UNIVERSIDADE FEDERAL DO CEARÁ
CENTRO DE CIÊNCIAS AGRÁRIAS
DEPARTAMENTO DE ENGENHARIA DE PESCA
PROGRAMA DE PÓS-GRADUAÇÃO EM ENGENHARIA DE PESCA

PEDRO FLORÊNCIO RIBEIRO

DINÂMICA DA FROTA ARTESANAL E REPRODUÇÃO DE DUAS ESPÉCIES ALVO CAPTURADAS NA RESERVA EXTRATIVISTA MARINHA PRAINHA DO CANTO VERDE, CEARÁ

FORTALEZA
2020

PEDRO FLORÊNCIO RIBEIRO

DINÂMICA DA FROTA ARTESANAL E REPRODUÇÃO DE DUAS ESPÉCIES ALVO CAPTURADAS NA RESERVA EXTRATIVISTA MARINHA PRAINHA DO CANTO VERDE - CEARÁ, BRASIL

Tese apresentada ao Programa de Pós-Graduação em Engenharia de Pesca do Departamento de Engenharia de Pesca da Universidade Federal do Ceará, como requisito parcial para obtenção do título de Doutor em Engenharia de Pesca. Área de concentração: Recursos Pesqueiros e Engenharia de Pesca.

Orientador (a): Caroline Vieira Feitosa, Dra.

Coorientador: José Roberto Feitosa Silva, Dr.

FORTALEZA

2020

Dados Internacionais de Catalogação na Publicação
Universidade Federal do Ceará
Biblioteca Universitária
Gerada automaticamente pelo módulo Catalog, mediante os dados fornecidos pelo(a) autor(a)

R371d Ribeiro, Pedro Florencio.
Dinâmica da frota artesanal e reprodução de duas espécies alvo capturadas na reserva extrativista marinha Prainha do Canto Verde - Ceará, Brasil / Pedro Florencio Ribeiro. – 2020.
64 f. : il. color.

Tese (doutorado) – Universidade Federal do Ceará, Centro de Ciências Agrárias, Programa de Pós-Graduação em Engenharia de Pesca, Fortaleza, 2020.
Orientação: Prof. Dr. Caroline Vieira Feitosa.
Coorientação: Prof. Dr. José Roberto Feitosa Silva.

1. Unidades de conservação. 2. Serra. 3. Guarajuba branca. 4. Manejo. I. Título.

CDD 639.2

PEDRO FLORÊNCIO RIBEIRO

DINÂMICA DA FROTA ARTESANAL E REPRODUÇÃO DE DUAS ESPÉCIES ALVO CAPTURADAS NA RESERVA EXTRATIVISTA MARINHA PRAINHA DO CANTO VERDE - CEARÁ, BRASIL

Tese apresentada ao Programa de Pós-Graduação em Engenharia de Pesca do Departamento de Engenharia de Pesca da Universidade Federal do Ceará, como requisito parcial para obtenção do título de Doutor em Engenharia de Pesca. Área de concentração: Recursos Pesqueiros e Engenharia de Pesca.

Aprovada em: ___/___/_____.

BANCA EXAMINADORA

_____
Prof.a Dra. Caroline Vieira Feitosa (Orientadora)
Universidade Federal do Ceará (UFC)

_____
Prof. Dr. Aldeney Andrade Soares Filho
Universidade Federal do Ceará (UFC)

_____
Prof.a Dra. Alessandra Cristina da Silva Farias
Universidade Federal do Ceará (UFC)

_____
Prof. Dr. Guelson Batista da Silva
Universidade Federal Rural do Semiárido (UFERSA)

_____
Dra. Natália Carla Fernandes de Medeiros Dantas
Instituto Federal do Rio Grande do Norte (IFRN)

AGRADECIMENTOS

O presente trabalho foi realizado com apoio da Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil (CAPES) – Código de Financiamento 001.

A ONG rare, por meio do projeto “Pesca para Sempre”.

Ao Profa. Dra Caroline Vieira Feitosa, pela excelente orientação e ao coorientador Prof. Dr. José Roberto Feitosa Silva.

Aos professores participantes da banca examinadora pelo tempo, pelas valiosas colaborações e sugestões.

Aos familiares, em especial minha mãe Maria da Graça Florêncio Barros, por não medir esforços durante esse tempo para a conclusão do doutorado.

Aos colegas da turma de doutorado, pelas reflexões, críticas e sugestões recebidas.

Aos pescadores da Prainha do Canto Verde, pelo tempo concedido nas entrevistas.

A coordenação do Programa de Pós-Graduação em Engenharia de Pesca em nome da Prof. Dr. Bartolomeu Warlene Silva e Souza.

