the Ecuadorian coast in Latin America tended to increase with the level of schooling of the interviewees (Fiallo and Jacobson 1995).

Notwithstanding, in villages around Nouabalé-Ndoki National Park (NNNP) in northern Congo, researchers found little evidence of the impact of education on residents' attitudes toward elephants conservation (Nsonsi et al. 2017). It is observed in this case that the positive attitudes came from villages where there was an existing conservation project. In an attitude survey in Mozambique, rural owners with higher levels of education were not associated with a predisposition to conserve the Renosterveld Coastal Overberg (OCR) in South Africa (Winter et al. 2005). The same trend was observed in an ethnoprimatology study in Fanjingshan National Nature (FNNR), southwest China's Guizhou Province. In this ethnobiological research, there was no correlation between the scores of conservation attitudes and the level of education of the local people (Ellwanger et al. 2015). However, in this local community, the residents had predominantly positive attitudes towards monkeys, even with the low overall level of education observed in the sample (Ellwanger et al. 2015).

Regarding to the association of the interviewees to Z-5 fishing association of Arraial do Cabo, we can point out that there was a difference of ethnoecological knowledge about sardines between members and non-members of the fishing colony. However, when comparing the attitudes between these two groups, it was noticed that the associates tended to have more positive attitudes regarding the conservation of sardines than those not associated with the fishing colony (Figure 4.4d). Some actions of this association of fishermen made these associated residents more favorable towards conservation of sardines than non-members. The information provided by the fishing colony on the closure of sardine fishing through the laws imposed by the Brazilian Institute for the Environment and Renewable Natural Resources (Ibama, Normative Instruction No. 15, of May 21, 2009) probably contributed to fishermen propensity to conserve this biological resource. The fear of breaking government and fishing colony´s laws, involving punishment, may have provided a preventive factor for attitudes to be favorable in this case.

The conservationist attitude and LEK about sardines varied between boat owners and non-boat owners (Figure 4.5a-b). Boat owners tended to have a greater ethnoecological knowledge about sardines. This finding reinforces the positive and significant correlation between income source and LEK that was observed. This is because fishermen who own boats usually receive more income than non-owners. This was also expected because generally those who command the fishing activity (priority areas for fishing, fishing effort and catch of sardines) are boat owners, who are also usually the boat-master. Therefore, they had a greater propensity to acquire knowledge about the ecology and biology of sardines.

It was clear that fishermen restricted to fishing have higher LEK and tended to range their attitudes towards conservation of sardines (Figure 4.5c-d). Ferreira et al. (2014) argue that fishermen restricted to fishing gain more experience in fishing methods and conservation strategies. This may help to explain the tendency of restricted fishermen to have greater local knowledge of sardines than fishermen with other sources of income. Through better knowledge of fishing gear, fishermen can better understand the ecology and biology of target species over time and to improve fishing effort.

These fishermen restricted to fishing may also have this LEK trend because they have a greater availability of time directed to the fishing activity. With this, they gain more experience and knowledge about the species due to a greater coexistence with the ecosystem and the temporal changes of the biological resources.

Normally, the most active fishermen in the fishery have more contact with boat masters, older fishermen, and other fishermen. Through informal conversations, various discussions about fishing strategies, occasional events during a fishing trip, and some experiences of former fishing professionals can be generated. The mere fact of being more present at these meeting places and the imminence of exchanges of information on these occasions may also have contributed much to our finding.

4.7 Implications for conservation and conclusions

Social-ecological studies on traditional fishing communities represent a valuable source of information on the current state of fisheries and may show their predisposition to work with conservationists in consensus around a marine biological resources (O'Bryhim et al. 2016). It is known that incorporation of both technical knowledge and local knowledge can increase accuracy in environmental monitoring (Giordano et al. 2010). However, even with some gaps in our traditional scientific knowledge, there is still resistance on the part of scientists to include local knowledge to aid scientific research, even with the imminent possibility of such knowledge to generate diversified and practical information (Mackinson 2001).

In the Southern Atlantic, the commercial catches of Brazilian sardinella have shown intense oscillations in recent decades due to their own life history, intense fishing effort and direct environmental variations (Cergole and Dias-Neto 2011). With the great vulnerability of fish stocks worldwide, here with an emphasis on *Sardinella brasiliensis*, we seek to combine scientific information with local knowledge. Mackinson and Nottestad (1998) suggested that this type of research can provide a more adaptive management and a mutual respect between all actors involved with the resource in question. In Latin America, for example where small and medium-scale fisheries have negative impacts on the marine ecosystem and are of great commercial and social importance to the population, the use of LEK can also contribute to increasing the success of legislation in the area of conservation (O'Bryhim et al. 2016).

Thus, incentives for the viability of ecological knowledge to be used in governance is needed, pertinent and timely (Adger et al. 2005). In this sense, local ecological knowledge emerges to provide high value and low cost information, especially when traditional sampling patterns are expensive or difficult to implement (Anadón et al. 2009), which can

be extremely useful for conservation biology efforts (Huntington 2000). However, it is known that this information derived from this knowledge depends on the methodology used, reliability and accuracy of the information collected to provide consistent data (Hamilton et al., 2012a). It also advises in this type of social research, approaches of detailed systematic methodologies with critical and refined treatments so that this local knowledge incorporates in reality what it says to represent in fact (Davis and Wagner 2003).

In the present study, when comparing data from the scientific literature with the LEK of Brazilian sardinella through the Likert scale, fishers from the fishing village of Arraial do Cabo showed moderate informal knowledge of the ecology and biology of Brazilian sardinella. The data in this analysis on the ethnobiology of *S. brasiliensis* that did not correspond to the scientific knowledge should not be totally discarded, but rather analyzed to see the possibility in the contribution of the formulation of new hypotheses for future ecological studies (Drew 2005; Silva et al. 2014). It is also worth noting that the LEK in this study had shown to be related to income source, level of education, boat ownership, associated and non-associated to the local fishing colony Z-5 and fishermen restricted and not restricted only to fishing activity. The behavior observed between the fishermen's variables and the LEK in our study is suggested as a source of additional information on the fishery resource in question for fishery managers both within and outside of the Marine Extractive Reserve of Arraial do Cabo for a better understanding the fisheries planning for sardine.

Attitudes towards conservation in this context can also be an important predictor of interests in the use of natural resources by local communities (Arjunan et al. 2006), and can be critical to their long-term sustainable management (Garekae et al. 2016). In addition to the purpose of the environmental attitude of expressing how certain information and informative quality are expressed by individuals in practice, this variable can also be influenced by institutional and social factors, which can direct and shape individuals' responsiveness (Lo et al. 2012).

In this context, it is known that the educational level is recognized with one of the most important variables to explain ecological concerns, everyday lifestyle, and behavior (Zsóka et al. 2013). But it is also known that the level of education does not always influence the variation of conservation attitudes (de Boer and Baquete 1998; Baral and Heinen 2007). Nevertheless, in a society with a greater contingency of people with high level of education,

the level of consciousness also tends to follow a higher standard, which may induce more positive attitudes (Shibia 2010). This social variable is also highlighted here as important because it is more related to people's sincerity and expectations (Kideghesho et al. 2007).

As a way to promote awareness and positive attitudes in practice regarding sardine conservation, it is indicated that medium-long-term multilateral efforts should be made between the Brazilian federal environmental government, managers of marine reserve, local fishermen's institutions (registered) and autonomous fishermen. Greater attention to the representativeness of boat owners is indicated in the involvement of possible assistance in changing the attitudes of fishermen in general. This is indicated because fishermen who were boat owners tended to have an ethnoecological knowledge about the natural resource in question greater than the fishermen have no boats. It should also be noted that boat-owners had more positive attitudes than non-owners. This fishermen's profile (boat owners) should still be evidenced as important because they generally lead local fisheries management in practice.

Extension of studies among teenage fisherman and adults is also advisable in this regard. According to Kideghesho et al. (2007), the education factor can be seen as one of the ways of changing attitudes as well as bringing individuals to other financial niches, which may lead to less pressure on biological resources. However, to foster proenvironment changes in residents' behavior, it is not only a question of changing their way of thinking, but rather of clarifying and improving the assimilation of these local members about the environment in which they live and the problems they confront (Smith 1995). In addition, promoting a viable environmental education with a strong public awareness in the many fishing associations of the Arraial de Cabo Region and local municipalities can help decisively in the attitudes and collaboration of a more adequate management small-scale fisheries of sardine in coast of Arraial do Cabo in the Southwestern Atlantic.

4.8 Acknowledgments

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5. Chapter IV

Local ecological knowledge (LEK) of the Brazilian sardine, *Sardinella brasiliensis* (Steindachner, 1879): a synthesis of the ethnoecology a Bio-Resource in a typical fishing village of Rio de Janeiro State, Brazil

5.1 Abstract

Fishers´ local ecological knowledge (LEK) presents the enormous potential to assist in the conservation of depleted natural resources available to small-scale fisheries worldwide. Due to the significant socioeconomic value of sardines in the Southwestern Atlantic, the objective of this work was to register the ethnoecological knowledge about Brazilian sardine of the traditional fishing village of Arraial do Cabo, Rio de Janeiro, Brazil. Social science tools were used to extract data from biology, ecology, unwritten social rules, and human uses of Brazilian sardinella. A qualitative analysis was performed through accurate coding and cross-checking using an emic-etic approach and all data made available was taken into consideration. Fishers highlighted information on areas of habitat, migration patterns, trophic ecology, and reproduction season. The LEK showed compliance with scientific literature in relevant points of the ecology and biology of this species. These ethnobiological findings indicate that fishers' LEK may be useful for new ecological research scenarios, especially in the case of sardines, which have a life history that leads to increased vulnerability due to overfishing and management difficulties. We also emphasize the importance of the exchange of information between all actors, directly and indirectly, involved in the sardine conservation.

5.2 Keywords

Fishers´ local ecological knowledge; Small-scale fisheries; Brazilian sardine, Ethnoecology; Southwestern Atlantic.

5.3 Introduction

The search for understanding the diversity of the relationships between human cultures and natural resources is crucial so that these individuals can continue to ensure the sustainable use of the resources available and ecosystem services (Pardo-de-Santayana and Macía 2015). In situations where the lacking of historical and physical data from a particular region is evident, traditional human knowledge gains strength and becomes the only available source of information about that environment (Huntington 2011).

The anthropologist Darrel Posey classically claims that ethnobiology is the study of knowledge and conceptualizations developed by any social body related to biology (Posey 1987). According to Paz and Begossi (1996), this ethnoscience constitutes the study of human perceptions about living organisms, and the understanding of how these populations classify them. This same term can also be understood as the field of study of biological and cultural knowledge of ethnic groups on plants and animals, as well as their interrelationships (Anderson et al. 2011).

From the academic point of view, ethnobiology has occupied a prominent role in connecting traditional populations with science and academia purposes, bringing together global and local knowledge, and also relating the environment to the biological and cultural dimensions of human experience (Albuquerque and Alves 2016). Regarding ethnobiology, one can say that the most preeminent areas are ethnozoology and ethnobotany (Arshad et al. 2014). This multidisciplinary science over time has also originated other critical areas of knowledge, such as ethnoecology, ethnomedicine, and ethnopharmacology (Albuquerque et al. 2013).

Specifically, ethnoecology is understood as the field of knowledge with an interdisciplinary approach that investigates how human communities understand nature through systems of beliefs, knowledge or cognitive systems and sets of practices (Toledo 1992; Marques 2001; Toledo 2002). However, it is worth emphasizing that ethnoecology and ethnobiology can not be considered mutually exclusive but complementary and interconnected fields in which they are related to local knowledge and biodiversity conservation efforts (Albuquerque and Alves 2016).

