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Fishers' knowledge in Southeast Brazil: The case study of the Brazilian sardine

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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 LEK about Brazilian sardine of the traditional fishing village of Arraial do Cabo, Rio de Janeiro State, Brazil. Social science tools were used to extract data from biology, ecology, food taboos and human uses of Brazilian sardine. 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 which have a life the history that leads to increased vulnerability due to overfishing and management difficulties. We emphasize the importance of continuously sharing the LEK of the sardines between the community, researchers, and managers in favor of a more effective socio-ecological conservation of this fishing resource in Arraial do Cabo.

1. Introduction

The search for understanding the diversity of the relationships between human cultures and natural resources is crucial so that these human beings 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 knowledge gains strength and becomes the only available source of information about that environment (Huntington, 2011).

Ethnoecological studies in this context emerge with the function of providing the local ecological knowledge (LEK) of human communities about the biology and ecology of natural resources (Begossi, 2008). This 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). The worldwide current research of fishers' knowledge has been showing conservationist insights (Braga et al., 2017a, b; Frans and Augé, 2016; Mathé and Rey-Valette, 2015; Quynh et al., 2018; Whitmore, 2016; Zhang and Vincent, 2017), and crucial ecological and biological information on marine species (Gaspare et al., 2015; Liu et al., 2016; Manzan and Lopes, 2016; Martins et al., 2018; Zapelini et al., 2017).

LEK still presents as a reliable 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 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 critical 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;

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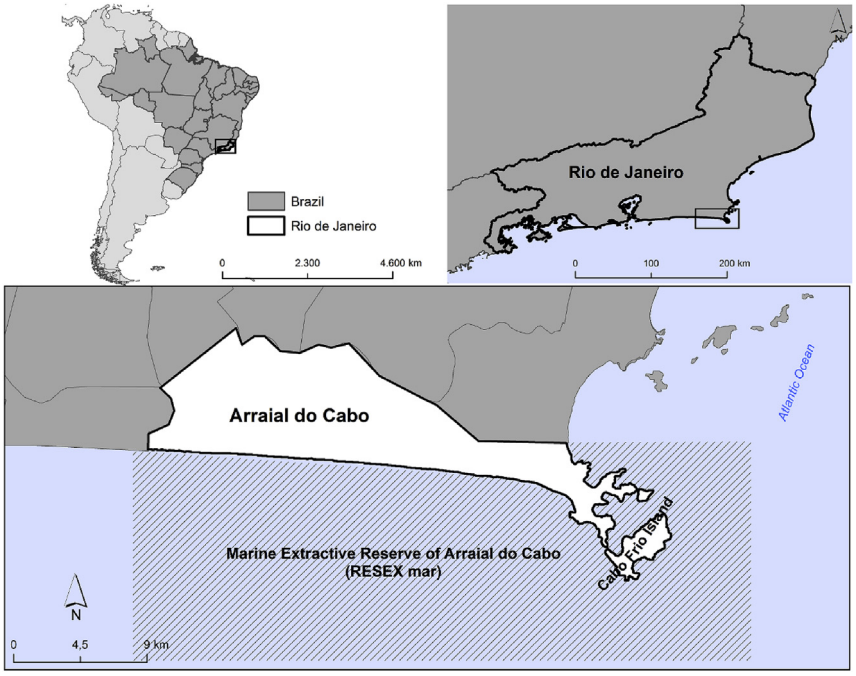


Fig. 1. Area of the study showing the municipality of Arraial do Cabo, and the limits of the Marine Extractive Reserve of Arraial do Cabo in Southeast Brazil. Credits: Anjos, M.

Gerhardinger et al., 2009), as occurs with the Brazilian sardine.

