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Fernando de Noronha (state of Pernambuco) fishermen's local ecological knowledge regarding the fish species used as bait

O conhecimento ecológico local dos pescadores artesanais de Fernando de Noronha (PE) sobre as espécies de peixes utilizadas como iscas

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ABSTRACT

Artisanal fishing on Fernando de Noronha is directly related to fishing for bait, since commercial fishing depends on these baits. This work aimed to analyze the local ecological knowledge of fishermen about the biology and ecology of the fish species used as bait on Fernando de Noronha (state of Pernambuco - PE) to support the planning of the local activity. Data collection was carried out through interviews with semi-structured scripts containing questions about the socio-economic profile of the fishermen and the biological and ecological aspects of the species used as bait. The data were analyzed qualitatively and quantitatively, seeking to represent a consensus among the informants and to compare the local ecological knowledge with the scientific literature through the method of comparative cognition and the hypothesis test. Sixty-nine fishermen were interviewed, using false herrings (*Harengula clupeola*) and mackerel scads (*Decapterus macarellus*) as their main bait fish, in still fishing and fishing using boats. The hypothesis test, applied to the mentioned results by more than 30% of the fishermen, showed a high degree of agreement between local ecological knowledge and the scientific literature, revealing detailed knowledge of the fishermen on the biological and ecological aspects of false herrings and mackerel scads. Catching bait fish on Fernando de Noronha proved to be extremely important, both for the relationship with artisanal fishing and for the maintenance of local knowledge and culture. The results obtained in this research should foster a very much-needed dialogue between fishermen and those responsible for managing conservation units to create legal and effective mechanisms to meet the demand for bait fish used in commercial fishing and to maintain a sustainable artisanal fishing model for Fernando de Noronha.

Keywords: ethnoecology; false herrings; artisanal fisheries; conservation units.

RESUMO

A pesca artesanal em Fernando de Noronha está diretamente relacionada com a pesca de iscas, pois delas dependem as capturas dos peixes comerciais. Este trabalho objetivou analisar o conhecimento ecológico local dos pescadores sobre a biologia e a ecologia das espécies de peixes utilizadas como iscas em Fernando de Noronha (PE), a fim de subsidiar o ordenamento da atividade local. A coleta de dados foi realizada por meio de entrevistas com roteiros semiestruturados que continham questões sobre o perfil socioeconômico dos pescadores e aspectos biológicos e ecológicos das espécies utilizadas como iscas. Os dados foram analisados qualitativamente e quantitativamente, buscando representar o consenso entre os informantes e comparar o conhecimento ecológico local com a literatura cientifica pelo método de cognição comparada e o teste de hipóteses. Foram entrevistados 69 pescadores, que utilizam a sardinha (*Harengula clupeola*) e o garapau (*Decapterus macarellus*) como principais iscas, em pescarias embarcadas ou desembarcadas. O teste de hipótese, aplicado em resultados citados por mais de 30% dos pescadores, demonstrou elevado grau de concordância entre o conhecimento ecológico local e a literatura científica, revelando o conhecimento detalhado que os pescadores possuem sobre os aspectos biológicos e ecológicos da sardinha e garapau. A captura de iscas em Fernando de Noronha mostrou-se de extrema importância, tanto para a relação com a pesca artesanal quanto para a manutenção dos saberes e da cultura local. Os resultados obtidos nesta pesquisa devem fomentar o diálogo necessário entre os pescadores e a gestão das unidades de conservação, a fim de criar mecanismos legais e efetivos para atender à demanda de iscas necessárias à atividade comercial e, ainda, à manutenção de um modelo de pesca artesanal sustentável para Fernando de Noronha.

Palavras-chave: etnoecologia; sardinha; pesca artesanal; unidades de conservação.

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Introduction

Biodiversity conservation is a set of practices aimed at maintaining ecological processes, genetic diversity, and primordial vital systems, as well as the endless use of ecosystems and species (IUCN, 2006). One of the main mechanisms for the conservation of biodiversity is the conservation units, which can be marine or terrestrial, designated for the conservation of natural resources and their biological diversity, as well as the associated cultural resources (Brasil, 2011).