Ethnoecological studies in a given community have the characteristic of providing local ecological knowledge (LEK) about a natural resource (Begossi 2008). This ethnoecological knowledge essentially aims to understand a specific group of human beings

about their ecosystems through the interaction between organisms and the environment, and between the organisms themselves (Olsson and Folke 2001). In this LEK scope, it is still important to note that not only the "experts" are a reference to knowledge within the community, but it is evident that the profile factors of respondents may have the ability to influence the credibility of the knowledge available for scientific purposes (Frans and Augé 2016).

Fishers´ LEK in this context presents as a solid partner of scientific knowledge, as it may possess the ability to supplement data from traditional science where they are scarce or absent (Le Fur et al. 2011; Uprety et al. 2012). Small-scale fishers, in particular, can provide detailed information on ecology and biology about fish species and thus assist in the conventional management of fishery resources, as well as generate testable hypotheses for science (Silvano and Begossi 2010). Another important link to LEK is its importance for tropical coastal fisheries where available information on fish stocks is not yet sufficient for fishing management (Berkes 2003; Gerhardinger et al. 2009a).

In the Southwestern Atlantic, Brazilian sardinella *Sardinella brasiliensis*, (Steindacher, 1879) (Teleostei: Clupeidae), is considered a bio-resource of extreme socioeconomic importance for the typical fishing communities of Brazil, such as Cabo Frio Region, Rio de Janeiro (Coelho-Souza et al. 2012). This small pelagic fish is historically known for its continuous overfishing and is marked by fluctuations in its population composition (Gigliotti et al. 2010). Also, sardines are presented as the most caught species in the fishing ports (47,204 tons) in the state of Rio de Janeiro (FIPERJ 2015).

Thus, with all these socio-ecological characteristics, the Brazilian sardine becomes a potential object of fishers´ LEK study belonging to small-scale fisheries due to their imminent possibility of generating a set of knowledge, beliefs, and practices about this fishery resource. Thus, the goal of this work is to summarize and document in detail local ecological knowledge (LEK) on the biology, ecology, unwritten social rules, and human uses of Brazilian sardinella (also known as Brazilian sardine) using the ethnobiological data collection tool. Fishers' LEK from the fishing village of Arraial do Cabo, Rio de Janeiro, Brazil, were also compared and discussed with the available scientific literature about sardines.

5.4 Methods

5.4.1 Study site

Community-based interviews were conducted in Arraial do Cabo (22° 57'57"S, 42° 01'41" W) State of Rio de Janeiro, Brazil (Figure 5.1). This region is located 117 km north from the city of Rio de Janeiro in a straight line and has a population of 29,304 inhabitants (IBGE 2017). Arraial do Cabo presents itself in the form of a small peninsula with about 30 km of beaches (Godoy et al. 2013), with a sectional area of 158,952 km² (IBGE 2017). It is composed of two regions surrounded by rocky beaches and an isthmus (Cordeiro et al. 2014).

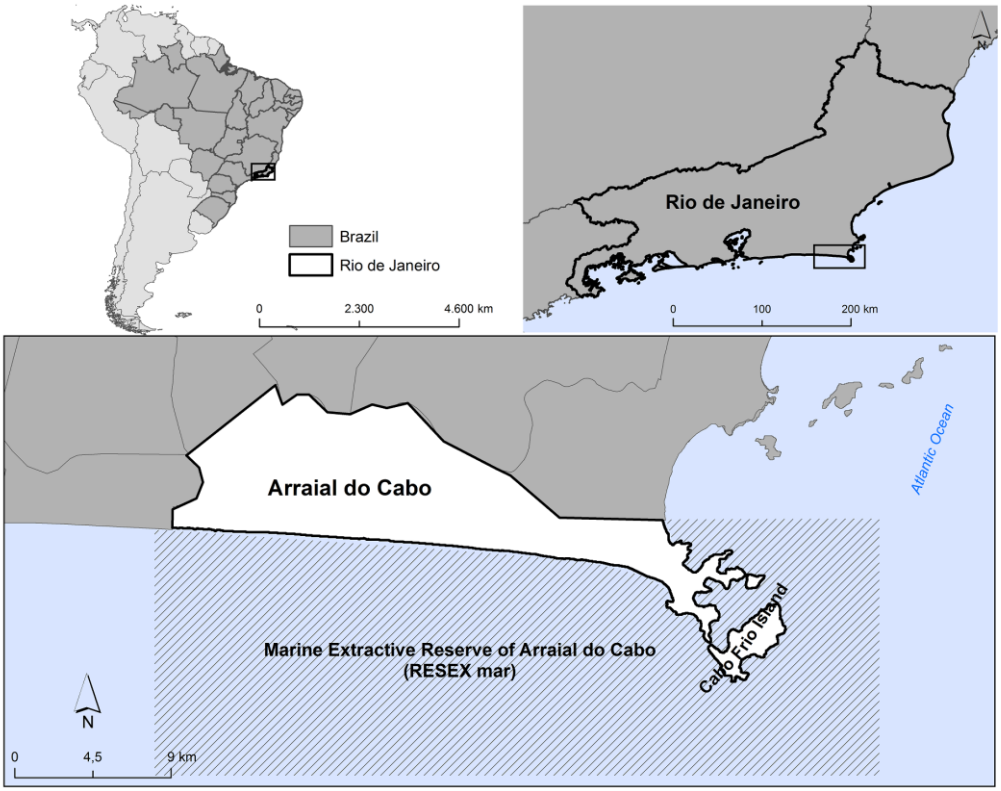

Figure 5.1 Area of the study showing the fishing community of Arraial do Cabo in the South America. Credits: Anjos, M.

In disagreement with the typical climate of the Brazil's southeastern coast (Tropical and predominantly humid) (Turcq et al. 1999), this peninsula presents according to Köppen's classification, as hot semi-arid climate (BSh) with five months of drought (Duarte 1998). The mean temperature and the average annual rainfall of the region respectively are about 23 °C and 823 mm/year (Godoy et al. 2013). During spring and summer, the northeast winds

are responsible for the upwelling events (Barbieré 1984), giving a direct impact on the biodiversity of the species, and consequently on the area's trophic structure (Valentin 1989).

In the Southwestern Atlantic, this area was designated as Marine Extractive Reserve (MER) of Arraial do Cabo on January 3, 1997, by Presidential Decree, being classified by the National Conservation System (Law N. 9.985/2000) as a Brazilian Conservation Unit (ICMBio 2017a). The Arraial do Cabo MER presents an area of about 51.601 ha (ICMBio 2017a) and presents multiple marine fisheries applied to diversified fishing gears (da Silva 2004; Bender et al. 2014). Its purpose is to conserve and guarantee the self-sustainable extraction of renewable bioresources through artisanal fisheries of the local community of Arraial do Cabo (ICMBio 2017a).

The local fishing village consists of about 1000 active fishermen (Giglio et al. 2017), and the Association with the largest participation of local fishers is the Z-5 Fishing Colony (da Silva 2004). The beaches with the biggest presence of fishers are *Anjos* Beach, *Grande* Beach, *Prainha* Beach and *Pontal* Beach. In the *Anjos* Beach we highlight the presence of the Z-5 Fishing Colony, Association of the Extractive Reserve of Arraial do Cabo (AREMAC), fishing port, jetty and the Brazilian Navy. Another beach of high relevance in the fishing activity of Arraial do Cabo is *Grande* Beach, where APAC (Fishers Association of Arraial do Cabo) is located.

5.4.2 Legal and Ethical aspects

The present research follows the ethical and legal obligations of the Brazilian Federal government (CAAE: 53819116.6.0000.5285). The Authorization for scientific activities within the Marine Conservation Unit was granted by the Chico Mendes Institute for Biodiversity Conservation (ICMBio), Ministry of the Environment of Brazil (nr. 52333-1) with the logistical support of the Centre for Studies, Research and Documentation on Healthy Cities (CEPEDOC), School of Public Health University of São Paulo, Brazil. Before the application of the questionnaire to the interviewee, the researcher explained the objectives of the research and soon after asked the interviewee for permission to apply the survey. The willingness to collaborate or not with the research was always respected. This procedure was performed through the “Statement of Informed Consent” (IC). This document presented information about the participation of the informants, research, and the institution of the researchers.

5.4.3 Interview data collection and analysis

Fieldwork was conducted from April to July 2016 on the four beaches with the highest fishing activity in Arraial do Cabo. The approach to fishers (all male) was carried out randomly and always individually. There were no women interviewed in the sample because of the gap between this group and the fisheries issues and their specific demands (Fonseca et al. 2016). The meeting with the informants was made mainly before the departure and after the arrival of the boats on the beaches of Arraial do Cabo. These two times of the day were chosen by the researcher because it was the most opportune moment for the interviewee (Albuquerque et al. 2014). In the first approaches, the interviewees first sought to create a friendly and trustworthy atmosphere as a way to reduce the biases of the information collected. An investment in the interrelations between the researcher and the communities is suggested in research using LEK (Brook and McLachlan 2008). Two native biologists belonging to the local community and directly connected to the local fishermen participated in this first phase of data collection. Monastersk (2009) shows that projects that involve local communities in data collection in scientific research contribute to the transfer of traditional knowledge in times of change.

The questionnaire was based on semi-structured interviews (Huntington 2000), since the probability of interviewing the same informant twice was low (Albuquerque et al. 2014). A pilot test was conducted previously to construct a well-delineated questionnaire (Huntington 2000; White et al. 2005). The interviews began after reading the "Statement of Informed Consent" and clarifying the research objectives for the informants. Field notebooks and occasionally electronic devices were used to record information. Three sections constituted the questionnaire to be applied (Table 5.1). The first part of the interview contained general information about the fishermen (name, age, nickname, interview location, education level, income source and residence time in Arraial do Cabo region). The respondent's name and nickname were optional. The standard of education was based on the Brazilian Education System: Elementary education 1 (1-5 years of study), Elementary education 2 (6-9 years of study), High school (10 to 12 years) and D: Higher education (13 years or more years of study). Informants who did not present any year of study were classified as Illiterate. The income source was converted into currency Euro (1 Brazilian Real = €0.29 Euro). The second section of the questionnaire contained information on general knowledge about fishing, structure, and work equipment, membership to a local

fishing association (Z-5 Fishing Colony, Association of the Extractive Reserve of Arraial do Cabo and APAC, Fishers Association of Arraial do Cabo or others). Also included data from fishing experience, active fisherman, boat owner, type and length of the boat and number of hours in each fishing effort per trip of Brazilian sardinella.

Table 5.1 Summary of the questionnaire used during the approaches to informers in Arraial do Cabo (N = 134).

Sections of the questionnaire	N of questions (%)
I. Fishers information - name, age, nickname, interview location, education level, income source, the residence time in Arraial do Cabo.	8 (22.2%)
II. Local knowledge about fishing - member of association fishing experience, active fishers, boat and fishing effort pert trip.	12 (33.3%)
III. LEK about sardines - folk taxonomy, habitat, migration, behavior, reproduction, lifetime, feeding, predators, socio-economic importance, food taboos and human uses.	16 (44.5%)
Total	36 (100%)

The last part of the interview sought to explore the local ecological knowledge (LEK) about of Brazilian sardinella (*Sardinella brasiliensis*). The points investigated in this section were: folk taxonomy, preferred habitat, migration, behavior, development of sardines, breeding season, fat accumulation season, lifetime, feeding, predators, socio-economic importance, food taboos and human uses. The informants at the beginning of this part participated in a projective test (Costa-Neto et al. 2009), in which they received a photograph of the of Brazilian sardinella for identification and the collection of possible local names (Figure 5.2).