The Brazilian sardine *Sardinella brasiliensis*, (Steindacher, 1879) is a small pelagic fish, distributed in the Western Atlantic, mainly found in the Gulf of Mexico, Brazil, and Uruguay (Fishbase, 2018). It is an oceanodromous and short-lived species of the Clupeidae family, forms compact schooling and lives in coastal waters near areas of high primary productivity (Cervigón, 1992; Paiva and Motta, 2000). Sardine is an omnivorous and fast-growing species (Schneider and Schwingel, 1999) and presents a diet based on phytoplankton and zooplankton (Costalago et al., 2015). This species has prominent ecological importance in the marine ecosystem due to its high abundance and its intermediate position in the food webs, which makes it a crucial keystone species (Jordán, 2009; Padovani et al., 2012).

This clupeoid is found mainly inhabiting coastal waters on the Southern Brazilian shelf, specifically between Rio de Janeiro State (22° S) and Santa Catarina (29° S) (Jablonski, 2007). According to the latest report released by the Rio de Janeiro State Fisheries Foundation, sardines are the most caught species in the fishing ports (47,204.60 tons), which represents 77.8% of all state production (FIPERJ, 2015). Precisely in the Cabo Frio system that includes the coast of Arraial do Cabo, sardine also stands out as the leading natural resource landed at the regional fishing port (FIPERJ, 2015). In addition to this fishing pressure, sardine mortality on the Brazilian coast is also linked to external forces such as climate change, starvation in the larval phase, predation, and death from pollution and habitat degradation (Cergole and Dias-Neto, 2011).

In the Southwestern Atlantic, Brazilian sardine is considered a biological resource of extreme socioeconomic importance for the fishing communities (Dallagnolo et al., 2010). Traditional artisanal fisheries in Arraial do Cabo captures this species of fish through purse seines in fishing boats known as small trawlers (Diegues, 2003). In the industrial fishing of the State of Rio de Janeiro, the capture of Brazilian sardines occurs mainly in industrial trawlers, but may also happen in tuna and "*douradeiros*" fleets (Ibama, 2015).

In Arraial do Cabo, all segments of the sardine fishing production chain, are present. However, this productive chain is in a fragmented way, showing distancing between production and consumption, where the middlemen are the most benefited (Mendonça et al., 2012). *S. brasiliensis,* in this frame of fishery production, stands out for presenting an essential regional stock mainly within the Marine Extractive Reserve of Arraial do Cabo (Coelho-Souza et al., 2012), where the local community presents exclusive permission for the fishing (Giglio et al., 2017).

Even with all the difficulties faced by sardine fishing around the world and its close relationship with traditional livelihood, fishers' LEK studies with this small pelagic fish are almost non-existent. There is only one report of an ethnozoological study with Brazilian sardines, but with a focus on conservationist attitudes (Braga et al., 2018b). Only two other scientific investigations of this scope focused on clupeoids but were based on another species in the North Atlantic (Braga et al., 2017a, b).

Thus, given the current vulnerability of small-scale fisheries management in Latin America, the adoption of innovative management approaches is essential to undermining the viability and sustainability of this sector (Leis et al., 2019). The Brazilian sardine in this scope becomes a potential object for the study of LEK in Arraial do Cabo (Braga et al., 2018a). Due to all the socio-ecological characteristics presented by the study area and its dependence on this fishery, there is an imminent possibility for local fishers to generate a set of knowledge about this fishery resource. In this perspective, the goal of this study is to summarize and document in detail local ecological knowledge (LEK) on the biology, ecology, food taboos and human uses of Brazilian sardine (also known as Brazilian sardinella) 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.

2. Methods

2.1. 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 (Fig. 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 km^2 (IBGE, 2017). It is composed of two regions surrounded by rocky beaches and an isthmus (Cordeiro et al., 2014). This peninsula presents according to Köppen's classification the Aw climate of southernmost occurrence in Brazil (Alvares et al., 2013). The mean temperature and the average annual rainfall of the region respectively are about 23 °C and 823 mm/year (Godoy et al., 2013).