RESUMO

O objetivo desta tese foi caracterizar a dinâmica da frota artesanal e a biologia reprodutiva das principais espécies alvo: serra (*Scomberomorus brasiliensis*) e guarajuba branca (*Caranx crysos*) capturadas Reserva Extrativista Marinha Prainha do Canto Verde. Durante os desembarques, amostrados de maio de 2016 a abril de 2018, foi aplicado um questionário para registrar informações sobre a atividade pesqueira. Para o estudo da biologia reprodutiva, em cada desembarque, os indivíduos foram identificados, fotografados, pesados (kg) e registradas as medidas morfométricas. Ainda em campo, as gônadas de cada exemplar foram retiradas, identificadas quanto ao sexo, pesadas (g), e retirados fragmentos para análise histológica. Foram acompanhados 382 desembarques em dois pontos de atracagem. Na Reserva, apenas embarcações não motorizadas são permitidas, onde 76,8% foram do tipo botinho e 23,2% bote. A maioria das pescarias é do tipo "viagem de um dia" representando 76,96% das viagens. O número de pescadores por embarcação variou de um a quatro, com maior frequência o número de dois pescadores por embarcação (46,86%), seguido por três pescadores (32,2%). No total, foram utilizados 31 locais de pesca (pesqueiros), onde os recifes artificiais (RA) apresentaram maior frequência de ocorrência, seguidos pelo veleiro naufragado, que funciona como um recife artificial de uso coletivo. Cinco artes de pesca são utilizadas, com destaque para o uso da linha e anzol, com 62,3%, seguida da rede de espera (29,95%). Uma maior captura por unidade de esforço foi registrada para a arte de pesca linha/ anzol com uma mediana de 0,42 (kg/pescador x horas). Na pesca com rede de espera, a mediana foi de 0,08 (kg/m^2 x horas). As maiores produções foram de serra e guarajuba branca. Para um total de 360 serras amostradas, a proporção sexual foi de 1M: 2.42F. O IGS máximo ocorreu entre junho e agosto/2017. O tamanho de primeira maturação (L_{50}) registrado para ambos os sexos foi de 46,8 cm de comprimento total, porém, quando separados foi de 44,7 cm para fêmeas e 47,5 cm para machos. Os indivíduos capturados por linha/anzol apresentaram mediana do comprimento total de 83 cm e 50 cm rede de espera. Para a guarajuba branca foram amostrados 375 exemplares, onde a proporção sexual foi de 1M: 2.86F. O IGS máximo ocorreu entre maio e junho/2017. O L_{50} registrado para ambos os sexos foi de 28,8 cm de comprimento total, quando separados foi de 28,1 cm para fêmeas e 30,7 cm para machos. Os exemplares capturados por linha/anzol apresentaram mediana do comprimento total de 47 cm e 35,5 cm para rede de espera. A época com maior intensidade de desova foi nos meses de maio a agosto, onde o IGS atingiu os valores máximos e maior frequência de indivíduos maduros. São necessárias medidas de manejo para a pesca da serra e guarajuba branca, pois o tamanho médio das capturas está muito próximo do

L_{50} e pode comprometer o recurso no futuro devido à sobrepesca de crescimento. Estas informações são importantes para o desenvolvimento de estratégias de manejo da pesca que garantam a exploração sustentável dos recursos pesqueiros.

Palavras-chave: Unidades de conservação. Serra. Guarajuba branca. Manejo.

ABSTRACT

The objective of this thesis was to characterize the dynamics of the artisanal fleet and the reproductive biology of the main target species: Spanish mackerel (*Scomberomorus brasiliensis*) and Blue runner (*Caranx crysos*) captured Prainha do Canto Verde Marine Extractive Reserve (MER). During landings, sampled from May 2016 to April 2018, a survey was applied to record information on fishing activity. For the study of reproductive biology, in each landing, the specimens were identified, photographed, weighed (kg), and the morphometric measurements were recorded. Still in the field the gonads of each specimen were removed and the sex. They were also weighed (g) and had fragments removed for later histological. A total of 382 landings at two landing points were monitored. Only non-motorized boats are allowed in the Reserve, approximately 77% of the vessels were row-boats and the other 23% were small sailing rafts. Most fisheries are of the "one day trip" type representing ~77% of the trips. The number of fishermen per boat varied from one to four, most often two fishermen per boat (~47%), followed by three fishermen (~32%). In total, 31 fishing sites (fishing grounds) were used, where artificial reefs presented a higher frequency of occurrence, followed by the shipwrecked sailboat, which works as an artificial reef for collective use. Five fishing gears are used, with emphasis on the use of the handline, with ~62%, followed by the gillnet (~30%). The monthly cost of fishing activity varied according to the modality, where the median was R$ 10,00. A higher catch per unit of effort was recorded for the handline gear with a median of 0.42 (kg/fisher*hours). In the gillnet fishery, the median was 0.08 (kg/m^2*hours). The largest productions were reported for Spanish mackerel and blue runner. For a total of 360 Spanish mackerel sampled, the sex ratio was 1M: 2.42F. The maximum GSI occurred between June and August/17. The length at first maturity (L_{50}) recorded for both sexes was 46.8 cm in total length, but when separated it was 44.7 cm for females and 47.5 cm for males. The individuals captured by handline had a median of 83 cm total length and 50 cm gillnet. For the blue runner 375 specimens were analyzed, the sex ratio was 1M: 2.86F. The maximum GSI occurred between May and June/17. The L_{50} recorded for both sexes was 28.8 cm in total length, when separated it was 28.71 cm for females and 30.7 cm for males. The specimens captured per handline had a median of 47 cm total length and 35.5 cm for gillnet. The most intense spawning season was from May to August, when GSI reached its maximum values and the highest frequency of mature individuals. Management measures are needed for the Spanish mackerel and Blue runner fishery as the average catch size is very close to L_{50} and may compromise the resource in the future due to growth overfishing. This information is

important for the development of fisheries management strategies that guarantee the sustainable exploitation of fisheries resources.

Keywords: Conservation units. Spanish mackerel. Blue runner. Management.

SUMÁRIO

1 INTRODUÇÃO

As unidades de conservação cumprem uma série de funções cujos benefícios são usufruídos por grande parte da população e ao mesmo tempo preservam ou conservam ecossistemas e a diversidade biológica. A proteção de áreas aquáticas traz inúmeros benefícios à sociedade. Isso porque funcionam como um instrumento de gestão pesqueira, devendo ser criadas e geridas visando não só a conservação da biodiversidade, mas também a recuperação dos estoques pesqueiros (BRASIL, 2010).