The emic-etic approach is used to evaluate interview script data after tabulation and categorization (Harris 1976). A qualitative analysis was performed through a careful coding and cross-checking, synthesizing information from different sources with a focus on the

richness of detail and depth of observed perceptions (Newing 2010). All data provided in the interviews were also analyzed using the model of integrating various individual competencies, in which all available knowledge was taken into account (Marques 1991). The species cited by the informants are available with the Fish Base repository version (02/2017), the International Union for Conservation of Nature (IUCN), and the Food and Agriculture Organization of the United Nations (FAO). The organization and standardization of the information acquired through the interviews were carried out in MS EXCEL. The fisher´s descriptive statistics were performed using the R Project for Statistical Computing version 3.3.2 (Team and others 2016).

Figure 5.2 Image of the Brazilian sardine used in the projective test. Credits: Carvalho Filho, A. FishBase.

5.5 Results

5.5.1 Interviewed fishers

A total of 134 interviews were carried out during the ethnobiological survey (all male). The application of the questionnaires during the fieldwork took place in four beaches in Arraial do Cabo, (*Anjos* Beach, N = 93; *Grande* Beach, N = 23; *Prainha* Beach, N = 11 and *Pontal* Beach, N = 7). The mean age of the fishermen (± standard deviation) was 48.6 years ± 13.6 years old, and all the interviewees were male. Only six fishermen were illiterate. The elementary education was the class of education that had the largest number of fishermen registered in the sample (Elementary Education, N = 87 and Elementary Education 2, N = 25). Sixteen fishermen belonged to the high school education class (High school incomplete, N = 4 and High school completed, N = 12). There were no fishermen with higher education level in the sample. More than half of the fishermen (60.4%) are natives of the city of Arraial do Cabo (also known as *Cabistas*). Of the others remaining,

21.6% live in Arraial do Cabo since childhood, 8.2% since teenagers, 9% since the age of majority, and only one interviewee does not reside in Arraial do Cabo. Eighty-one (60.4%) of fishers interviewed are members of the Arraial do Cabo fishing association Z-5, and fifty (37.3%) of fishermen are registered in the Association of the Extractive Reserve of Arraial do Cabo (AREMAC). Most of the respondents (86.6%) are active in the fishing currently, and 47% have monthly income source directly from the fishing activity. About income source, the lowest recorded value was € 87, and the highest was € 2030, and the average income of the fishermen (± standard deviation) was 420.5 ± €256.8 Euros.

The fishermen interviewed have on average (± standard deviation) 27.1 ± 12.2 years of experience in the fishing activity in the village of Arraial do Cabo. Only 27.6% of the fishermen have their boat. The most used boats in the artisanal fisheries of Arraial do Cabo according to the fishermen are: "boca aberta" or "open mounth" in which the width of the cross-section of the boat is large (47 citations), "canoa" or canoe (29 citations), "traineira" or trawlers (26 citations) and "convés" or deck boat (21 citations). Other boats were also remembered as the "caíco" or small canoe (8 citations) and "barco de turismo" or touristic boat (2 citations). Sixty-six fishermen (49.3%) engage in fishing daily, 31 informants reported fishing for 2-4 times per week, 30 informants for 5-6 times per week, five fishermen weekly and two fishermen monthly. The average duration of deep sea fishing per trip (± standard deviation) was 22.1 ± 66.8 hours.

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5.5.2 Fish folk taxonomy

In the projective test, 91% of the respondents correctly identified the Brazilian sardinella. Nine fishermen did not determine the species correctly in the first time, but in the second response, they correctly attributed the name. Only three informants did not identify the sardine species through the projective test.

In the fishing village of Arraial do Cabo, local common names were given to *S. brasiliensis*. Among the 91% of fishers who correctly identified the species, the folk name *sardinha-maromba* (116 times) was the most cited name by the fishermen. Other names were also pointed out by the informants: *sardinha* and *sardinha-verdadeira* (10 times each), *sardinha-lisa* (2 times) and *sardinha comum*, *sardinha boca-torta* and *sardinha-meã* were remembered only once by fishers.

5.5.3 Preferential Habitat

More than half of the fishermen (63.4%, N = 85) reported that sardines are found mainly along the coast, and 35.1% (N = 47) on the coast and high seas. Only two respondents did not respond to this questionnaire item. Informants also cited a diversity of sardine habitats, citing probable locations that this animal prefers to remain, such as hot water, clean water, rocky coastlines, muddy areas of the sea, rocks, places with calm waters and areas of high biodiversity. It was also mentioned that the sardines approach the beaches (sands) in the spawning season. The depth variation was organized into three interval-classes (0-50 m: 74.4% of fishers; 0-100 m: 15.7% and 0-200 m: 9%). Only one interviewee did not answer this question.

The fishermen interviewed also mentioned the probable areas where the clupeoid in question could be found in Arraial do Cabo. The areas most referred to by the informants were *Anjos* Beach and *Grande* Beach (57 citations each), *Prainha* Beach (39 citations), *Forno* Beach (33 citations), *Pontal* Beach (28 citations), *Brava* Beach (13 citations), and *Pontal do Atalaia* or *Prainhas* Beach (12 citations). The Arraial do Cabo MER was also remembered for the fishermen (8 times), as well as *Franceses* Island (6 times) and *Cabo Frio* or *Farol* Island (4 times).

5.5.4 Behavior and development

The sardines show the schooling behavior according to all fishermen. The vernacular name *manta* and *manchas* were mentioned as synonymous of schools. One of the fishermen said that sardines move in a synchronized way and that they remain in schools as a way to protect themselves from predators.

The sardines are primarily migratory fish for 62.7% of the fishermen (N = 84) interviewed in Arraial do Cabo. This clupeoid according to the fishermen comes from the South (54 citations), from the North (8 citations) and can originate from the South and the North (6 citations) of Brazil. Seven informants also said that they could originate from the high sea toward the coast. Eight fishermen related the migration of sardines with their spawning season. Of these, seven fishermen said that the sardines migrate from the South to the North of Brazil to spawn. Only one informer stated that species migrate from North to South for the same purpose. Of the entire sample, fifty fishermen (37.3%) did not say anything about sardine migration.

The development of sardines shows rapid growth (N = 107, 79.9%). Other informants (N = 4) stated that the sardine presents an intermediate growth rate (neither fast nor long), and 11.9% of fishers (N = 16) indicated that this species shows a slow rate of growth. Seven respondents did not know how to comment. Most of the informers (N = 105, 78.4%) reported that *S. brasiliensis* have the roe phase in its initial development. Four fishermen report that sardines present only the larval stage, and nineteen (14.2%) report that sardines exhibit both stages of development in their life. Six fishermen did not know how to answer this question. Regarding the lifetime of sardines, more than half the informants (N = 84, 62.7%) said that they are short-lived fish and another 38 informants (28.4%) said that sardines are long-lived fish. Five fishermen said that sardines have an intermediate-life (neither short nor long) and seven other fishermen did not present this knowledge.

5.5.5 Reproductive, fat accumulation and spawning

Most fishers (N = 86, 64.2%) do not know when the sardines start to reproduce. Another fifteen informants (11.2%) said the sardine mature at one year of age, 13 others between 3-6 months of age, and two between 7-12 months. Others indicated that this clupeoid fish is available for reproduction within a range of 10-15 cm (N = 6) and a range of 16-20 cm (N = 5).

Brazilian sardinella accumulate fat for later reproduction during February (11 citations), March and June (10 citations each). The artisanal fishermen also emphasized the months of January and July (9 citations each), December (8 citations), August (5 citations), September, October, and April (4 citations each) and May and April (3 citations each). Ten fishermen said that they accumulate fat during the spawning season. Some fishermen have stated that sardines accumulate fat according to the seasons (winter: 9 times, summer: 6 times, spring: 3 times and autumn: 1 time). One fisherman reported that they spawn up to 4 times a year (Figure 5.3).

The sardine spawning season occurs between December to March mainly. The month of January was the most cited by the fishermen of Arraial do Cabo (53 citations), followed by February (47 citations), December (46 citations) and March (31 citations). The local fishing community also mentioned the months of September and August (10 citations each), July (9 citations), April (8 citations), June (7 citations), October (5 citations) and May (2 citations).

Some fishermen also cited summer (18 times), winter (3 times) and spring and autumn (1 time each) as the time when sardines spawn. Informants also mentioned the number of times they generate each year (2x a year = 5 citations, 3x and 4x a year = one citation each). In this section, 48 fishermen (35.8%) were not able to say exactly how many months the sardines probably spawn on the coast (Figure 5.4).

5.5.6 Sardines food items and Predators

Fishermen elucidated the main constituents of the diet of sardines (Table 5.2). According to informers, this animal acquires nutrients through the ingestion mainly of plankton (51 citations), small fish (35 citations) and algae or *limo* (slime) (35 citations). Other food items were the small shrimp (13 citations), *purgãozinho* or *pulgãozinho* (13 citations), sea larvae (9 citations), and *manjuba* in general (9 citations). The folk name "purgãozinho or pulgãozinho" refers to a mixture of small fish and small shrimps for a group of fishermen. The vernacular name "manjuba" in general as referenced above, corresponds to several small fish by another group of fishermen. *Manjuba* was also divided into two other types by other fishers. Some informants said that the *manjuba* were sardines own spawn (5 times cited). Other fishers pointed out that manjuba were the spawn of other fish species (2 times cited). Flour was also mentioned in the interviews as a kind of artificial feeding of sardines (7 times). Nutrients from the upwelling were also cited as food for this clupeoid, as well as fish roe and microorganisms in general (3 times cited for each). Remains of fish (2 citations), Krill and impurities of the sea (1 citations each), were also remembered by fishermen.

The members of the fishing community of Arraial do Cabo also show knowledge about the trophic chain relationship between sardines and other animals (Table 5.3). The main predators of *S. brasiliensis* mentioned were: *anchova/bluefish* (117 times), *dourada/ common dolphinfish* (40 times), *bonito-listrado/skipjack tuna* (40 times), *baleia/whale* (38 times), *tubarão/shark* (34 times), *espada/largehead hairtail* (31 times), *aves/birds* (22 times) and *lula*/*squid* (22 times). Informers also mentioned *cavala*/*king mackerel* (17 times), *golfinho/dolphin* (16 times), *pintagola*/*yellowtail amberjack or lesser amberjack* (15 times), *olhete/lesser amberjack* (13 times), *xaréu/crevalle jack* (11 times), *atum/tuna fish* (10 times) and *xerelete/ horse-eye jack* (10 times).