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, 2018). The Arraial do Cabo MER presents an area of about 51.601 ha (ICMBio, 2018) and presents multiple marine fisheries applied to diversified fishing gears (Bender et al., 2014; Da Silva, 2004). Its purpose is to conserve and guarantee the self-sustainable extraction of renewable biological resources through artisanal fisheries of the local community of Arraial do Cabo (ICMBio, 2018).

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. These two beaches received a more significant sample effort of data collection because they are the most relevant sampling points within this fishing village. This sampled effort did not influence the results because there is a high turnover of fishermen between the beaches, being Anjos Beach and Grande Beach the main destinations of the fishers within this community.

2.2. Legal and ethical aspects

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 fishers, research, and the institution of the researchers.

In this part of the interview, the fishermen did not want to sign the CI. However, the fishers agreed to conduct the interviews in a secretive manner, requiring a copy of the Statement of Informed Consent as a precautionary measure. This situation was due to the availability of information generated by them that could confront the position of the directors of the local fishing associations.

2.3. Interview data collection and analysis

The methods used in this LEK survey had a mixed character, with methodology and analysis of different areas of knowledge (ecology, psychology, social anthropology, and sociology). 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 due to the distancing of this group with the specific sardine fishery in this area. The meeting with the interviewees was made mainly before the departure and after the arrival of the boats on the beaches of Arraial do Cabo. These schedules did not affect the work and fishing trips of individuals in the community. In the first approaches, the interviewees first sought to create a friendly and trustworthy atmosphere to reduce the biases in 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. Monastersky (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 interviewees. Field notebooks and occasionally electronic devices were used to record information. Three sections constituted the questionnaire to be applied (Supplementary Material 1). The first part of the interview contained general information about the fishermen (name or nickname, age, 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 (10–12 years) and D: Higher education (13 years or more years of study). Interviewees 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. Also included data from fishing experience, active fisherman, boat owner, a frequency of fisheries, type of boat and number of hours in each fishing effort per trip of Brazilian sardine. The last part of the interview sought to explore the local ecological knowledge (LEK) about of Brazilian sardine (*S. brasiliensis*). The points investigated in this section were: folk taxonomy, preferred habitat, migration, behavior, development of sardines, breeding season and fat accumulation season. Also, we explored the lifetime, feeding, predators, socio-economic importance, food taboos and human uses. The fishers at the beginning of this part participated in a projective test (Costa-Neto et al., 2009). In this procedure, the fishermen received a photograph of the of Brazilian sardine for identification and the collection of possible local names (Fig. 2).

The emic-etic approach was 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 interviewees 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).

3. Results

3.1. Interviewed Fishers

A total of 134 interviews were carried out during the survey with fishers from Arraial do Cabo. This collected sample represents more than 13% of the total fishermen's population of this community (Braga et al., 2018b). 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

Fig. 2. Image of the Brazilian sardine used in the projective test. Credits: Carvalho Filho, A. Fishbase.

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 (83.6%) registered in the sample (Elementary Education I, 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 (1 Brazilian Real = €0.29 Euro), 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 interviewees reported fishing for 2–4 times per week, 30 interviewees for 5–6 times per week, five fishers weekly and two monthly. The average duration of deep sea fishing per trip (± standard deviation) was 22.1 ± 66.8 h.

3.2. Fish folk taxonomy

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

3.3. 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. Fishers 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.