Studies have demonstrated the reality of the users of these resources, especially the communities that live in conservation units, emphasizing the importance of involving local residents and artisanal fishermen in discussions about nature conservation or the implementation and improvement of a management plan, since they have in-depth local ecological knowledge about the environment and its available resources (Ferreira et al., 2021; Lima et al., 2021; Zeineddine et al., 2022).

Local ecological knowledge encompasses terrestrial and aquatic environments and is acquired through everyday practices. In the case of artisanal fishermen, they have detailed knowledge of the classification, conservation, biology, ecology, and behavior of the animals managed, in addition to the exploited environment and factors associated with it. In many cases, this may be the only source of information available or a way to increase the reliability of data, being indispensable for the local management of fishing activities (Casal and Souto, 2018; Mazzochi and Carlos, 2020; Kellermann et al., 2021).

The importance of local ecological knowledge is gradually being recognized in Brazil, mainly as a tool for the management of fisheries, applied in approaches such as fishery recruitment, growth, migration, trophic ecology, mortality, behavior, among other aspects (Feitosa et al., 2019; Neves, 2020; Kellermann et al., 2021).

In the Fernando de Noronha Archipelago, there is an imminent conflict between artisanal fishermen and the authorities responsible for managing conservation units regarding the areas where bait fish can be caught for local artisanal fishing (Dominguez et al., 2016; Martins, 2018; Zeineddine et al., 2021). Although fishing on Fernando de Noronha has been cited in some studies (Dominguez et al., 2013, 2016; Martins, 2018; Zeineddine et al., 2021, 2022), there is a lack of scientific knowledge about the biology and ecology of fish species used as bait. Thus, this study aimed to analyze the local ecological knowledge of artisanal fishermen from Fernando de Noronha on the biological and ecological aspects of the fish species used as bait to support the planning of the local activity and facilitate important decisions.

Study area

The Fernando de Noronha Archipelago (Figure 1) is located 215 miles off the northeastern coast of Brazil, has a volcanic formation, is composed of 21 islands and islets, with Fernando de Noronha being the main island and the only inhabited, with approximately 17 km^2 in length (Claudino-Sales, 2019).

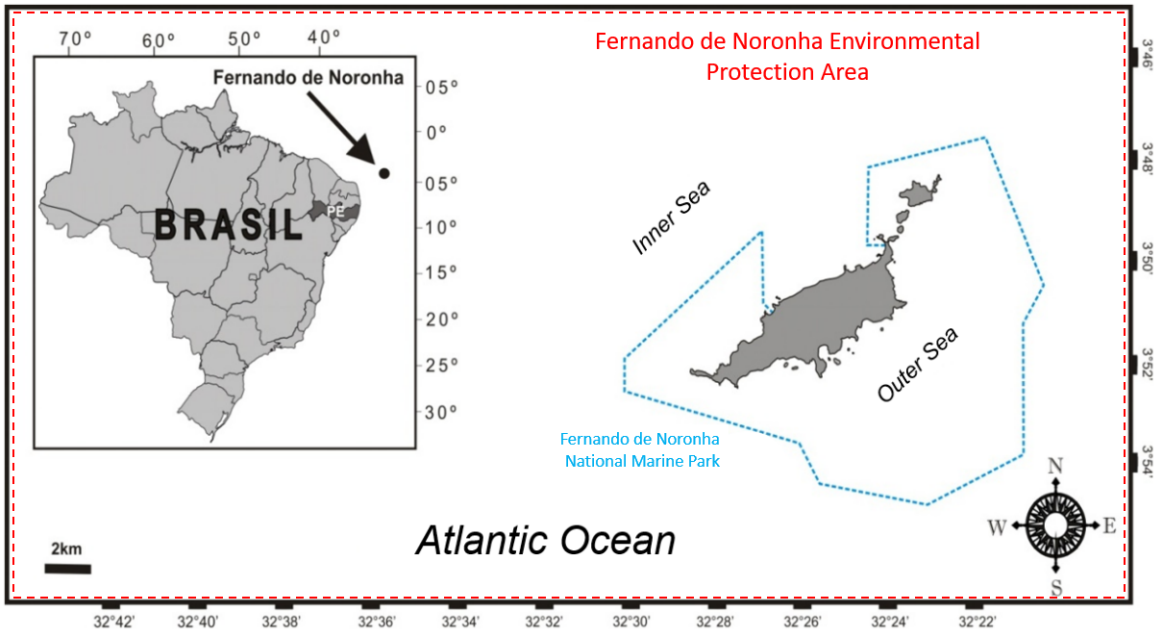

Figure 1 – Location of the Fernando de Noronha Archipelago with the demarcation of the Environmental Protection Area (in grey) and Marine National Park (inside blue line).