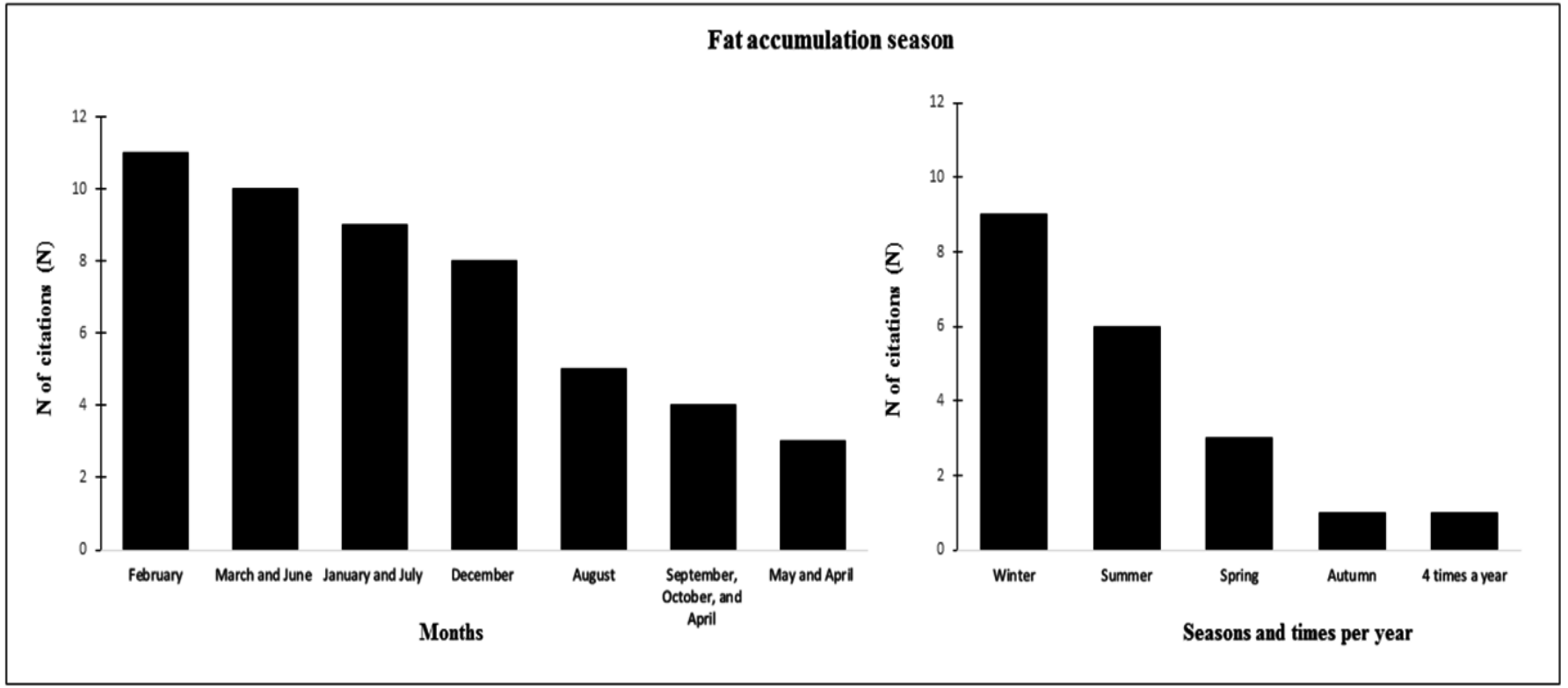

Figure 5.3 Sardine fat accumulation time according to the fishers.

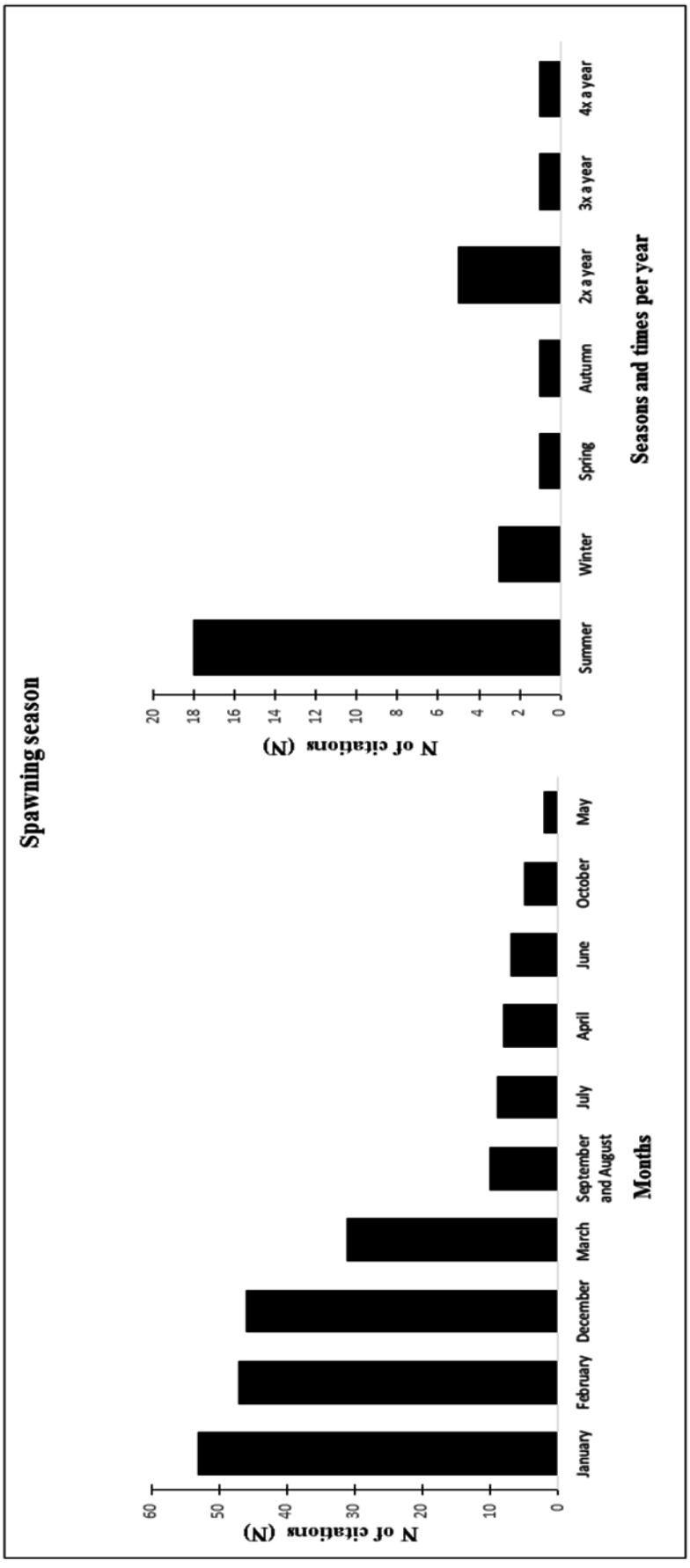

Figure 5.4 Season of sardines spawning according to the informants.

Table 5.2 Components of the sardine diet reported in anthropological interviews.

Sardines food items	N of citations by fishers
Plankton	51
Small fish	35
Algae or “limo”	35
Small shrimp	13
“Purgãozinho” or “pulgãozinho”	13
Sea larvae	9
“Manjuba” in general (small fish by another group of fishers)	9
Flour (artificial feeding)	7
“Manjuba” (sardines own spawn)	5
“Manjuba” (spawn of other fish species)	2
Nutrients from the upwelling	3
Fish roe and microorganisms in general	3
Remains of fish	2
Krill and impurities of the sea	1

Table 5.3 Folk taxonomy about sardine´s predators according to the fishermen.

Folk Name	Common Name (English)	Scientific Name
Anchova	Bluefish	*Pomatomus saltatrix* (Linnaeus, 1766)
Dourada	Common dolphinfish	*Coryphaena hippurus* Linnaeus, 1758
Bonito-listrado	Skipjack tuna	*Katsuwonus pelamis* (Linnaeus, 1758)
Baleia	Whale	In General
Tubarão	Shark	In General
Espada	Largehead hairtail	*Trichiurus lepturus* Linnaeus, 1758
Aves	Birds	In General
Lula	Squid	*Doryteuthis (Doryteuthis) pleii* (Blainville, 1823) and *D. sanpaulensis* (Brakoniecki, 1984)
Cavala	King mackerel	*Scomberomorus cavala* (Cuvier, 1829)
Golfinho	Dolphins	In General
Pitangola	Yellowtail amberjack or Lesser amberjack	Probably: *Seriola lalandi* Valenciennes, 1833 or *S. fasciata* (Bloch, 1793)
Olhete	Lesser amberjack	Probably: *Seriola fasciata* (Bloch, 1793)
Xaréu	Crevalle jack	*Caranx hippos* (Linnaeus, 1766)
Atum	Tuna fish	*Thunnus* spp.
Xerelete	Horse-eye jack	*Caranx latus* Agassiz, 1831

5.5.7 Unwritten social rules and human uses

Food taboos and beliefs were evidenced in the fishing village of Arraial do Cabo about Brazilian sardinella (N = 40, 29.9%). These fishermen pointed out that the sardine was "remosa" fish. This term was used for fish that are restricted for human consumption by this fishing community. Eleven fishermen (8.2%) justified the presence of this specific food taboo. They said that the sardine was “remosa” because it had "dark” meat (5 citations), "strong" meat (2 citations), “greasy” meat (2 citations) and "red" meat (1 citation). One informant also justified this finding by saying that the sardine had a “bleeding” meat and that this species had its "open caudal fin”.

Groups recognized by fishermen as more exposed to sardine consumption were: individuals with injuries (N = 9), post-operate periods (N = 6), general illnesses (N = 6), increased uric acid (N = 4), diabetes (N = 4), some types of inflammation (N = 3), blood (N = 2) and skin (N = 1) problems, elderly (N = 2) and pregnant women or in the puerperium (N = 3). Other informers (N = 90, 67.2%) said that this small pelagic had no food restriction (not remosa). Fishers (N = 70, 52.2%) also pointed out the importance of sardines due to the presence of omega-3 fatty acids. People with heart disease and people with health problems related to blood, cholesterol, bone, and brain are indicating the use of omega-3.

The sardines present significant socioeconomic importance in Arraial do Cabo (N = 80, 59.7%). Fishermen (28.4%, N = 38) showed taboos and beliefs about the sardine resource. Fifteen informants (11.2%) declared that this pelagic species present low value, and one fisherman did not respond to this part. The local community uses this fishing resource for various purposes. The sardines can be utilized as baits (N = 131), commerce (N = 101) and industry (canning, N = 54; flour, N = 3, and ration, N = 3). Six fishermen use the symbolic image of the sardine for the craft trade.

5.6 Discussion

5.6.1 Fish folk taxonomy

The ethnoichthyology and experiences of a fishing community can collaborate with the scientific literature through the folk taxonomy, since these individuals may reflect the availability of the species in an environment (Begossi et al. 2008). Our results showed that the popular name *sardinha-maromba* was the most name mentioned by fishermen in Arraial do Cabo to *S. brasiliensis*. In the FishBase repository, this same

common name is assigned to this clupeoid (Fishbase 2014). The names *sardinha*, *sardinha-verdadeira* and *sardinha boca-torta* are also considered as synonyms of this small pelagic in the same database (Fishbase 2014). The term "sardinha-verdadeira" is also frequently used in Southeast Brazil as the popular name for *S. brasiliensis* (Freire and Pauly 2005). However, the vernacular names *sardinha-meã*, *sardinha-lisa* and *sardinha comum* had no relation with *S. brasiliensis* according to the scientific literature, and presumably may be new names or less used names used for this species.

5.6.2 Preferential Habitat

Brazilian sardinella is a typical pelagic fish of the Brazilian coastal waters (Vasconcellos 2003), bays and estuaries (Paiva and Motta 2000). It is also still worth emphasizing the presence of this species in marine ecosystems of high productivity (Soares et al. 2011). As far as depth (m) is concerned, *S. brasiliensis* is found from coastal regions up to 100 m (Valentini and Cardoso 1991) and is mainly species caught in depths ranging between 30 -100 m (Cergole and Dias-Neto 2011). In our research, the perception of most fishers interviewed about the preferred sardine habitat was consistent with this available scientific information. About 90% of the fishermen cited a similar marine distribution pattern, which ranged mainly depths from 0 to 100 m.