No Brasil, a gestão da pesca por meio de Áreas Marinhas Protegidas (AMPs) ainda está em desenvolvimento, no entanto, várias populações costeiras estão buscando maneiras de proteger seu estilo de vida e cultura, e garantir o uso sustentável dos recursos naturais em Reservas Extrativistas Marinhas (SANTOS; SCHIAVETTI, 2014). As Reservas Extrativistas são compreendidas como áreas protegidas pelo poder público que devem ser usadas por populações que tradicionalmente sobrevivem de atividades relacionadas ao extrativismo (MENDONÇA; MORAES; COSTA, 2013).

A implementação de Unidades de Conservação no Brasil se intensificou a partir dos anos 2000, porém, muitas ainda não conseguiram trazer benefícios consistentes, com problemas na aplicação de medidas regulatórias. Este é o caso de muitas Reservas Extrativistas Marinhas que permitem o uso sustentável dos recursos por residentes das áreas, apresentando conflitos entre a gestão e os pescadores, entre os próprios pescadores que apoiam e os contrários a criação da reserva, muitas vezes causado por falta de mecanismos regulatórios como o plano de manejo. De acordo com um estudo realizado por Santos e Schiavetti (2014) sobre a gestão das Reservas Extrativista Marinhas no Brasil foi mostrado que das vinte existentes, apenas 5% contam com planos de manejo ou em andamento, 5% possuem, mas não foram preparados no local da reserva, em 45% o plano de manejo está em preparação e em 45% não apresentam planos de gestão para a área.

A Reserva Extrativista Marinha Prainha do Canto Verde foi criada em 2009 por meio de um Decreto Federal de 05 de junho de 2009, apresenta uma área de 29,804.99 hectares. Pertence ao distrito de Paripueira, localizado no município de Beberibe, que está situado no litoral leste do estado do Ceará. Esta reserva se insere entre campo de dunas fixas e móveis, lagoas temporárias e planícies alagáveis, apresentando como principais atrativos paisagísticos: praia aberta com mar calmo, dunas, coqueiral, lagoas e como destaque a comunidade que tem na pesca artesanal, feita em jangadas, sua principal fonte de renda (MENDONÇA, 2012).

A pesca na Resex Prainha do Canto Verde é a principal fonte de renda, complementada por agricultura de subsistência, comércio e turismo comunitário. Possui uma relação estreita com o mar, mas o elemento terra também é importante em seu modo de vida, uma vez que é o espaço de realização de trabalhos manuais artesanais como bordados, labirintos e rendas, além de pequenos plantios de subsistência (MENDONÇA; MORAES; COSTA, 2013). Parte da produção pesqueira é consumida na comunidade pelos próprios moradores e turistas ou comercializada na região de Beberibe/Aracati por vários intermediários da própria comunidade ou regiões vizinhas.

As informações sobre a produção pesqueira na reserva são escassas ou subestimadas. Segundo Almeida e Pinheiro (2002) as espécies capturadas pela frota pesqueira da comunidade são lagostas (*Panulirus argus* e *Panulirus laevicauda*), grandes peixes pelágicos como serra (*Scomberomorus brasiliensis*), cavala (*Scomberomorus cavalla*), bonito (*Euthynnus alleteratus*), camurupim (*Megalops atlanticus*), grandes peixes demersais ou de meia água, tais como garoupa (*Epinephelus* spp.), guarajubas (*Carax* spp.), dentão (*Lutjanus jocu*), pargo (*Lutjanus purpureus*), beijupirá (*Rachycentron canadum*) e pequenos peixes pelágicos como sardinha (*Sardinella brasiliensis*), agulha (*Hemiramphus* spp.), palombeta (*Chloroscombrus chrysurus*), que muitas vezes são pescados para servir de isca para peixes maiores.

A fim de estabelecer os procedimentos administrativos para o controle, regulação e ordenamento para o desenvolvimento da atividade pesqueira artesanal nos limites da MER, o órgão gestor ICMBio (Instituto Chico Mendes de Conservação da Biodiversidade) em parceria com o conselho deliberativo elaborou uma resolução (RESOLUÇÃO n. 02 de 31 de março de 2012) listando as modalidades de pesca que são permitidas. Assim, ficaram permitidas as seguintes modalidades de pesca: linha/anzol, covo ou manzuá e cangalha, rede fundeada para peixe, viveiro (armadilha) para peixe, pesca de camarão com rede do tipo rengalho, espinhel, rede caçoeira boieira e rede de agulha. Também ficou definido como pesca artesanal somente aquela realizada com embarcações a vela, sendo proibida a utilização de embarcação motorizada para qualquer atividade pesqueira (BRASIL, 2012).

No entanto, somente esta resolução não tem sido suficiente para reduzir as pressões sobre os recursos pesqueiros da região. Muito embora exista esse acordo de pesca e grande partes dos pescadores concordem com as restrições, é consenso o declínio na abundância de algumas espécies (e.g. Lagosta *Panulirus* spp., Guaiuba *Ocyurus chrysurus*, Ariacó *Lutjanus synagris* e Cavala *Scomberomorus cavala*). Nos limites da Resex é comum a ocorrência de

pesca ilegal, onde embarcações motorizadas de municípios próximos vêm pescar na região (Informação verbal).[1]

Após mais de dez anos de existência, a reserva ainda não possui plano de manejo, é comum na comunidade a ocorrência de conflitos de interesse, seja entre os próprios pescadores, bem como moradores e grileiros. Todas as unidades de conservação devem dispor de um plano de manejo, onde esse plano facilitará o alcance dos objetivos estabelecidos na criação da Unidade de Conservação. Para isso torna se necessário à busca de informações das pescarias por meio de coleta de dados dos desembarques e monitoramento biológico das espécies alvo, para determinar o comprimento médio das espécies capturadas, tamanho de primeira maturação sexual e época de reprodução. Essas informações servirão para embasar a criação do plano de manejo e assim a reserva possa ter efetividade nas medidas de controle, garantindo o desenvolvimento sustentável da atividade.