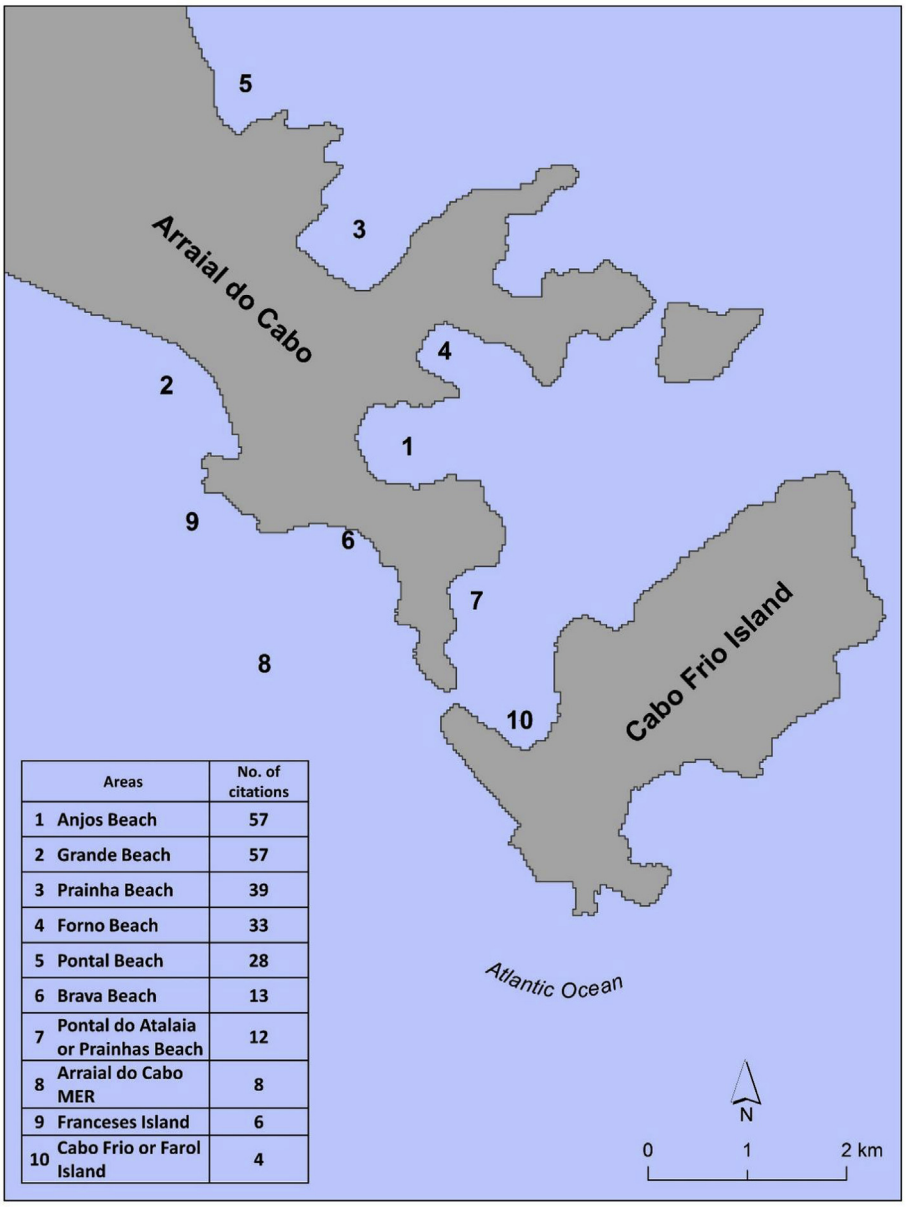
The fishermen interviewed also mentioned the probable areas where the clupeoid in question could be found in Arraial do Cabo (Fig. 3). The areas most referred to by the fishers were Anjos Beach and Grande Beach (57 citations each), Prainha Beach (39 citations), Forno Beach (33 citations), Pontal Beach (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).

3.4. 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 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 fishers 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 fishermen (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



	Areas	No. of citations
1	Anjos Beach	57
2	Grande Beach	57
3	Prainha Beach	39
4	Forno Beach	33
5	Pontal Beach	28
6	Brava Beach	13
7	Pontal do Atalaia or Prainhas Beach	12
8	Arraial do Cabo MER	8
9	Franceses Island	6
10	Cabo Frio or Farol Island	4

Fig. 3. Probable areas of sardine habitat on the coast of Arraial do Cabo. Credits: Anjos, M.