Anjos Beach is known to be an area in Arraial do Cabo influenced by several anthropogenic sources (port activity and sewage disposal) and to a lesser extent by upwelling (Cury et al. 2011). However, even with these characteristics, local fishers (N = 57, 42.5%) have pointed this area as a probable sardine habitat when they approach the coast of Arraial do Cabo. Another area that had an expressive highlight was the *Grande* Beach (N = 57, 42.5%). The mention of this area by fishers may have occurred because this beach is the focus of incoming schools in the region due to local understanding of the migratory fish flow due to intense marine upwelling along this coast (da Silva 2004). The fact that *Grande* Beach is heavily influenced by the great upwelling along the coast, with its cold and nutrient-rich waters (Costa et al. 2017), may also have been one of the factors that influenced our finding.

5.6.3 Behavior and development

It is known that *S. brasiliensis* is a fish species that forms large shoals and tends to move in a coordinated and synchronized way in its migrations (Paiva and Motta 2000;

Moreira et al. 2015). In our ethnobiological database, we find the same pattern of information about the migratory behavior of sardines.

The oceanographic, meteorological and salinity conditions on the coast in Southeastern Brazil Bight (SBB) have a particular influence on the migration patterns of specimens of the genus Sardinella (Sunyé and Servain 1998). For Matsuura (1996), unlike temperate sardines that present migrations with greater reach due to the search for food, Brazilian sardines are limited only to the SBB area. In the present study, the majority of fishermen (N = 54) indicated that the sardine migration is predominant from the South to the Arraial do Cabo region. However, the interviewees would not limit themselves to the presence of sardines at SBB - Cape São Tomé, Rio de Janeiro (22º 45 S) until Cape Santa Marta, Santa Catarina (29º S). Other informants (N = 14) still report that this movement also happens from Arraial do Cabo to the north coast of Brazil.

The study conducted in Arraial do Cabo also showed results similar to the biological information on the development of sardines (Vasconcellos 2003; Cergole and Dias-Neto 2011; Dias et al. 2014). Almost 80% of the fishermen pointed out that this fish has fast growth, and 62.7% of the informants stated that the sardine has short-lived.

The small pelagic fish life history, such as anchovies and sardines, is composed of roe phase and larval stage (Ganias 2014; Fogarty and Moksness 2016). Fishers´ LEK (78.4%) indicated only the roe phase constituting the initial sardine phase. However, it is known that at the end of the larval stage, changes in body proportions begin to occur to initiate the pre-juvenile stage of the sardine (Cergole and Dias-Neto 2011). Therefore, most informants may not have distinguished both phases because the larval phase is often imperceptible and of no referential value to fishers.

5.6.4 Reproductive, fat accumulation and spawning

The SBB coastal waters are the main reproductive area for Brazilian sardinella (Bakun and Parrish 1990). This small clupeiform fish has a reproductive phase strongly influenced by adverse environmental factors and possible recruitment failures of the species (Cergole et al. 2002). High mortality and early maturity are typical characteristics of this sardines (Cergole et al. 2002). Their first maturation occurs at about one year and half of age and a length of 16-17 cm (Cergole and Dias-Neto 2011). Saccardo and Rossi-Wongtschowski (1991) state that they have the gonadal maturity at about one year of age. Some fishermen interviewed in the local community (11.2%) recognized that sardines

also reach sexual maturity at approximately one year of age. There were also informants (N = 5) who said they reached maturity in the range of 16-20 cm.

The recruitment season established by the Brazilian Institute for the Environment and Renewable Natural Resources (IBAMA) for *S. Brasiliensis* is from June 15 to July 31 (ICMBio 2017b). Cergole (1995) highlights the month of July as the most prominent recruitment season. The recruitment time of this species corresponds to the time that juveniles, about 90mm in length and a half year old, move to the open sea to recruit adult fish stocks (Schwartzlose et al. 1999; Cergole and Dias-Neto 2011). However, it is important to note that these fish incorporated into adult stock are not necessarily immediately available for breeding (Cergole and Dias-Neto 2011).

It is known that sardines accumulate fat to grow and mainly to produce energy to produce the male and female gametes necessary for breeding in the following months (IPMA 2016a). At the end of spawning the sardine is lean due to the energy expenditure released during the whole breeding season (IPMA 2016a). When questioned about the period in when sardines grow and accumulate fat, fishermen remembered the months of June and July. However, the months of January, February and March were also well mentioned, which is worth noting. The main months quoted by the fishers corresponded to the same time interval of the recruitment of the species.

The spawning season of Brazilian Sardinella occurs predominantly in spring and summer (Matsuura 1998; Kurtz and Matsuura 2001), with peak activity in December and January (Matsuura 1998; Moraes et al. 2012). However, there are reports of spawning throughout the year, depending on the oceanographic conditions (Cergole and Dias-Neto 2011). Informants reported the sardine spawning data similar to those found in scientific literature. Fishers also show the months of January and December with the high expressiveness of mentions. Informants also highlighted summer as the season of the year with more sardines spawning peaks on the coast of Arraial do Cabo. Informants also indicated other months of the year. This fact indicates the probable occurrence of sardines breeding throughout the year.

5.6.5 Sardines food items and Predators

The availability of microzooplankton in the natural environment of sardines, causes the Brazilian sardinella larvae to use this resource substantially as part of its early-life diet (Kurtz and Matsuura 2001). Nonetheless, in its adult phase, the zooplankton (autumn and spring) and phytoplankton (winter) become the main food constituents of

this species (Saccardo and Rossi-Wongtschowski. 1991; Cergole and Dias-Neto 2011). This information on the food ecology of sardines agreed with the fishermen's statements in this study. Informants in this context revealed that sardines feed mainly on plankton, algae, small invertebrates, and larvae.

Small pelagic fishes exert control in the dynamics of upwelling environments on the upper and lower levels of the trophic chain, such as few school species (Cury et al. 2000). Brazilian sardine, at this intermediate trophic level, serve as food for various species of fish, as well as for birds and marine mammals (del Favero et al. 2017). Paiva and Motta (1999) highlight the bonito-listrado (*Katsuwonus pelamis*) as a potential predator of sardines in the State of Rio de Janeiro. The predatory fauna of the sardine was also composed of xaréu (*Caranx hippos*) and xerelete (*Caranx latus*) in this same fishing port (Paiva and Motta 1999). Fishermen from Arraial do Cabo mentioned these same fish during the interviews, as well as other larger fish, whales, and marine birds. This finding proves the detailed knowledge that these members of this community present about the trophic chain of *S. Brasiliensis* in Arraial do Cabo.

5.6.6 Unwritten social rules and human uses

Human ecology and biological anthropology are areas of knowledge responsible for discussing the role of food taboos in human society (Begossi and Braga 1992). The taboos and food aversions in this perspective can be understood as a set of social and religious sanctions that regulate the human behavior, which may or may not be applicable in biological conservation (Colding and Folke 1997; Berkes et al. 2000). The taboo can also be predicted specifically as a ban on food that could lead to the death of individuals or can be derived only from a culturally institutionalized ban (Patnaik 2007).

In the fishing community in Arraial do Cabo, almost thirty-percent of interviewees, reported food taboos with *S. brasiliensis*. The fishers' food aversion of Brazilian sardine was evidenced by the terms "strong meat," "greasy meat," "red meat," "bleeding meat," and "open caudal fin". The popular name "remosa" was attributed to the Brazilian sardine in this study due to the food restrictions of the flesh of this small pelagic.

In the caiçaras community of the Brazilian Atlantic Forest, the term "carregado" was considered synonymous of "reimoso" that refers to the type of meats that should be avoided (Seixas and Begossi 2001). A similar term termed "raimoso" was attributed to the European pilchard in Portugal for the same purpose (Braga et al. 2017a). Certain specific groups of human beings note the presence of food restrictions. The specific

taboos (Colding and Folke 2001) were a woman during pregnancy, puerperium and men and females in postoperative and with illnesses. This type of specific restriction was already carried out by local communities of Amazonas decades ago (Begossi 1992). In the fishing village of the city of Ilhéus, in the Northeast of Brazil, there are also signs of specific taboos with the same peculiarities (Braga and Schiavetti 2013).

Human society uses food taboos on animals for a variety of reasons (Colding 1998). In this ethnobiological study, the food taboos were not associated with the preservation of the sardine resource. According to Begossi et al. (2004), here is still needing to explore this relationship between food taboos and biological conservation. This work is indicated because reducing the exploitation of a particular species does not necessarily mean the relief of pressure to the fishery resources since it can generate the overfishing of other species (Begossi et al. 2004). However, there are reported cases of these formal institutions helping to protect species and reduce pressure on endemic species of economic importance (Jones et al. 2008). Colding and Folke (2001) also point out that these informal institutions can contribute to ecosystem management through the connection between community and conservationists.

In the clupeoid family, sardines are the most recognized species due to their economic importance in the markets and the trade of products and byproducts in general (Leonardo et al. 2016). The catches of this species in the Brazilian fishing fleet are destined for the most part for canning industries (Sterzelecki et al. 2017), and live baits of other species of fish, especially tuna (Santos and Rodrigues-Ribeiro 2010; Baloi et al. 2017). This information goes according to the socioeconomic importance given to this small pelagic in the daily life, and the fishing activity of the local community of fishers of Arraial do Cabo.

5.7 Ethnobiological Insights and Conclusion

The LEK is an important instrument for the elaboration and execution of resolutions of increment in the conjuncture of conservation (Shepherd 2010). The ecosystem management in this sense began to distinguish LEK due to the possibility of legitimacy in providing a large amount of information relevant to the environmental purpose (Cosham et al. 2016). This environmental preservation should always have as a principle the inclusion of all people dependent on the natural resource available, as well as insertion of all related communities and their livelihood to make this better management (Hunn et al. 2003). The worldwide current research of fishers´

ethnoecological knowledge has been showing conservationist insights (Mathé and Rey-Valette 2015; Frans and Augé 2016; Whitmore 2016; Braga et al. 2017b; Zhang and Vincent 2017) and ecological and biological information on marine species (Silvano and Begossi 2005; Gaspare et al. 2015; Manzan and Lopes 2016). There is also a trend of work seeking LEK around food taboos, beliefs and medicinal purposes (Braga et al. 2017a; Braga and Schiavetti 2013; Leeney et al. 2015; Aburto et al. 2015).

In the present study, it was not different since fishermen reported information on the biology, ecology, food restrictions and beliefs of sardines in the fishing village of Arraial do Cabo. We highlight here LEK on the folk taxonomy, new ranges of habitat (depth), patterns of migration, preys and predators, and reproduction season of *S. brasiliensis*. This database provided by fishermen may serve as a basis for future ecological research scenarios around this species. Drew (2005) argues that veiled components of this type of traditional knowledge can design testable hypotheses and collaborate on conservation projects. This tendency to use the LEK of fishers for this purpose is advisable mainly in Brazil, where a gap in biological data on fish resources still exists (Silvano and Valbo-Jørgensen 2008).