Dessa forma, o presente estudo objetivou caracterizar a atividade pesqueira na Reserva Extrativista Marinha Prainha do Canto Verde, Beberibe – Ceará além de estimar os parâmetros reprodutivos das espécies: serra (*Scomberomorus brasiliensis*) e guarajuba branca (*Caranx crysos*).

Os resultados da pesquisa são apresentados em três capítulos, escritos sob forma de artigos científicos. O Capítulo 1, intitulado “Caracterização e produtividade da pesca artesanal em uma reserva extrativista marinha no Nordeste do Brasil”, o Capítulo 2 “Biologia reprodutiva da serra *Scomberomorus brasiliensis* (Teleostei: Scombridae): o principal alvo na pesca artesanal de uma reserva extrativista marinha no Nordeste do Brasil” e o Capítulo 3 “Biologia reprodutiva da guarajuba branca *Caranx crysos* (Teleostei: Carangidae): espécie alvo na pesca artesanal em uma reserva extrativista marinha no Nordeste do Brasil”.

[1] Informação fornecida pelo presidente da Associação de moradores da Prainha do Canto Verde, Lindomar Fernandes Lima, em setembro de 2017.

2 CAPÍTULO 1: Characterization and productivity of artisanal fisheries in a marine extractive reserve in Northeast Brazil

Characterization and productivity of artisanal fisheries in a marine extractive reserve in Northeast Brazil

Pedro Florêncio Ribeiro[1] & Caroline Vieira Feitosa[2]

[1]Programa de Pós-graduação em Engenharia de Pesca da Universidade Federal do Ceará, Campus do Pici, Fortaleza – Ceará – Brasil. pedro88phb@hotmail.com.

[2]Instituto de Ciências do Mar da Universidade Federal do Ceará, Fortaleza, CE – Brasil. carol_feitosa@ufc.br.

ABSTRACT

The Prainha do Canto Verde Marine Extractive Reserve is located in the municipality of Beberibe/CE and has a community made up of artisanal fishermen. The objective of the present study was to characterize the fishing activity and productivity in the Marine Extractive Reserve (MER). During the landings we used a questionnaire to record the information regarding the type of vessel, fishing gear, costs, production and marketing price of the target species. A total of 382 landings of non-motorized vessels were monitored at two landing points. Approximately 77% of the vessels were row-boats and the other 23% were small sailing rafts. For the most of the fishing trips the duration is less than one day, composing ~77% of the expeditions. The number of fishermen per boat ranged from one to four, but two fishermen per boat were observed more frequently (~47%) followed by three fishermen (~32%). A total of 31 fishing grounds were identified, with the private artificial reefs (AR) showing the higher frequency of use, followed by a wrecked sailboat, which also works as a natural fishing ground. Five fishing gears are used, with emphasis on the use of the handline, with ~62%, followed by the gillnet (~30%). The monthly cost of the fishing varies according to the fishing gear, of which the median was US$ 1.88. The largest productions were composed by Spanish mackerel and Blue runner. A higher catch per unit effort was recorded for the handline gear with a median of 0.42 (kg/fishermen x hours). In the gillnet fishing, the median was 0.08 (kg/m^2 x hours). The artisanal fishing in the MER is focused on the capture of several species with different fishing gears that usually carry out the “one day trip” fishing trip. The predominant fishing gears are the handline and the gillnet, which have the Spanish mackerel and blue runner as the target species.

Keywords: Conservation unit. Spanish mackerel. Blue runner. Fishing gear.

2.1 Introduction

Artisanal fisheries are an important source of employment, income and food for coastal communities around the world (Fuente; Vázquez & Carvajal, 2016), which may include family or unsalaried labor, once the fishing equipment has limited autonomy (Clauzet; Ramires & Barrella, 2005). In Brazil, artisanal fishing plays an important role in the conservation of biodiversity due to its extractive nature as artisanal fishing needs adequate planning for the balance and maintenance of ecosystems and coastal communities; due to its dependence on fishing for environmental services; and due to the need of management and regulations, which result in more democratic governing mechanisms (Silva, 2014).

The establishment of protected areas or conservation units is one of the main strategies for the conservation of biodiversity (Prates et al., 2007). The relationship between biodiversity conservation and Marine Protected Areas (MPAs) or Conservation Units (CU) is complex due the need of studies regarding compositions of animal and plant species over long periods (Fournier & Panizza, 2003). In Brazil, the Conservation Units are subdivided as sustainable use and integral protection, where the extractive reserve category is inserted as being of sustainable use. The main purpose of the extractive reserves (ER), or "ER", is to foster local development through environmental, socio-economic and political sustainability initiatives. This requires the management of natural resources as regulated by participatory planning, which is shown by the organizational structure of ER and their missions provided by law (Prost, 2007).

The Prainha do Canto Verde Marine Extractive Reserve was created in 2009 by a Federal Decree of June 5, 2009. It is a typical community of coastal artisanal fishermen, which has been the center of several mobilizations that go through the coastal social movements of the state in the last twenty years. It is a reference for community organization, which presents relevant results in its struggles and demands for its citizenship rights (Galdino, 2012). However, the MER still lacks a management plan due to conflicts of interest among the community members. There is a fisheries management agreement, but it is not fully complied by everybody. Therefore, it is necessary to obtain data on landings and fishing production to understand the use of the local fishery resources. Such information will serve as a basis for the management plan to ensure sustainable use of the MER.