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 respondents (N = 84, 62.7%) said that they are short-lived fish and another 38 fishers (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.

3.5. Reproductive, fat accumulation and spawning

Most fishers (N = 86, 64.2%) do not know when the sardines start to reproduce. Another fifteen respondents (11.2%) said the sardine mature at one year of age, 13 others between 3 and 6 months of age, and two between 7 and 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 sardine 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) (Fig. 4a). 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 (Fig. 4b).

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) (Fig. 5a).

Some fishermen also cited summer (18 times), winter (3 times) and spring and autumn (1 time each) as the time when sardines spawn.

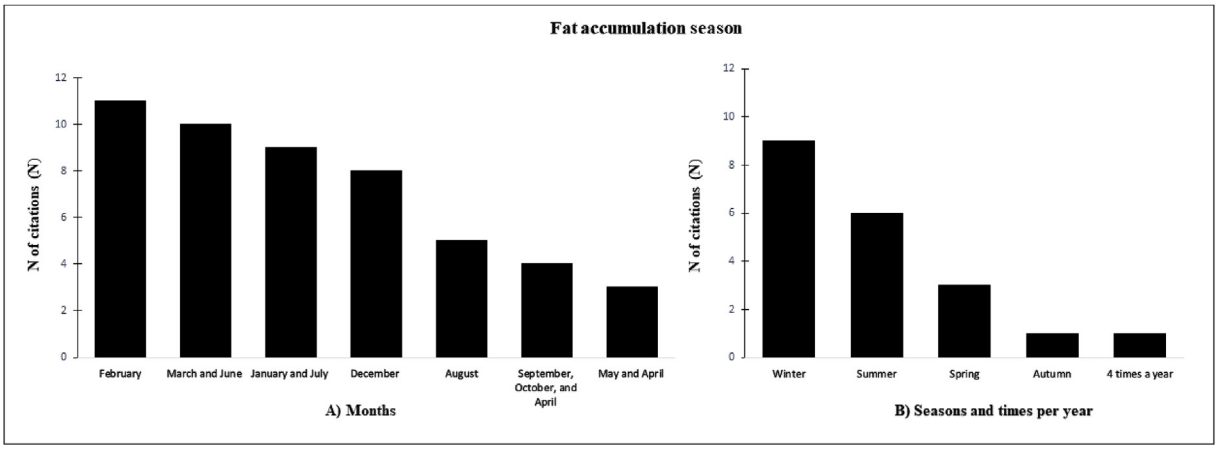


Fig. 4. Sardine fat accumulation time according to the fishers.

Fishers 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 (Fig. 5b).

3.6. Sardines food items and predators

Fishermen elucidated the main constituents of the diet of sardines (Table 1). 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 respondents 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 2). 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).