Fernando de Noronha is composed of sandy and pebble beaches located all around the island, divided into the "outer sea" and the "inner sea". The inner sea, facing continental Brazil, is where most of the sandy beaches are located, in addition to being a more protected place because it has minor influence from trade winds and currents from the southeast (Carvalho et al., 2021).

The Fernando de Noronha archipelago is a county of Pernambuco state in Brazil and has its entire fortress area located in two conservation units, legally created in 1988 and currently managed by the Chico Mendes Institute for Biodiversity Conservation (ICMBIO). The environmental protection area (APA) corresponds to 30% of the total area of the archipelago, a conservation unit where sustainable use is authorized, thus allowing human occupation and the renewable use of natural resources, such as artisanal fishing. The Fernando de Noronha National Marine Park (PARNAMAR-FN) corresponds to 70% of the archipelago's total area, and is intended to fully protect the environment, that is, only ecological tourism, contemplation, and research are allowed (Noronha, 2018).

The prevailing conflict regarding the local fishing activity is a result of the creation of an integral protection unit (marine national park), which prohibits fishing and, consequently, reduces the local fishing area (Martins, 2018; Zeineddine et al., 2022).

Methods

Data collection was carried out through interviews with semi-structured scripts that initially addressed information about the socio-economic profile of fishermen (source of income, age, education, marital status, hometown, among others). Then, the scripts addressed aspects of their local knowledge concerning the ecology and biology of the fish species used as bait (questions about habitat, food, fish school formation, and behavior, among others).

After the first stage of the interview, the key informants were defined through the criterion "time of fishing for bait", that is, all fishermen who have been fishing with natural baits for more than five years were considered key informants.

To reach a satisfactory sample, the "snowball" technique was used (Biernacki and Waldorf, 1981), in which, at the end of each interview, the fisherman being interviewed indicates another fisherman, thus seeking to cover as many specialized informants as possible on the subject addressed. For this survey, the saturation number reached through this technique was 69 fishermen, so we consider this number to be 100% of the informants.

The identification of the species used as bait was carried out through specialized bibliography (Carpenter, 2002; Araújo et al., 2004; Marceniuk, 2005; Gomes et al., 2010). The scientific nomenclature and systematic classification were also revised (Menezes et al., 2003; Nelson, 2006; Eschmayer, 2011).

The methodological procedures were approved by the Human Research Ethics Committee of the Universidade Santa Cecília under report No. 389.163. The survey development in the Conservation Unit was authorized by the Biodiversity Authorization and Information System (SISBIO) (No. 40953-1). Fishermen completed Informed Consent Forms.

The data were analyzed using the percentage of citations on each aspect addressed, in which the information cited by 10% (or more) of the informants was considered to be the most relevant. This analysis is known as "informant consensus", and is based on the degree of agreement between the respondents' answers, allowing to assess the importance of the use of the resources discussed in the question according to the number of citations for each piece of information (Silvano and Begossi, 2005; Zeineddine et al., 2018).

The piece of information most cited in the consensus was matched with the scientific literature through comparative cognition tables (Marques, 2001) and bibliographic reviews in order to verify any consistency between the local ecological knowledge and the scientific literature.

The results of comparative cognition were analyzed according to the "hypothesis test", which consists of generating hypotheses through ethnoecological data in order to support and operationalize research and management practices. The hypotheses were generated from information cited by 30% (or more) of the fishermen and tested according to the degree of agreement with the scientific literature consulted (Silvano and Valbo-Jørgensen, 2008).

Results

Sixty-nine artisanal bait fishermen were interviewed, most of them male (98%), ranging from 23 to 72 years old, and with incomplete elementary/middle school (52%), complete high school (24.1%), and complete elementary/middle school (19.4%). Only 33.3% of the fishermen are natives, the others are from Recife, PE (50.7%), Natal, RN (state of Rio Grande do Norte) (8.7%), and other locations in these states (5.8%).