The present study aims to characterize the artisanal fishing activities and productivity in the Prainha do Canto Verde Marine Extractive Reserve, Beberibe - Ceará, by analyzing the labor, costs, production and catch composition.

2.2 Material and Methods

2.2.1 Study area

The Prainha do Canto Verde Marine Extractive Reserve is located in the Paripueira district, Beberibe municipality, on the east coast of the state of Ceará. The reserve has an area of 29,804.99 ha (Galdino, 2012; ICMBio, 2019) (Figure 1).

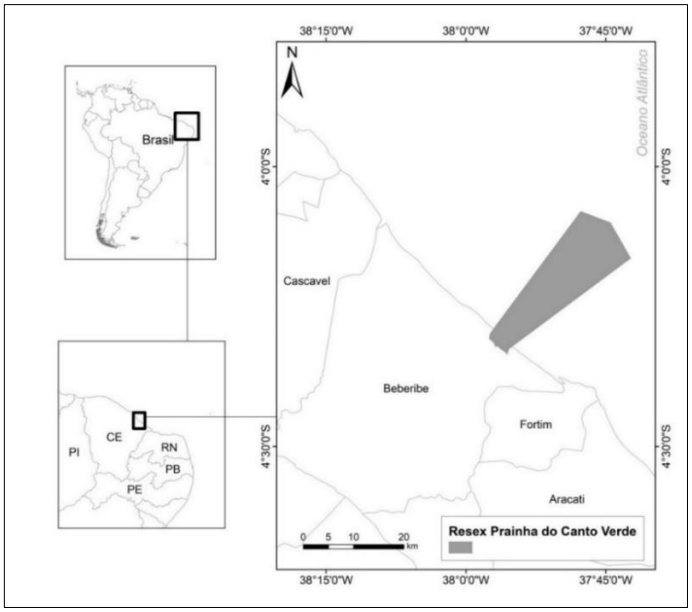


Figure 1. Location of the Prainha do Canto Verde Marine Extractive Reserve, Beberibe municipality, on the east coast of Ceará.

2.2.2 Samples

Landings were monitored monthly from May 2016 to April 2018. Fishing activities were characterized through direct observations and a semi-structured questionnaire, which was submitted to and approved by the Research Ethics Committee of the Federal University of Ceará (CAAE: 79895017.0.0000.5054). The project was registered in the Biodiversity Authorization and Information System (Number: 52552-1 and 52552-2) for data collection as following:

- By direct observation: name of vessel, number of fishermen, location of landing, species caught, and total production per species (kg).

- Interviews with fishermen: fishing area (name of place, depth); duration of fishing trip; fishing gear used and its characteristics (length and width of the net, mesh size, type and number of hooks); expenses (food, ice and maintenance of the vessel), and marketing price of the species.

Sampling efforts were concentrated on the following target species in the MER fisheries: lane snapper (*Lutjanus synagris* Linnaeus, 1758); king mackerel (*Scomberomorus cavalla* Cuvier, 1829); mutton snapper (*Lutjanus analis* Cuvier, 1828); yellowtail snapper

(*Ocyurus chrysurus* Bloch, 1791); blue runner (*Caranx crysos* Mitchill, 1815); horse-eye jack (*Caranx latus* Agassiz, 1831); yellow jack (*Caranx bartholomaei* Cuvier, 1833); sea bass (*Centropomus* spp.) and spanish mackerel (*Scomberomorus brasiliensis* Collette, Russo & Zavala-Camin, 1978). Red lobster (*Panurilus argus* Latreille, 1804) and green lobster (*Panulirus laevicauda* Latreille, 1817) were observed as well.

By-catch was sampled and identified *in situ* at the species level. Technicians participated in the sampling and were previously trained in the laboratory to follow identification keys and guides of Carvalho-Filho (1999) and Humann & Deloach (2002). The species were listed in evolutionary order as proposed by Nelson (2006).

2.2.3 Fishing productivity

For the estimates of the Catch per Unit of Effort (CPUE - $kg/m^2.hr$) we considered the production (kg), net length (m^2) and duration of the fishing expedition (number of settings) when using the gillnet, popularly known as *caçoeira*. For the handline fishing (kg/fisher.hr) we considered the production (kg), number of fishermen per sailing raft (popularly known as *jangada*), and duration of the fishing trip.

The values of the per kilogram of target species were converted into US dollars (US$1.00 = R$5.32) according to the average exchange rate during the present study. Values will be presented in both US$ and R$ when necessary for comparisons with previous studies.

2.2.4 Data analysis

The data monthly production values (kg), production per gear and were tested for normality and homoscedasticity using the Shapiro-Wilk (1965) and Levene (1960) tests. Then were compared with Kruskal-Wallis test (Zar, 1984) and significance was analyzed by the Mann-Whitney post-hoc test (1947). was. The statistical software used for all analyses was PAST® (Hammer; Harper & Ryan, 2001) and the level of significance considered was 5%.

2.3 Results

A total of 382 fish landings were monitored at two of the three landing points: (1) "Prainha" and (2) "Caucaia". The other point is called "Morro do Chapéu" and is practically used by fishermen who do not agree with the MER rules and therefore, did not allow the monitoring of their fisheries.

2.3.1 Vessels and description of the fisheries

The non-motorized vessels are classified by length (m) according the Z-11 fishing colony of Beberibe, CE as being a large sailing raft (> 6.0 m), small sailing raft (5.0 - 5.99 m) and row-boat (3.30 - 4.99 m). Of the sampled vessels, 76.8% were rowing boats and 23.2% were small sailing rafts.