Table 1
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

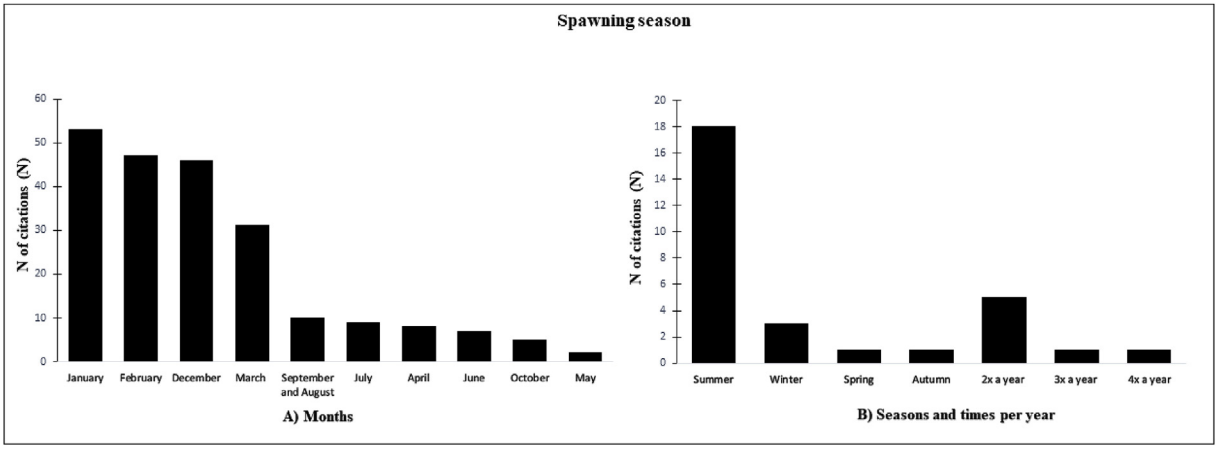


Fig. 5. Season of sardines spawning according to the fishers.

Table 2
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

3.7. Food taboos and human uses

Food taboos and beliefs were evidenced in the fishing village of Arraial do Cabo about Brazilian sardine (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 fish 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%). 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. These interviewees reported using the image of sardines for decoration utensils, and various types of souvenirs of the Arraial do Cabo.

4. Discussion

4.1. 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, 2018). The names *sardinha*, *sardinha-verdadeira* and *sardinha boca-torta* are also considered as synonyms of this small pelagic fish in the same database (Fishbase, 2018). 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.

Finally, the 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 this sense, our results collaborated with the information on the ethnotaxonomy variations of this species when reporting seven folklore names of Brazilian sardines (Table 3).

4.2. Preferential habitat

Brazilian sardine 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 and 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.

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 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 (Table 3).

4.3. 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 (Moreira et al., 2015; Paiva and Motta, 2000). 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

Table 3
Data on the ecology of Brazilian sardines and Fisher's LEK that corroborate and refute the scientific literature.

Section	Literature	Fisher's LEK corroborated	Fisher's LEK refuted
Folk taxonomy	sardinha-maromba, sardinha, sardinha verdadeira and sardinha boca-torta (Fishbase, 2018).	*"sardinha-maromba, sardinha, sardinha verdadeira and sardinha boca-torta".*	*"sardinha-lisa, sardinha comum* and *sardinha-meã"*
Preferential Habitat	Depth (m): coastal regions up to 100 m (Cergole and Dias-Neto, 2011; Valentini and Cardoso, 1991).	"ranged mainly depths from 0 to 100 m".	"0–200 m".
	Inhabits coastal waters, bays and estuaries (Paiva and Motta, 2000; Vasconcellos, 2003).	"mainly along the coast". "areas of high biodiversity".	"on the coast and high seas". "hot water, clean water, rocky coastlines, muddy areas of the sea, rocks, places with calm waters and beaches (sands)".
	Grande Beach: intense marine upwelling and focus of fish shoals (Costa et al., 2017; Dias et al., 2014).	"Grande Beach".	"Anjos Beach, Prainha Beach, Forno Beach and Pontal Beach".
Behavior and development	Forms large shoals (Moreira et al., 2015; Paiva and Motta, 2000).	*"manta* and *manchas*: synonymous of schools".	"sardines move in a synchronized way and that they remain in schools to protect themselves from predators".
	Migration: Brazilian sardines are limited only to the SBB area (Matsuura, 1996; Sunyé and Servain, 1998).	"from South of Brazil to the Arraial do Cabo region".	"from the North of Brazil". "from the South and the North of Brazil". "depends on the spawning season".
	Development: rapid growth (Cergole and Dias-Neto, 2011; Dias et al., 2014; Vasconcellos, 2003).	"rapid growth".	"intermediate growth". "slow growth".
Reproductive (Maturation)	First maturation occurs at about one year and half of age and a length of 16–17 cm (Cergole and Dias-Neto, 2011).	"in the range of 16–20 cm".	"in the range of 10–15 cm".
	Gonadal maturity occurs around a year old (Saccardo and Rossi-Wongtschowski, 1991).	"sardine reached sexual maturity at about one year of age".	"3–6 months of age". "7–12 months of age".
Fat accumulation	Sardines accumulate fats in the months before breeding (IPMA, 2016).	"primarily: June and July". "others: January, February and March".	The main months quoted by the fishers (Fig. 4) corresponded to the same time interval of the recruitment of the species (ICMBio, 2017).
Spawning season	Predominantly in spring and summer (Kurtz and Matsuura, 2001; Matsuura, 1998), with peak activity: December and January (Matsuura, 1998; Moraes et al., 2012).	"Spring and Summer". "December to March".	"Winter and Autumn". "April, May, June, July, August, September". "2x, 3x or 4x per year".
Food items	Zooplankton and Phytoplankton (Cergole and Dias-Neto, 2011; Saccardo and Rossi-Wongtschowski, 1991).	"plankton, algae, small invertebrates, and larvae".	*"purgãozinho, manjuba,* remains of fish, impurities of the sea".
Predators	Various species of fish, as well as for birds and marine mammals (del Favero et al., 2017).	"fish, birds, sharks, whales and dolphins". (Table 2).	Fishers mentioned a species diversity (Table 2).
	Bonito-listrado (*Katsuwonus pelamis*), xaréu (*Caranx hippos*) and xerelete (*Caranx latus*) (Paiva and Motta, 1999).	"bonito-listrado, xaréu e xerelete"	