Among those interviewed, only 17.4% live exclusively from fishing, selling their fish in restaurants, inns, or to local families. As it is a region where tourism is very disseminated, many fishermen also work in tourism-oriented activities, including as tourist guides (66.6%), inn staff (21.7%), with boat trips (14.5%), or sport fishing (10.2%). They also fish in their free time and on weekends.

Bait fishing is carried out by all (100%) artisanal fishermen on the island, the preference is for live baits, and the fish species used as bait are false herrings (*Harengula clupeola*), used by 100% of the respondents, and mackerel scads (*Decapterus macarellus*), by 27%.

According to the fishermen interviewed, false herrings feed on plankton and algae, and serve as food for all fish and birds on the island (Figure 2).

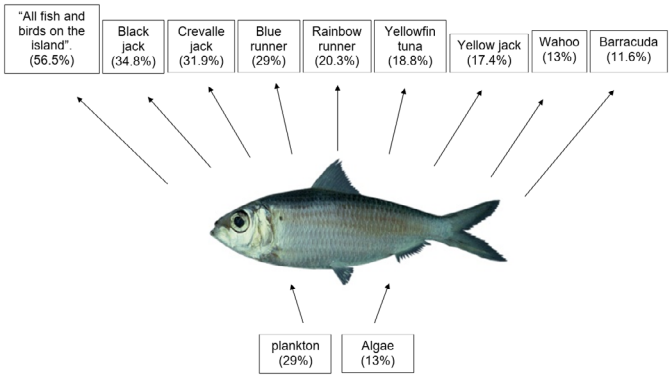

Figure 2 – False herring trophic chain — *Harengula clupeola*, according to artisanal fishermen from Fernando de Noronha (Numbers in parentheses indicate the % of citation).

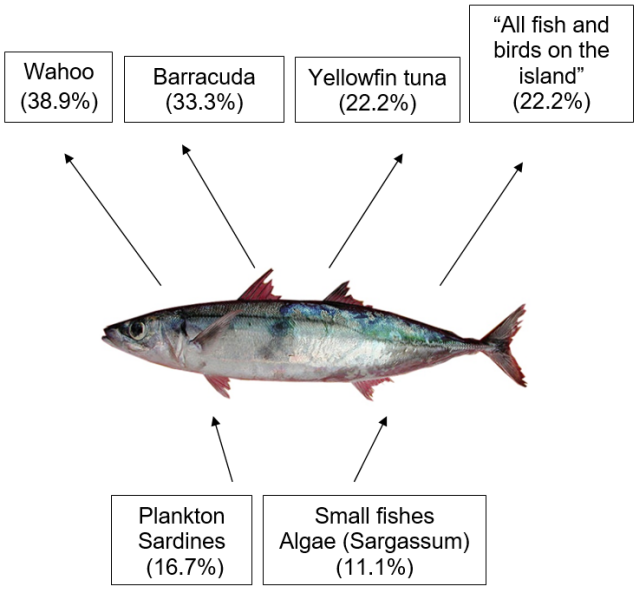

Figure 3 – Mackerel scad trophic chain — *Decapterus macarellus*, according to artisanal fishermen of Fernando de Noronha (Numbers in parentheses indicate the % of citation).

The mackerel scad feeds on luminescent plankton, false herrings, algae, and small fish, and serve as food to all species that are caught in fishing (Figure 3).

The comparative cognition contained in Table 1 shows the specific local ecological knowledge demonstrated by the fishermen.

Regarding predation, 56.5% of the interviewees claim that false herrings serve as food to all fish on the island, the most cited are in Table 2.

Table 1 – Comparison between the local knowledge of fishermen from Fernando de Noronha (PE) and the scientific literature on the diet of the main bait fish used.

Cited bait	LEK	N	%	Scientific literature
False herring N = 69	Don't know Plankton Algae	20 20 9	29 29 13	Plankton, small fish, copepods, diatoms, decapods, polychaetes, amphipods and megalopa larvae (Carranza et al., 2021)
Mackerel scad N = 18	Shinny plankton False herring Small fish Algae Don't know	3 3 2 2 2	16.7 16.7 11.1 11.1 111	Zooplankton, small invertebrates and crustaceans, fish (Clupeidae) and larvae (Honebrink, 1990; Roux and Conand, 2000).

LEK: Local ecological knowledge; N: number of citations; %: percentage of citations.