The number of fishermen per boat varied from one to four, with a higher frequency of two fishermen (46.86%), followed by three fishermen (32.20%), and 19.37% with a single fisher. Generally, in "one day " fisheries, i.e. fishing expeditions with a duration of one day, one to two fishermen were observed per boat.

The duration of the fishing ranged from one to five days with the highest occurrence of single day fishing expeditions (76.96%) followed by two days with 14.40%. Longer trips of three and four days were less frequent during the sampling period, corresponding with 2.62 and 5.76%, respectively.

A total of 31 fishing grounds were recorded, with the most frequent areas being artificial reefs (AR - known by fishermen as "marambaias") at 17.11%, followed by a wrecked sailboat and the logs (Figure 2).

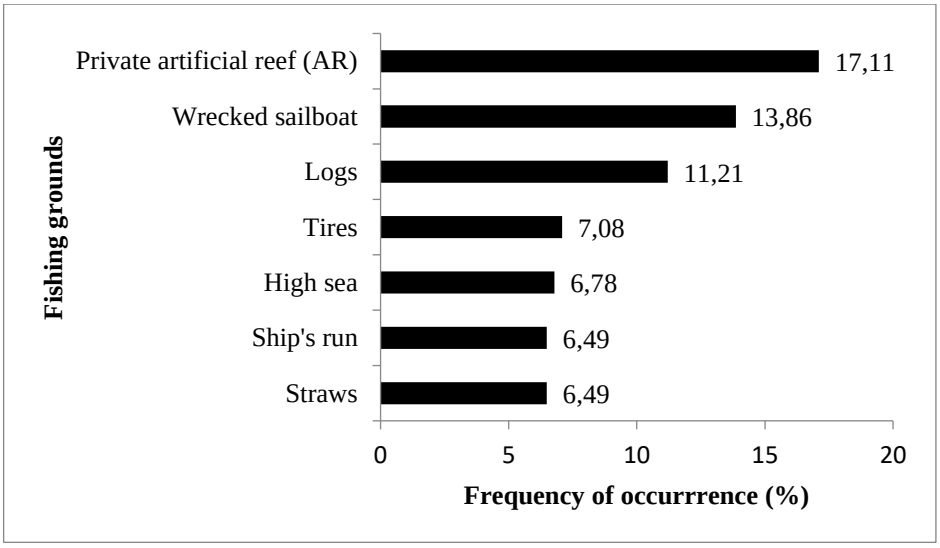


Figure 2. Fishing grounds used more than 5 % in the Prainha do Canto Verde MER artisanal fishing from May 2016 to April 2018.

Of the seven fishing spots with a frequency above 5%, four were artificial, one was natural, a fishing ground marked with GPS by fishermen and another that is outside the MER limits. Artificial reefs are of private use, of which only the owners know the locations. The wrecked sailboat (accidentally) works as a fishing ground with open access, and the logs that are composed of tree stumps and branches are open access as well, whereas wooden structures

known as “garajaus” are of private use. The latter is built with native wood and is noted as an alternative for the standard artificial reefs used in the reserve (Figure 3).

Figure 3. “Garajau” type structure used as an artificial reef in the Prainha do Canto Verde Marine Extractivist Reserve, Beberibe, CE.

The depths recorded for the main fishing spots were as follows: 13.56±2.37 m for artificial reefs, 14.80±1.40 m for the wrecked ship, 14.34±1.65 m for the logs and 15.69±1.29 m for the tires, all of which were closest to the shore. Fisheries activities carried out on the high seas were at an average depth 31.98±7.90 meters.

2.3.2 Characterization of fishing gear and techniques

Five types of fishing equipment were observed, with the highest frequency for the handline fishing with 62.30%, from which four are intended for catching fish and one for lobsters (Table 1). (Figure 4).

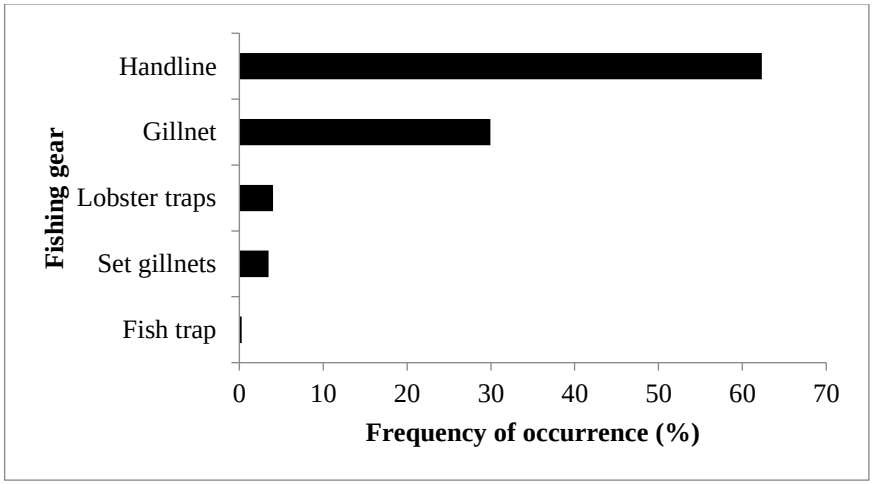


Figure 4. Frequency of occurrence of fishing gear used in the artisanal fisheries of the Prainha do Canto Verde Marine Extractive Reserve, Beberibe, CE.

Of these, four are intended for catching fish and one for lobsters (Table 1).

Table 1. Description and methods of fishing gear used in the artisanal fisheries of the Prainha do Canto Verde Marine Extractive Reserve, Beberibe, CE.