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, most 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 (22° 45 S) until Cape Santa Marta, Santa Catarina (29° S). Other fishers (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 (Cergole and Dias-Neto, 2011; Dias et al., 2014; Vasconcellos, 2003). Almost 80% of the fishermen pointed out that this fish has fast growth, and 62.7% of the respondents 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 (Fogarty and Moksness, 2016; Ganias, 2014). 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 interviewees may not have distinguished both phases because the larval phase is often imperceptible and of no referential value to fishers.

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 fishers shared about sardines. The fishermen's knowledge in this work also 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). Finally, 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 Arraial do Cabo with the Brazilian sardines (Table 3).

4.4. Reproductive, fat accumulation and spawning

The SBB coastal waters are the main reproductive area for Brazilian sardine (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 sardine (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 fishers (N = 5) who said they reached maturity in the range of 16–20 cm.

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 length range of the species in Arraial do Cabo (Table 3).

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, 2017). 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 90 mm in length and a half year old, move to the open sea to recruit adult fish stocks (Cergole and Dias-Neto, 2011; Schwartzlose et al., 1999). 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, 2016). At the end of spawning, the sardine is lean due to the energy expenditure released during the whole breeding season (IPMA, 2016). When questioned about the period 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.

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 study in which the informants also shared LEK about the time of fat accumulation of the sardines for their later reproduction (Table 3).

The spawning season of Brazilian sardine occurs predominantly in spring and summer (Kurtz and Matsuura, 2001; Matsuura, 1998), 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). Respondents reported the sardine spawning data like those found in scientific literature. Fishers also show the months of January and December with the high expressiveness of mentions. The interviewees also highlighted summer as the season of the year with more sardines spawning peaks on the coast of Arraial do Cabo. Fishers also indicated other months of the year. This fact suggests the probable occurrence of sardines breeding throughout the year. In conclusion, fishers from Arraial do Cabo also shared information about the spawning (Table 3), from the same perspective as other ethnobiological studies (Nirmale et al., 2012; Silvano and Begossi, 2010; Zapelini et al., 2017).

4.5. Brazilian sardines food items and predators

The availability of microzooplankton in the natural environment of sardines, causes the Brazilian sardine 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 (Cergole and Dias-Neto, 2011; Saccardo and Rossi-Wongtschowski, 1991). This information on the food ecology of sardines agreed with the fishermen's statements in this study. Fishers 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.

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 assemblage 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). Member of the fishing village of Arraial do Cabo showed the same pattern and shared specifics information about sardines' trophic chain, exhibiting details about preys and predators of this small pelagic species (Table 3).