The refined knowledge of the interviewees about the habitat and habits of the bait fish is notorious, most of them said that false herrings are found on the shore (approximately 7 meters deep) at feeding times, a statement confirmed by the scientific literature consulted (Table 3).

Regarding the false herring spawning season, the interviewees claim that it occurs every time the moon phases change, as it is the time when it is possible to frequently observe small (juvenile) and ovate (adult) organisms. This means, for fishermen, that reproduction occurs throughout the year, a fact also mentioned for the mackerel scad (Table 4). Fishermen claim that sexual dimorphism exists in the two species mentioned, but 37.7% of them could not differentiate male from female individuals.

For the mackerel scad, 5.6% of the fishermen stated that the male also has eggs. However, 22.2% did not know how to differentiate them, the rest did not point out the dimorphism of the species.

In relation to abundance and reproduction, fishermen claim to observe schools. In the case of false herrings, schools occur when individuals are spawning or when they have already spawned schools of juveniles.

The influence of the moon phases on fisheries was stated by 84% of the interviewees (Table 5), and the moon phases most cited as influential for fishing activities are: new, full, and crescent moons, as the tide is better and so they can catch greater volumes of fish.

The hypothesis test showed a high agreement between LEK and scientific knowledge in all related aspects (Table 6).

Table 2 – Comparison between the local knowledge of fishermen from Fernando de Noronha (PE) and the scientific literature on predatory animals of the species used as bait.

Cited bait	LEK	N	%	Scientific literature
Sardine N = 69	All fish and birds on the island	39	56.5	Frigatebird (*Fregata magnificens*): fish from the Clupeidae, Engraulidae, Sciaenidae and Carangidae (false herring and mackerel scad) families. Thitty (*Anousstolidus*): Organisms of the Clupeidae family. (Nascimento and Azevedo-Júnior, 2005; Correia et al., 2021).
	Black jack (*Caranx lugubris*)	24	34.8	Small fish, planktonic crustaceans and invertebrates (Velasco-Reyes et al., 2022).
	Crevalle jack (*Caranx hippos*)	22	31.9	Small fish, planktonic crustaceans and invertebrates (Velasco-Reyes et al., 2022).
	Blue runner (*Caranx crysos*)	20	29	Small fish, planktonic crustaceans and invertebrates (Velasco-Reyes et al., 2022).
	Rainbow runner (*Elagatis bipinnulata*)	14	20.3	Small fishes, crustaceans and cephalopods (micronekton) (Wang et al., 2022).
	Yellowfin tuna (*Thunnus albacares*)	13	18.8	Fishes and fish larvae, crustaceans (mainly stomatopods) and cephalopods (Martins, 2020).
	Yellow jack (*Caranx bartholomaei*)	12	17.4	Small fishes, planktonic crustaceans and invertebrates (Velasco-Reyes et al., 2022).
	Wahoo (*Acanthocybium solandri*)	9	13	Small fishes, crustaceans and cephalopods (Martins, 2020).
	Barracuda (*Sphyraena barracuda*)	8	11.6	Voracious and carnivorous predators, feeding mainly on small fishes (Martins, 2020).
Mackerel scad N = 18	Wahoo (*Acanthocybium solandri*)	7	38.9	Small fishes, crustaceans and cephalopods (Perelman et al., 2017; Martins, 2020).
	Barracuda (*Sphyraena barracuda*)	6	33.3	Voracious and carnivorous predators, feeding mainly on small fishes (Martins, 2020).
	All fish and birds on the island	4	22.2	Frigatebird (Fregata magnificens) – fishes from Clupeidae, Engraulidae, Sciaenidae and Carangidae Family (Nascimento and Azevedo-Júnior, 2005).
	Yellowfin tuna (*Thunnus albacares*)	4	22.2	Fishes and fish larvae, crustaceans (mainly stomatopods) and cephalopods (Martins, 2020).

LEK: Local ecological knowledge; N: number of citations; %: percentage of citations.

Table 3 – Local ecological knowledge of Fernando de Noronha fishermen about the bait fish species caught and their habitats.