Fishing gear	Description	Operation method
Handline	The length of line released per fisher was 38.42±12.21 m, of which each one usually uses two lines with three hooks on each. Thirteen types of hooks were registered, with greater frequency of occurrence those of numbers 6 and 14. The numbers 3, 4, 5, 9, 11, 13 15, 20 were also used.	The average operating depth was 17.37 ± 8.20 m, ranging from 9.0 to 49.0 meters, the latter in fisheries more distant from the coast (high seas).
Gillnet	The average length of the nets was 76.22±17.75m and the height was 1.98±0.20 m. Each vessel used on average 25 nets with the same length and height measurements. The mesh of the nets varied between 7, 8, 9, 10, 13 and 14 cm. The most frequently used net was the 9 cm mesh (76.52%), followed by the 8 cm mesh with 12.12%.	The operating depth was 16.73 ± 5.29 m. The number of settings per fishing trip varied from one to two for each day at sea. Each setting can be made every 12 hours and the net is submerged for three to four hours. The process of setting the net lasts up to two hours, while the hauling and storage of the production lasts another two hours.
Set gillnets	The set gillnets locally named as "rengalho", differs from the traditional gillnet due to the purpose of the fishing, fishing ground, and species of interest. The average length of the net was 68.99±22.16 m and the height was 1.5±0.23 m. An average of 13 nets with the same length and height (m) were used. The meshes used were 7, 8, 9 and 12 cm.	This fishing is practiced near the coast with operating depths of 8.26±3.29 m. The number of settings varies from one to two, lasting three hours. Fishermen usually moore their nets close to shore in the late afternoon. Then, the nets are removed in the early morning of the following day.
Fish traps	This structure is used as a trap for catching fish. It is made with a wooden frame and covered with wire mesh (5 cm) with a length of 2.0 m and height of 1.2 m.	Operating depths of 12.74±0.0 m. The traps are submerged for up to 48 hours. Inside the trap there is a plate that serves as bait by reflecting light to attract the shoals of fish.
Lobster traps	These traps are only used from June to November. The average number of "traps" used per sailing raft was 15.00±3.46.	Operating depths of 12.26±3.21 m. Fishermen set the traps with bait (e.g. fish heads) on gravel beds. After 48 hours, the traps are collected to observe for the presence of lobsters.

2.3.3 Production and catch composition

The highest monthly fish yields were found in the months of December and April of year 1(2016-2017) ($H = 36.98$, $p = 0.0001162$) (Figure 5A). In year 2 (2017-2018), the highest production was from January to March ($H = 82.85$, $p = 4.133E^{-13}$) (Figure 5B).

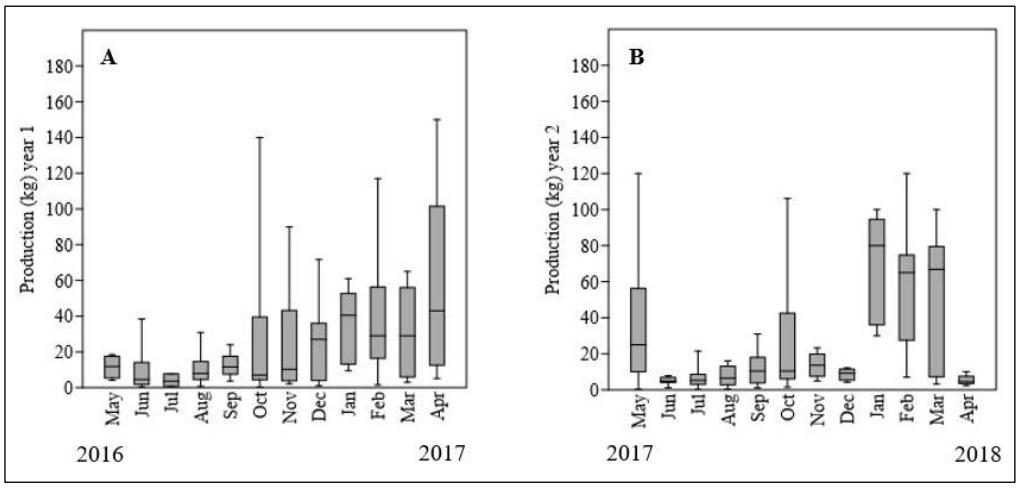


Figure 5. Monthly production (kg) of fish caught of the artisanal fishing practiced in the Prainha do Canto Verde Marine Extractive Reserve, Beberibe, CE from May 2016 to April 2018 (A: year 1; B: year 2).

The fishing gear with the highest production averages were the gillnet and handline for both year 1 ($H = 36.7$, $p = 10.082E^{-08}$) and year 2 ($H = 44.3$, $p = 1.983E^{-11}$) (Figure 6).

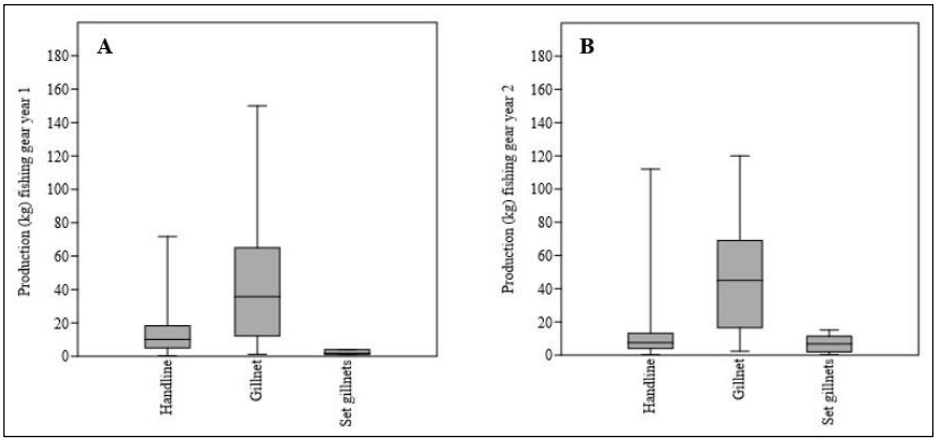


Figure 6. Monthly production (kg) per fishing gear of the artisanal fishing practiced in the Prainha do Canto Verde Marine Extractive Reserve, Beberibe, CE from May 2016 to April 2018 (7A: year 1; 7B: year 2).