Fishers' knowledge about the Brazilian sardine provided in this fishing community showed correspondence with the scientific literature in the essential points discussed. The members of this fishing village emphasized the social importance of this resource to the community and manifested the presence of food taboos that were not related to conservation measures. The next step would be to include this ethnobiological information provided for analysis at meetings between fishers, conservation biologists, managers, and environmental government with the aim of promoting greater social inclusion of the less favored by making sardine decision-making processes about small-scale fisheries. The stakeholder discussion would be interesting both from the human scientific part of history and to generate an approximation and a better understanding of the attitudes of these communities as well as provide the opportunity of these local populations to aggregate a reliable and more scientific basis on the fisheries resource in question. It is suggested to search for the constant exchange of information between ecologists and ethnobiologists about the gaps in information on fish stocks with the intention of narrowing and delineating future research for sardine conservation in small-scale fisheries.

5.8 Acknowledgments

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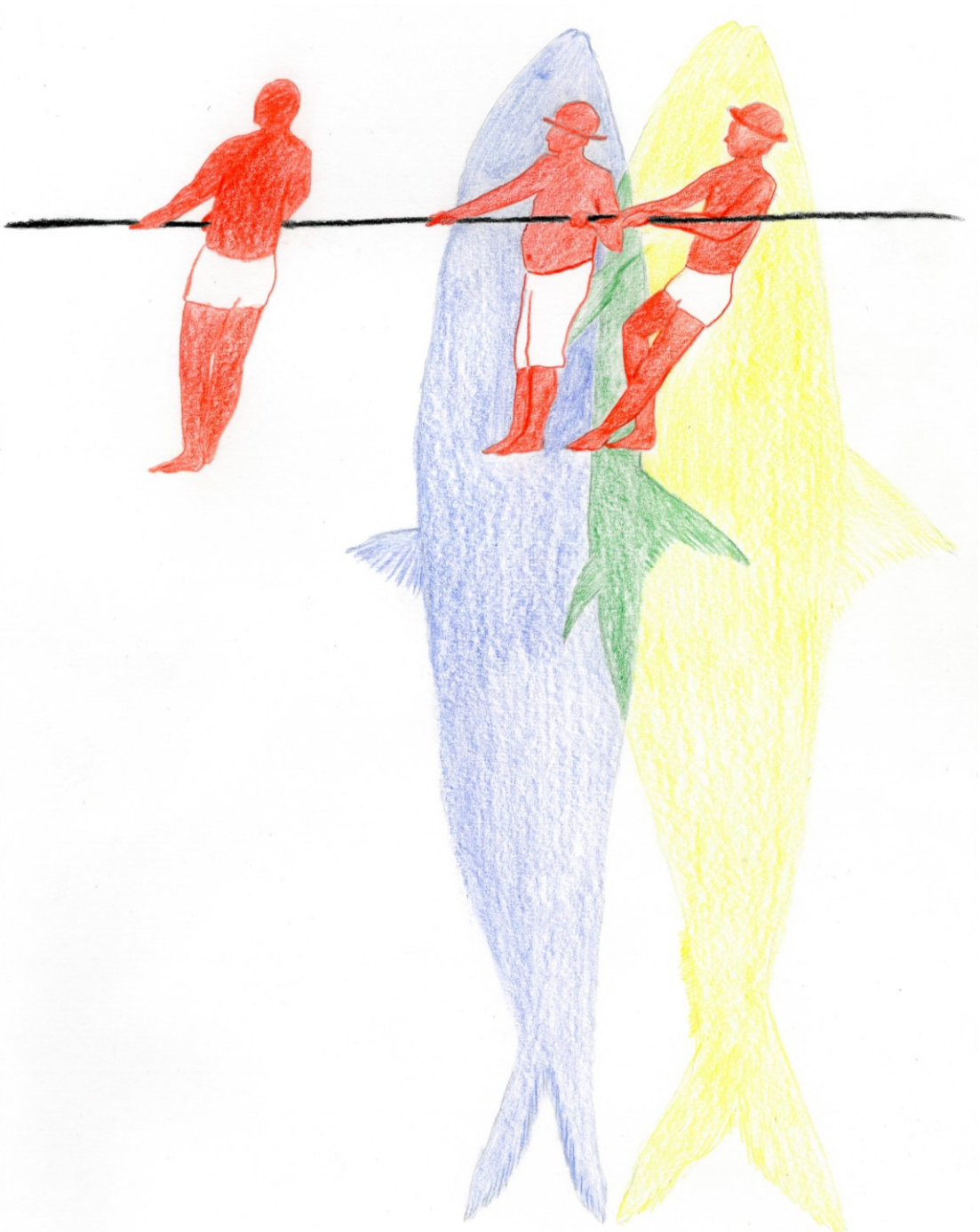

6. General Discussion

6.1 Local ecological knowledge (LEK) of European pilchard and Brazilian sardine

The present ethnobiological research explored the interlinkages between the ecology and biology of two small pelagic species present in the Atlantic Ocean and the related fishing communities. Begossi et al. (2008) suggest that data of this nature can aggregate knowledge about scientific research on biodiversity conservation. Interviewees in both studied areas (Brazil and Portugal) explicitly provided informal expertise about taxonomy, habitat, behavior, migration, development and reproduction, fat accumulation and spawning season and trophic chain of sardines. Fishers also reported human uses, beliefs, and food taboos in sardines incorporated in the surveyed fishing villages.

Study on fishers' knowledge about the folk taxonomy (ethnotaxonomy) of biological resources can support the monitoring of fisheries in the case of catch declarations of any nature to be used in fisheries management (Previero et al. 2013). The use of different folk names for Brazilian sardine, for example, could be making it difficult to count the catches of this species, which is an obstacle in the process of recovering their fish stock (Freire and Pauly 2005). In the community studied in Portugal, four folk names were attributed to European sardines, while in the fishing village of Southeast Brazilian investigated, fishermen reported seven folk names of Brazilian sardine.

The knowledge of artisanal fishers can also be an outlet when scientific data on the distribution of some species (habitat) lack, as was the case with skates (Rajidae) in Portuguese inland waters (Serra-Pereira et al. 2014). Community-based interviews of Fiji's two main islands have also reported a rich source of references on the habitat of shark species (Rasalato et al. 2010). In Peniche and Arraial do Cabo, the informants followed the same line and provided additional information on the habitat and vertical and horizontal distribution of the sardines in the environment.

Fishers reported the schooling behavior and migration of the fish investigated in Búzios Island, southeastern Brazilian coast (Silvano and Begossi 2012), in the same way, that fishermen shared about sardines in Peniche and Arraial do Cabo. Specifically, members of the local community of Peniche also revealed the behavior of the sardine in front of the presence of the predator, as well as the practice of movement in large schools.

In a community in Guinea-Bissau, fisher's local ecological knowledge (LEK) showed the breastfeeding behavior as one of the causes of the decrease of sawfish

(Pristidae) in this area (Leeney and Poncelet 2015). The fishermen´s knowledge in this thesis showed possible new variations in sardine migration behavior, which also happened with 13 species of fish of great economic importance in seven communities distributed in the Southeast and Northeast of Brazil (Silvano et al. 2006). In the state of Santa Catarina, Brazil, local fishers shared information about the behavior of mullets in the migration routes (Herbst and Hanazaki 2014), similar to the one presented in the previous chapters of this dissertation with the sardines of both marine systems.

Most Australian anglers recorded details of some reproductive traits about marine bluefish (*Pomatomus saltatrix*) in Southeast of Queensland (Silvano and Begossi 2005). Seahorses (Syngnathidae) observation operators were aware of the development and reproduction aspects of this species in a local community in Pernambuco, Northeastern Brazil (Ternes et al. 2016). In contrast, our study showed that fishermen's knowledge of sardine reproduction was more insufficient, with limited information on the age at which they are suitable for breeding in Peniche, and the length range of the species in Arraial do Cabo. The lack of data on reproduction was even more evident with fishers about the groupers (Epinephelidae), in Mafia Island, Tanzania (Gaspare et al. 2015). In the Inuit community of the province of Quebec, Canada, residents exposed knowledge about the annual changes in body condition of the beluga whale (*Delphinapterus leucas*), impressing the season of the year that the belugas lose and gain fat (Breton-Honeyman et al. 2016). It was not different in the fishing village of Southwestern Atlantic analyzed in this present work, as well as in Peniche, in which the informants also shared LEK about the time of fat accumulation of the sardines for their later reproduction.

Fishers in the southern coast of Bahia state, Brazil, reported the Atlantic goliath grouper (*Epinephelus itajara*) spawning sites where the highest abundance of this species occurred in Abrolhos Bank (Zapelini et al. 2017). Informants shared data on the likely bluefish spawning season in five artisanal communities along the Brazilian coast (Silvano and Begossi 2010). According to these human populations, these species spawning mainly during the winter (Silvano and Begossi 2010). In the fishing village of Mirya, India, data on the reproduction of a significant food species to the members of local communities (mud crab, *Scylla serrata*), have shown reproductive peaks of the species mainly between November and February (winter) (Nirmale et al. 2012). Members of the two communities investigated in this thesis also shared information on this topic and appeared to be generally in agreement with published biological data of the two sardine species.

Fisher´s informal knowledge in the Republic of Guinea in Africa has proved to be a satisfactory source of information about the diet and trophic chain of a sizeable demersal assemblages of fish species known as the Sciaenid community (Le Fur et al. 2011). In the absence of biological data on the fish fauna on the Southeast coast of Brazil, Fisher's LEK showed to be a concise auxiliary tool to estimate trophic levels of fish species, as well as to design food-webs (Silvano and Begossi 2012). In the present thesis, fishers from Arraial do Cabo and Peniche showed the same pattern and shared specifics information about sardines' trophic chain, exhibiting details about preys and predators of this small pelagic species.

The presence of taboos and food beliefs were not very representative in the two samples in Brazil (30%) and Portugal (6.9%) on sardines. There was also no relation to these non-social rules to the conservation of this fishing resource. An explanation for a greater inexpressiveness of beliefs and taboos in this fishing village in Portugal is the possible escape from the active workforce for other economic activities due to the low remuneration and imposed legislative measures (Santos et al. 2012b), to the detriment of the artisanal fisheries. The insertion of technological components and the presence of means of communication into the daily life of younger and adult fishers may also lead individuals from both Atlantic systems to no more extended care about the traditional teachings and knowledge handed down by the ascendants over generations.

Thus, this work presented potential information on the LEK of a natural resource, as is observed in artisanal fisheries worldwide (Anadón et al. 2010; Bender et al. 2014; Rosa et al. 2014; Koster et al. 2016; Bevilacqua et al. 2016; O'Bryhim et al. 2016; Frans and Augé 2016; Lima et al. 2017). Despite geographical, cultural, and environmental differences, both communities have specifically provided considerable data on the ecology and biology of two small pelagic species (sardines). We highlight here the LEK about folk names, new areas of habitat (depth), migration routes, fat accumulation season, spawning stations, prey and predators of Brazilian sardine and European sardines.

6.2 Assessing local ecological knowledge (LEK) and attitudes towards conservation of European and Brazilian sardine

The more significant commitment of the scientific community and scientific literature to traditional knowledge is also a participatory mechanism to better integrate local communities guaranteeing their actively involved in decision-making (Huntington 2011). Understanding how these local populations manage and understand the natural resource is paramount for the survival of these communities in a sustainable way (Pardo-

de-Santayana and Macía 2015). It is also essential to realize how society and all the actors involved can come together so that there is a better set of conservationist and sustainable environmental actions (Tonin and Lucaroni 2017).