Cited bait	LEK	N°	%	Scientific literature
False herrings N = 69	Open sea/day Shore/night	31	44.9	Occurs in bays, beaches, mangroves, estuaries, brackish lagoons, and along with islands and reefs. Large schools are found along sandy beaches. In shallow waters, they seek for food not only on the water surface but also on the sandy bottom (Pattikawa et al., 2018).
	Shore	25	36.2	
Mackerel scad N = 18	Open sea	10	55.6	Prefers oceanic clear waters, most commonly around islands. Sometimes are found near the surface, but generally between forty and two hundred meters deep, pelagic specie (Love et al., 2015; Pattikawa et al., 2018).
	Open sea and beach (shore)	2	11.1	

LEK: Local ecological knowledge; N: number of citations; %: percentage of citations.

Table 4 – Local ecological knowledge of fishermen about the reproductive aspects of bait fish in the Fernando de Noronha Archipelago.

Characteristic		LEK	N	%	Scientific literature
Spawning season	False herring	Don't know "*Moon phases*" Did not answer	23 13 33	33.3 18.8 47.9	Summer spawning and recruitment in late winter or early spring (Pinto et al., 2022).
	Mackerel scad	Don't know "*Whole year*" Did not answer	2 2 14	11.1 11.1 72.8	Spawns from March to October and recruitment in November (Costa et al., 2020).
Sexual dimorphism	False herring	"*Female spawn*" Don't know Did not answer	29 26 14	42 37.7 20.3	The female tends to be bigger than the male (Figuerola-Fernández *et al*., 2008; Lemos, 2013).
	Mackerel scad	Don't know Did not answer	4 14	22.2 72.8	The portion of the anal fin is dark in males and light in females, has no significant difference in size (Costa et al., 2020).
Reproductive method	"Goes to open sea to spawn" No answer		7 62	10.1 89.9	Mackerel scad: Spawn occurs away from the shore (Costa et al., 2020) False herring: Recruitment and breeding in the coastal zone (Vasconcellos et al., 2007).
Abundance vs. Reproduction	"Many fishes means reproduction" "Nothing related" "Spawning"		25 21 14	36.2 30.4 20.3	Schools are associated with spawning (Hatanaka et al., 2006).

LEK: Local ecological knowledge; N: number of citations; %: percentage of citations.

Table 5 – Local ecological knowledge of Fernando de Noronha fishermen about how the moon phases influence fisheries.

Characteristic	LEK	N	%	Scientific literature
Moon influence	Have influence Don't have influence	58 13	84 18.8	Have influence (Zeineddine et al., 2021; Tognere and Tosta, 2022).
Types of influence	Tide Luminosity Fish quantity	24 14 13	34.8 20.3 18.8	Moon phases are directly associated with tides, luminosity, and available nutrients (Bakun, 1996; Tognere and Tosta, 2022).
Most productive moon phase	New moon Full moon Crescent moon	24 22 9	34.8 31.9 13	Mackerel scad: best results in fishing occur on the new moon and on nights without the moon (Roos et al., 2007). Other fish: Full moon and new moon (Zeineddine et al., 2021).

LEK: Local ecological knowledge; N: number of citations; %: percentage of citations.

Table 6 – Degree of agreement about the hypotheses generated through ethnoecological data (only data cited by more than 30% of fishermen).

Hypothesis	Degree of Agreement
All fish and birds on the island feed on false herrings and mackerel scads	High agreement
Mackerel scads live in the open sea False herrings live on the shore and open sea	High agreement High agreement
Moon phase and tide amplitude influence fishing activities False herrings feed on plankton Plenty of fish schools means post reproduction phase	High agreement High agreement High agreement

Discussion

The local ecological knowledge of artisanal fishermen is usually detailed and includes several aspects related to the environment and exploited resources (Silga et al., 2021).

Fishermen from Fernando de Noronha identify trophic interactions in their daily routines, such as predation associated with the fish caught using baits. This knowledge about the trophic ecology of fish has utilitarian importance, especially regarding the correct insertion of the food item in the form of bait, which generates greater fishing productivity and improvement of fishing efforts (Marques, 2001).

Studies related to the composition of food items through the stomach content of the fish caught by the fishermen interviewed highlighted organisms from the Clupeidade (false herring) and Carangidae (mackerel scad) families as food items for these fishes (Perelman et al., 2017; Vaeske-Jr. et al., 2018; Martins, 2020; Velasco-Reyes et al., 2022). The same food items were observed by Nascimento and Azevedo-Júnior (2005) for shorebirds from the Abrolhos archipelago, by Di Beneditto and Siciliano (2021) in shorebirds

from Rio de Janeiro, and by Correia et al. (2021) in boobies from the Gulf of Guinea.