4.6. Food taboos 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 (Berkes et al., 2000; Colding and Folke, 1997). 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).

There is a growing inclination of research that seeks to investigate the LEK of local communities around food taboos (Aburto et al., 2015; Braga et al., 2017b; Braga and Schiavetti, 2013; Leeney et al., 2015). In Arraial do Cabo it was not different, and almost thirty percent of fishers reported presenting food taboos with *S. brasiliensis*. The trend observed in our study may be in part explained by the insertion of technological components and the presence of means of communication in the daily life of younger and adult fishers. This fact may have helped the individuals from Arraial do Cabo to no more extensive care about the traditional teachings and knowledge handed down by the ascendants over generations.

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 fish. 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., 2017b).

Certain specific groups of human beings note the presence of food restrictions. The specific taboos (Colding and Folke, 2001) were reported in Arraial do Cabo with women during pregnancy and the puerperium, and men and women in the postoperative and with diseases. 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 LEK 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 (Baloi et al., 2017; Santos and Rodrigues-Ribeiro, 2010). Brazilian sardine was recognized as a species of great social and economic importance for artisanal fishing in the region of Arraial do Cabo. All this highlight in this village in the South Atlantic occurs mainly due to the dependence of fishers on the sardine resource. Merchants and industry representatives widely seek this species, as well as being used as a food resource by *Cabistas*. This perspective was also in agreement with Coelho-Souza et al. (2012) in the same area. Additionally, the fish catches data provided by the Rio de Janeiro Fisheries Institute also demonstrates this dependence on this fishing resource in Southeast Brazil (FIPERJ, 2015).

5. Conclusions

Fishers reported information on the biology, ecology, food restrictions and beliefs of sardines in the fishing village of Arraial do Cabo. Data about the popular taxonomy shared in this study can be very important to collaborate in the control and catches associated with sardine fishing locally. The diversity of data on the preferential environment of sardines should also be considered and may contribute to a better understanding of the spatial distribution of this species in Arraial do Cabo. Fishers varied their responses with the scientific literature on the migration of these fish, which may indicate possible behavioral changes of this species in the region. Variations of the biological data were also evident in the part that sought to investigate the maturation season or the age in which they are suitable for reproduction. Data pointed out by the fishermen about the fat accumulation season of sardine were similar to the recruitment season of the species available in the literature. It is suggested at this point a detailed investigation in future ecological and ethnobiological studies to try to understand this finding. Some fishers from this fishing village also have reported spawning of sardines throughout the year. Other interviewees mentioned spawning in various months of the year, differing from the biological data already available. Fisheries managers should pay attention to these data, as this issue is directly related to possible divergences between fishers and the rules imposed by the government on biological closure. Fishermen also emphasized the social importance of this resource to the local people and manifested the presence of food taboos that were not related to conservation measures.

Fisher's LEK of biology and ecology about *S. Brasiliensis* in most cases corroborate with data already published on this species (Table 3). Refuted informal knowledge data should not be discarded but analyzed and if feasible, subsequently indicated for future research that may add to the ecological knowledge of this species. Drew (2005) further argues that veiled components of this type of traditional knowledge can project 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).

Finally, management meetings on sardines should include fishers, conservation biologists, managers and environmental governance. The general objective would be to promote greater social inclusion of the underprivileged by making them part of the decision-making processes on small-scale fisheries. The discussion of the interested parties can generate an approximation, and a better understanding of the attitudes of the community of Arraial do Cabo (Braga et al., 2018b). Also, such interaction may provide the opportunity for these local populations to aggregate a more scientific and reliable knowledge base about sardines. We also advise the constant exchange of information between ecologists and ethnobiologists on the gaps in fish stock data. This procedure can support to narrow and delineate future research on sardine conservation in small-scale fisheries in Arraial do Cabo.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.ocecoaman.2018.08.021.

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