Adequate coastal management requires a high demand from local people as well as organizations that somehow disturb and benefit from marine ecosystems (Paterson et al. 2011). In this context, local ecological knowledge becomes an auxiliary tool to infer possible changes in resources and artisanal fisheries (Coll et al. 2014). The appreciation of local conservationist attitudes also appears here as a way of guiding managers in determining compliance with norms to improve the conceptions of the local community (Nsonsi et al. 2017).

Studies that seek to evaluate the LEK of fishers on a natural resource based on ecological indexes are still scarce. In this sense, taking advantage of this apparent gap, one of the main goals of this study was to assess the ethnoecological knowledge of artisanal fishers on European and Brazilian sardine. Fisher´s informal knowledge, when compared with published biological data, was considered moderate (Likert Scale of 0-1) in Peniche/Portugal (0.55), and Arraial do Cabo/Brazil (0.56). From another point of view, in the State of Bahia, Brazil, through the same scale, local informants showed knowledge below the moderate (0.43) about sea turtles (Braga and Schiavetti 2013).

Therefore, it is possible to say that these local fishermen present a considerable knowledge about the sardines in both local communities verified when compared with the specialized literature. Similar to our general findings, LEK data on the abundance and distribution of a reptile species showed the close relation to data from standard field sampling protocols (Anadón et al. 2009). Most Fishers also provided biological data on the snapper group (Teleostei: Actinopterygii), as reported in the literature (Caló et al. 2009). An environmental hypothesis simulated through the fishermen's knowledge approach also followed the same pattern and was supported by biological data as a way of understanding the ecological changes and resources exploited in a Neotropical freshwater ecoregion (Rosa et al. 2014).

Fishers and scientists are also in consensus when it comes to the case of Baltic cod (*Gadus morhua*) from Poland (Figus et al. 2017). In this case, there were similarities of both sources about the abundance and body condition of this species. The reports of local people were also according to the analysis of the gonadal maturation of a teleost fish (*Hoplias malabaricus*) in Northeast Brazil (Silva et al. 2014). Finally, three artisanal fishing communities in Brazil presented a partial general knowledge about the bottlenose

dolphins (*Tursiops truncatus*) that will be useful in the conservation of these cetaceans (Zappes et al. 2014).

Understanding how a particular public behaves on the environment may be expressive due to the possibility of this knowledge in showing the possible behavioral stimuli of individuals facing an environmental problem (Jefferson et al. 2014). The role of the citizen in marine ecological issues can support marine governance and only materializes with the development of a robust relationship between the state and the individual (McKinley and Fletcher 2012). Perceptions and attitudes in this context play an essential role in any conservation intervention, which may contribute to a better environmental understanding (Tonin and Lucaroni 2017).

The adapted concept of attitude applied in this work was the psychological predisposition of an individual in favor or disfavor to an environmental resource relationship (Ajzen and Fishbein 1980; Eagly and Chaiken 1993; Milfont and Duckitt 2010). On this basis, with the support of the Likert scale, the attitudes of local fishers in Peniche on European sardines proved to be positive and in Arraial do Cabo, conservation attitudes towards Brazilian sardines were moderate. Notwithstanding, there are currently fluctuations in the sardine population units due to their overexploitation both in the Iberian Peninsula (ICES 2016) and in the South Atlantic (Dias et al. 2014). In this sense, it can be said that perhaps the positive attitudes in Peniche and more moderate in Arraial do Cabo are still recent. The possible influence of the direct consequences of the laws imposed by the actors responsible for fisheries management in both localities and the fear of penalties with the possibility of severe punishments may be contributing to the behavioral change of fishers. We also argue that current sardine fishing in both systems may be facing these difficulties mainly due to the intense negative attitudes of anglers in the past, which may reflect on current fish stocks. Environmental and climate change and overfishing in marine ecosystems in this context have predominantly intensified this concern (de Lara and Corral 2017). That being the case, all of these factors together may have led fishers to change their behavior on this fishing resource.

Another possible scenario here is that these fishing villages analyzed in this thesis should follow the same trend observed in several communities around the world, where the active management of fishery resources does not take into account the participation of local people (Mellado et al. 2014). Thus, the inability to include fishers continuously in decision-making may have contributed to the fact that these individuals, in a hidden way, did not present positive conservationist attitudes in practice on sardines during fishing trips. However, it is known that participation and acceptance of the human

dimension in the decision-making process of this character can contribute decisively to the effectiveness of biodiversity conservation purposes (Novacek and Cleland 2001; Pinto et al. 2015). In this context, in both fishing villages (Brazil and Portugal), it becomes vital to find new ways to increase conservation forces and tools so that these individuals recognize and respond better to connections with the marine ecosystem (Vincent 2011).

6.3 Local ecological knowledge, attitudes, and fishermen profile

This thesis investigated the possible relationships between local ecological knowledge (LEK), attitudes and socioeconomic variables of fishers as a way of collaborating in the better understanding of the use of the fishery resource (sardines) by the communities studied in Brazil and Portugal. The knowledge of these social, economic, and biological drivers was also verified because these factors can contribute to a better understanding of the functioning of the socio-ecological system in both communities. These predicates also become essential for consistent management and proper maintenance of the ecosystem (Luksenburg and Parsons 2014).

When comparing LEK with the predefined educational class, the Portuguese fishing community analyzed showed that LEK is significant only when comparing less educated fishers with the more educated fishermen. However, the second level of education sample did not follow this pattern. In this general way, we cannot affirm that the LEK is necessarily related to the degree of schooling in this case. We argued here that the fisher´s ethnoknowledge at this intermediate level may be more related to the dynamic, practical and observational experience as reported in Hill et al. (2010) than the knowledge acquired through schooling. In a fishing community in northeastern Brazil, it was also not possible to fully explain the variations of LEK about sea turtles through the educated classes of local artisanal fishermen (Braga and Schiavetti 2013). Notwithstanding, in Arraial do Cabo, it showed a significant association between the LEK and the three educational classes. Possibly the most qualified fishermen presented more varied sources of information, which served to compose and solidify their LEK in sardines.

In the Brazilian fishing village, the ethnoecological knowledge of Brazilian sardine was also a predictor of other socioeconomic variables of the informants (income source, boat ownership, fishers exclusive of fishing activity or not, non-associated and associated to a fishing Association). The informants with the most significant income source are usually masters of fishing, and boat owners in the community of Arraial do Cabo. Fisheries control and monitoring are traditionally carried out by these community

experts. As a result, fishers from higher income sources and boat owners were more likely to present more accurate informal knowledge about sardines than low-income fishers and informants who had no boats.

Regarding the occupation of this interviewees, the daily contact with fishing equipment, considerable sampling and greater connections with specialized fishers may have made the informants restricted to fishing more knowledgeable about sardines. In the same region, fishers associated with the fishing colony did not present more profound knowledge than non-members. The LEK, in this case, may be linked to other variables and not to the simple fact that fishers are associated or not with the local fishing colony/association. The fact that there are other fishing associations in Arraial do Cabo may also have influenced this finding.

Attitudes towards biodiversity conservation of natural resources can show correlation with some sociodemographic variations (Aipanjiguly et al. 2003; Winter et al. 2005; Tomićević et al. 2010; Shuib et al. 2012; Badola et al. 2012; Ellwanger et al. 2015) and the ethnoknowledge of local communities. Support for this environmental maintenance becomes especially vulnerable when available resources are exhausted, and the interests of dependents are impaired (Kideghesho et al. 2007). Therefore, verification of the motivations, values and perceptions of local communities can be essential for the development of sustainable and resilient environmental management projects. Also, the preservation of the coastal resource becomes more favorable when it is sought to adapt or modify these local values perpetuated by people depending on these resources (Cinner and Pollnac 2004), which can sometimes be an obstacle to the realization of conservation projects.

LEK in Arraial do Cabo did not show a relationship with fishers' attitudes regarding the conservation of Brazilian sardine, while in Peniche a positive correlation was found between LEK and attitudes about European sardines. Following the same observation found in this Portuguese community, the analysis of knowledge and attitudes of local people in Tampa Bay, Florida, USA, also showed a positive correlation between local knowledge and conservationist attitudes about a particular marine mammal (*Trichechus manatus latirostris*) (Aipanjiguly et al. 2003). In this sense, these findings may be useful to form a solidified basis for the mediation of dialogues between local public and managers for the perpetuation of conservation of these species in the most relevant way (Aipanjiguly et al. 2003).

It should also be noted that in the Peniche fishing village, informants should not be using LEK available for their benefit. These fishermen may be willing to conserve

sardines because of troubling information linked to the vulnerability of sardine populations on the Portuguese Atlantic coast and because of personal conclusions about what they are reporting during fishing trips. Thus, fishers may be using the LEK to avoid potential breeding habitats, to prevent fishing for immature juveniles, not to use prohibited fishing nets and to respect fishing closure periods.

The attitudes were statistically significant when compared with the age of the fishermen and the education level in Peniche. Attitudes were still predictors of non-associated and associated fishers of a fishing colony, boat owners and boat non-owners, fishers exclusive of fishing activity or not, and educational level in the Brazilian fishing community evaluated. Attitudes towards conservation of European sardines, more specifically, were negatively correlated with the age of the informants in Peniche. Older fishers may have exhibited negative attitudes due to an unprecedented maximization of fishing effort and lack of restrictions on fishing activity at the time they were active fishermen. Thus, this old predisposition not to conserve sardine stocks persisted in the consciousness of these informants, which may have reflected in the attitudes verified. These individuals still tend to be less supportive when planning, reorganizing and learning something new (Marshall and Marshall 2007). This negative propensity may have contributed to the fishermen not fully assimilating the need to preserve the resource in question. However, younger anglers may have been able to absorb and better assimilate the information available from the environmental point of view, which made them predisposed to conserve the resource. In the Marsabit National Reserve (MNR) in Kenya, the younger generation also followed this same trend and showed more positive attitudes towards maintaining local wildlife (Shibia 2010). A study of the perception of small-scale fishers in two marine protected areas (MPAs) in the Brazilian Northeast also showed that younger anglers tended to have a more positive impression of conservation measures applied to natural resource users than older fishermen (Silva and Lopes 2015).

In the fishing community analyzed in the State of Rio de Janeiro, when comparing the attitudes between two groups of fishers (associated and not associated with a fishing Association), there was a tendency for the associates to have more positive attitudes regarding the conservation of the Brazilian sardine. Information generated about the closure of the species in assemblies with members of a Z-5 fishing association of Arraial do Cabo may have contributed to this result. In addition to this information, we argue that the fear of punishment by the Brazilian environmental agency has also induced more positive attitudes toward sardines. In Brazil, the Law 9,605 (February 12, 1998) and

Decree No. 6,514 (dated July 22, 2008) show, for example, that breaching the sardine closure may lead to fines, arrests, and seizures of fishing gear.

As for fishermen's attitudes towards conservation of Brazilian sardine, there were also statistically significant differences between boat owners and boat non-owners, and fishers exclusive to fishing activity and non-exclusive. However, here we can only say that informants restricted to fishing activity tend to vary their attitudes towards the conservation of sardines. The widespread reliance on a particular resource may be a hindrance for fishers who support conservation measures (Marshall et al. 2010). Perhaps these more flexible attitudes have been observed because of the fishers' high financial dependence on the sardine resource, which may cause them to change their actions according to their needs. The low qualification of anglers in general also makes them more trapped in the fishing activity in Arraial do Cabo, and this can generate an imminent possibility of behavioral changes in front of this fishing resource in adverse conditions.