In studies on the diet of false herrings and mackerel scads (Honebrink, 1990; Roux and Conand, 2000; Carranza et al., 2021), algae, plankton, and smaller fish were found as food items, information consistent with the local ecological knowledge about the eating habits of the cited bait fish species and the predatory fish that feed on these baits (high agreement with the generated hypothesis). It is worth noting that the fishermen said that one of the mackerel scad's food items is the false herring itself, which is smaller than it, corroborated by the scientific literature (Honebrink, 1990; Roux and Conand, 2000), thus demonstrating the high level of observation, detailing, and local ecological knowledge, in addition to the importance of fishing activities and bait fish capture to maintain this knowledge.

Regarding fish habitat, the fishermen recognize only the horizontal distribution, stating that false herrings and mackerel scads live in the open sea, but swim to the coastal region to feed or reproduce. Nevertheless, the fishermen's responses were similar to the information available in the consulted literature (Love et al., 2015; Pattikawa et al., 2018).

The local ecological knowledge about the reproductive aspects differed from the scientific literature regarding the season and way of reproduction and sexual dimorphism, but it was in agreement about the abundance of fish. Ferreira et al. (2021) also point out a low agreement between local and scientific ecological knowledge regarding the reproduction of the studied species.

In biological studies, such difficulty in analyzing the life history of fish is also observed, which makes this field very important for future biological and ethnobiological surveys, in addition to the fact that the divergent information contained in this study may generate new hypotheses for surveys about the same theme (Silvano and Valbo-Jørgensen, 2008).

The influence of lunar cycles on fisheries on Fernando de Noronha has been previously mentioned by Zeineddine et al. (2021). According to Bakun (1996), in high amplitude tides, there is certain turbulence, which can cause dissociation of the material deposited on the seafloor, leaving it suspended and available for photosynthesis, which explains the "amount of fish" mentioned by the fishermen, who prefer to fish in the full and new moon tides.

The phases of the moon have a great influence on tidal level variations and the luminosity of the nights (Tognere and Tosta, 2022), which is really associated with still fishing and fishing using boats. Some research on the local ecological knowledge of fishermen corroborated the perception of fishermen from Fernando de Noronha regarding the type of influence and preference of lunar phases for fishing (Nascimento et al., 2018; Zeineddine et al., 2021).

The hypothesis test approach applied in this survey had, for all the hypotheses generated through local ecological knowledge, a high degree of agreement with the scientific literature, which highlights the importance of local fishermen for the maintenance and preservation of traditional knowledge, as well as the accuracy and reliability of scientific knowledge.

A dialogue between the local ecological knowledge of fishermen from Fernando de Noronha and the scientific knowledge is of great importance, since the information generated by both are complementary, thus being able to support research studies and be a source of information on how to manage and conserve exploited fishing resources, as also reported in other studies (Carr and Heyman, 2016; Martins, 2018; Lima et al., 2021; Kellermann et al., 2021; Zeineddine et al., 2022).

Conclusion

Bait fish are caught by all artisanal fishermen of Fernando de Noronha, which makes the activity extremely important for the development of local fishing.

Artisanal fishermen have a detailed knowledge of the biology and ecology of the fish exploited as bait in the Fernando de Noronha Archipelago, especially regarding food and habitat. However, it is extremely important for the conservation of resources and fishery management to include reproduction aspects in the knowledge of fishermen. Thus, there is a need for detailed studies on the reproductive behavior of these species so that they can be shared between local and scientific knowledge and generate new subsidiary information for the management of this resource.

The results obtained in this research should promote the much-needed dialogue between fishermen and the authorities responsible for managing conservation units in order to create legal and effective mechanisms to meet the demand for bait fish used in commercial fishing, and maintain a sustainable artisanal fishing model for Fernando de Noronha.

Contribution of authors:

ZEINEDDINE, G.: Conceptualization; Investigation; Data curation; Writing — first draft; BARRELA, W.: Conceptualization, Writing — first draft; ROTUNDO, M.: Supervision, Writing — first draft; Formal analysis; RAMIRES, M.: Supervision; Methodology; Writing — first draft.

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