As for boat ownership, statistically, there was a smaller variation in attitude index among those who own a boat. This pattern observed in this case shows that boat owners (those who typically have the most significant income source and tend to have higher LEK) are inclined to keep the fishery resource analyzed very similar to each other. In this way, managers can use this information to control sardine fishing better. Possibly by a chain reaction, a better understanding with boat owners can trigger changes in attitudes in other fishers who depend on each boat.

The education level of local populations also can motivate the predisposition of the human being to conserve any environmental resource (Mehta and Heinen 2001; Winter et al. 2005; Kideghesho et al. 2007; Suryawanshi et al. 2014; Ellwanger et al. 2015; Nsonsi et al. 2017). In all study sites, the most qualified fishermen had more positive attitudes towards the conservation of sardines. Even so, the promotion of educational programs and community information sharing programs on sardine conservation is essential to establish and improve these attitudes in both communities in practice. This statement applies especially in Arraial do Cabo, where the attitudes were more moderate. The use of these types of approaches in these communities, which are taken into account by all stakeholders together with adequate environmental education, is essential for better management of the conservation of vulnerable species (Liu et al. 2016), as is the case of both objects of study of this thesis.

7. Conclusion

This thesis demonstrates the importance of understanding local ecological knowledge (LEK) and attitudes regarding the conservation of sardine species in two fishing communities in different geographic regions and with different socio-environmental contexts. This present research in Peniche and Arraial do Cabo provided new informal knowledge in this scientific and environmental field, being recognized as the first ethnobiological investigation on small pelagic (sardines) in America/Europe. Portugal, especially Peniche, due to the lack of studies on ethnobiology and ethnoecology, proved to be a potential field of investigations of this type.

The social science data collection tool (well-delineated questionnaire) provided profiles of artisanal fishers from both communities succinctly. The fishermen shared the biological and ecological knowledge of the sardines that showed agreement with the scientific literature. Taboos and food aversions were not recurrent in both fishing villages and showed no connection with conservation measures of the clupeoids in question. Fishers from the fishing village of Peniche as well as from Arraial do Cabo showed moderate knowledge about the biology and ecology of sardines when compared to the scientific literature according to the Likert scale. Conservationist attitudes were more favorable in the Portuguese fishing village than in the local Brazilian fishing community.

In Peniche, the interviewed with higher LEK, with a higher educational level, and at a younger age presented more positive attitudes regarding conservation of sardines. Nevertheless, the LEK did not necessarily correlate with the educational level of the fishermen in this case. In the fishing community of Arraial do Cabo, the Conservationist attitudes showed no correlation with LEK. However, attitudes and LEK were correlated with the income source, educational level, boat ownership, fishers associated or non-associated to the Z-5 Fishing Colony of Arraial do Cabo, and fishers restricted to fishing activity or not.

The informal knowledge available about sardines from both local communities that were not compatible with the scientific literature should not be discarded. Some ecology and biology data from sardines provided through this knowledge can be filtered and support the formulation of testable hypotheses for future ecological studies. Thus, contrasting information provided by fishermen can be determined through further surveys, which may contribute to a better knowledge of the ecology of this species. Also,

LEK and attitudes can also be useful to try to improve managers' knowledge about the use of fishing resources (sardines) by artisanal fishing and serve as a basis for enhancing and solidifying educational and communication interventions in both fishing villages. The relationships found between the fisher´s socioeconomic factors, attitudes, and LEK also can contribute to a better understanding of the management of sardines from the socio-environmental point of view.

The next step would be to integrate the knowledge of ethnobiologists, conservation biologists, and managers as a way of generating new mutual exchanges of information without the favor of anyone. This approach of all the actors involved can collaborate in a better management of sardines in small-scale fishing, as well as in the maintenance of artisanal fishing in both local communities.

8. References

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9. Supplementary material

9.1 Additional file 1

Statement of Informed Consent (IC) and agreement to participate in the research

Caro Senhor,

Meu nome é Heitor de Oliveira Braga. Sou estudante da Universidade de Coimbra e estou a fazer um estudo sobre o conhecimento da sardinha com pescadores aqui em Arraial do Cabo/Peniche. Tal pesquisa pretende saber as características da pesca artesanal, assim como buscar o conhecimento ecológico local dos pescadores sobre as áreas em que as sardinhas aparecem mais, os locais onde elas provavelmente se reproduzem entre outros aspectos do seu ciclo de vida. Também irei pesquisar as atitudes dos pescadores em relação a conservação desta espécie.

Para a realização da pesquisa preciso conversar com alguns pescadores em Arraial do Cabo/Peniche como o senhor. Se sentir-se à vontade para colaborar com nossa pesquisa irei aplicar um questionário com perguntas relacionadas a sardinha. Se o senhor permitir, as entrevistas poderão ser gravadas por meio de um aparelho eletrônico. Essas gravações com as informações registradas poderão ser repassadas para um cd e guardadas em meu local de trabalho na Universidade. Caso seja autorizado, irei tirar algumas fotos da arte de pesca, da ação de pesca e da espécie de animal estudada em alguma eventualidade. Essas imagens somente poderão ser divulgadas em revistas ou reuniões científicas como imagens ilustrativas. Se no meio da entrevista o senhor desistir de colaborar com o nosso estudo não será prejudicado de forma alguma. A sua identidade será mantida em sigilo e apenas as informações serão registradas. Se o senhor permitir, seu nome será coletado e anotado nos roteiros de entrevistas. Sendo necessário entrevistar o senhor novamente para coletar outras informações, esses dados pessoais irão facilitar meu o estudo.

A sua opinião será muito importante para o nosso estudo, pois os dados coletados nas entrevistas poderão contribuir para a conservação do meio ambiente, para o conhecimento ecológico local sobre as sardinhas e para que a cultura e a tradição dos pescadores artesanais não se percam ao longo das gerações. As informações coletadas irão fazer parte de um trabalho que poderá ser publicado em revistas científicas, além de constituir um relatório para ser entregue na Capes Brasil. Posteriormente essas informações serão divulgadas aos pescadores de Arraial do Cabo/Peniche para o conhecimento de todos, através de banners ou folhetos autoexplicativos. Caso o senhor concorde em participar da entrevista, peço que o senhor assine este termo de consentimento, que também será assinado por mim, que sou o pesquisador responsável. Dessa forma, uma cópia ficará comigo e a outra com o senhor. Caso o senhor não queira

assinar, sua decisão será respeitada. Em caso de dúvida, por favor pergunte. Desde já agradeço. Meu endereço de trabalho é na Universidade de Coimbra, Departamento da Ciências da Vida, Centro de Ecologia Funcional, Coimbra, Portugal, CEP: 3000-456, Telefone: +351918562333 e Fax: 239 855211. E-mail: heitorob@gmail.com.

Eu, _____, idade: ____, aceito participar da pesquisa intitulada "Conhecimento ecológico local (CEL) de pescadores em áreas marinhas protegidas (AMP´s) no Oceano Atlântico (Brasil e Portugal): Sardinha-verdadeira e Sardinha Européia", tendo sido devidamente informado e esclarecido, como disposto acima.

_____ _____

Heitor de Oliveira Braga (Pesquisador Responsável). Assinatura do voluntário.

_____, ____ / ____ / ____.

Local dia mês ano

A rogo do Sr(a) _____, assinam:

"marca do polegar":

_____ _____

Assinatura da Testemunha 1. Assinatura da Testemunha 2.

9.2 Additional file 2

Script of interview applied in Peniche, Distrito de Leiria, Portugal

*Before the interview is carried out the reading of Statement of Informed Consent (IC)

Date: ____/____/____. Number of interview: _____.

Part I. Profile of fishermen

1- Name and/or Nickname (Optional):

2- Location of the interview:

3- Age:

4- Level of education: ( ) illiterate; ( ) A (1st Cycle: 1-4 years of study); ( ) B (2nd Cycle: 5-6 years of study);

( ) C (3rd Cycle: 7-9 years of study); ( ) D Secondary Education: 10-12 years of study; ( ) Higher education

5- Time of residence in Peniche?

6- Fishing currently?

7- Fishing time?

8- Income source? Other source of income?

9- Do you have a boat?

10- Type and length of boat you use for fishing?

11- Fishing time at sea?

12- Other relevant information on fisheries?

13- Sardine fishing schedule?

Part II: Local ecological knowledge (LEK) about the European sardine *(Sardina pilchardus)* **in Peniche, Portugal**

1- Folk taxonomy or popular taxonomy?

2- Preferential Habitat (Where does the sardine live?)

3- Route and Migration (Where does the sardine go and where does it come from? Ideal route?)

4- Depth Interval (m) - (How deep is it?)

5- Behavior (Form schools?)

6- How long (months or years) are the sardines already ready to reproduce?

7- Time of spawning / breeding (months or season). Discuss spawning of Sardine.

8- Development - How do you grow (slow, fast, etc.)? At some point in your life are larvae, eggs?

9- When (months or season) they accumulate fat (they grow and fatten)?

10- Do they have a long or short life?

11- Predators (Who eats it?)

12- Preys (What does sardine eat?)

13- Economic and personal importance (low, medium or high)?

14- What are the uses of sardines? (Bait, market, no utility, etc.)

15- What time of year (months) would you choose to stop sardine fishing?

16- For medicinal purposes? Craft purposes? Food restriction? Medicine purpose?

9.3 Additional file 3

Script of interview applied in Arraial do Cabo, Rio de Janeiro, Brazil

*Before the interview is carried out the reading of Statement of Informed Consent (IC)

Date: ____/____/____. Number of interview: _____.

Part I. Socio-demographic variables of fishermen

1- Name and/or Nickname (Optional):

2- Location of the interview:

3- Age:

4- Level of education: ( ) Low level - illiterate and Elementary School 1 - up to 5 years of schooling); ( ) Basic level (Elementary School 2 - 6 to 9 years); ( ) Intermediate level (Secondary school - 10 to 12 years).

5- Monthly income source?

6- Time of residence in Arraial do Cabo?

7- Fishing currently? Yes or no?

8- How much fishing experience do you have?

9- Fishing effort at sea?

10- Are you a member of any fishing association? Which association?

11- Do you have a boat?

Part II: Fisher´s Local ecological knowledge (LEK) about the Brazilian sardine *(Sardinella brasiliensis)* **in Arraial do Cabo, Rio de Janeiro, Brazil**

1- What is the name of this species? Folk name?

2- Habitat - Coastal? High sea? (Where does the sardine live?)

3- Depth Interval (m) - (How deep is it? Most found depth?)

4- Schooling behavior (Form schools?)

5 - When are the sardines ready to reproduce?

6- Time of spawning / breeding (months or season).

7- Development (Rapid or short growth?)

8- Do they have eggs, larvae at some point in their lives?

10- Which animals consume sardines in the sea?

11- What do sardines feed?

12- Time of the last biological closure?

Part III: Attitudes towards conservation about the Brazilian sardine

1 - Do you think it necessary to stop fishing the sardines in a few months of the year to preserve them?

2 - What do you do when you catch very small sardines?

3 - During sardine fishing, should all sizes of individuals be captured?

4 - Do you think there should be all natural predators of sardines in the marine ecosystem?

5 - During the time of fat accumulation of the sardine are many sardines fished in the boats?

6 - Can all types of fishing gear be used for sardine fishing?

7 - The season you are fishing sardines of better quality is during the summer?

8 - In the middle of the year, is there a lot of sardines in your fishing?

9 - When you perform sardine fishing, is any kind of purse seine used?

10 - In catching other fish species during the biological closure of sardine incidental capture of sardines mixed with the schools of other species may occur. In a situation like this what do you do?