The target species with the highest yields were blue runner (*Caranx crysos*) with 3423.50 kg and spanish mackerel (*Scomberomorus brasiliensis*) with 2685.60 kg (Figure 8). Only 21.30 kg were recorded for the lobsters throughout the sampling period.

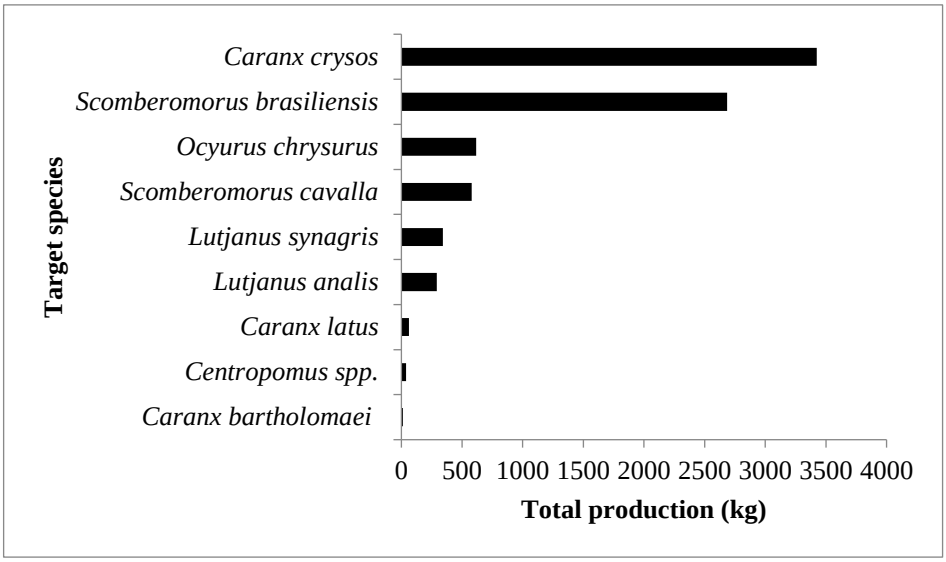


Figure 7. Total production (kg) per species of fish in the artisanal fishing practiced in the Prainha do Canto Verde Marine Extractive Reserve, Beberibe, CE from May 2016 to April 2018.

A total of 46 species of fish belonging to 25 families were recorded. Of these, 37 were considered as by-catch when fishing for the target species (Table 2). Some of the by-catch species presented some commercial value and others were consumed by the fishermen.

Table 2. List, in evolutionary order (Nelson, 2006), of fish species considered as bycatch in the artisanal fishing of the Prainha do Canto Verde Marine Extractive Reserve, Beberibe, CE, with their Family and common names.

Family	Specie	Common name	English name	Environment	Eating habit	Fishing gear
Carcharhinidae	*Carcharhinus limbatus* (Muller & Henle, 1839).	Tubarão grossim	Blacktip shark	Reef-associated	Carnivore	Handline
	Rhizoprionodon lalandii (Muller & Henle, 1839).	Tubarão rabo seco	Brazilian sharpnose shark	Demersal	Carnivore	Handline
	Rhizoprionodon porosus (Poey, 1861)	Cação	Caribbean sharpnose shark	Reef-associated	Carnivore	Handline
Dasyatidae	*Hypanus* spp.	Raia	Stingray	Demersal	Carnivore	Handline
Megalopidae	*Megalops atlanticus* (Valenciennes, 1847)	Camurupim*	Tarpon	Pelagic	Carnivore	Handline
Albulidae	*Albula vulpes* (Linnaeus, 1758)	Ubarana	Bonefish	Reef-associated	Carnivore	Handline; Gillnet
Muraenidae	*Muraena pavonina* (Richardson, 1845).	Moréia pintada	Whitespot moray	Demersal	Carnivore	Handline
Clupeidae	*Opisthonema oglinum* (Lesueur, 1818).	Sardinha	Atlantic thread herring	Pelagic	Planktivore	Handline
Ariidae	*Cathrops spixii* (Agassiz, 1829).	Bagre branco*	Madamango sea catfish	Demersal	Carnivore	Handline; Gillnet; Set gillnets
	Genidens genides (Cuvier, 1829).	Bagre amarelo*	Guri sea catfish	Demersal	Carnivore	Handline; Gillnet
Belonidae	*Strongylura marina* (Walbaum, 1792).	Agulha	Atlantic needlefish	Reef-associated	Carnivore	Handline
Holocentridae	*Holocentrus adscensionis* (Osbeck, 1765).	Mariquita	Squirrelfish	Reef-associated	Carnivore	Gillnet
	Myripristis jacobus (Cuvier, 1829)	Olho de boi	Blackbar soldierfish	Reef-associated	Planktivore	Gillnet; Set gillnets
Epinephelidae	*Cephalopholis fulva* (Linnaeus, 1758).	Piraúna	Coney	Reef-associated	Carnivore	Gillnet
Epinephelidae	*Epinephelus* spp.	Garoupa*	Grouper	Demersal	Carnivore	Handline

Table 2. Continued...

Family	Specie	Common name	English name	Environment	Eating habit	Fishing gear
Malacanthidae	*Malacanthus plumieri* (Bloch, 1786).	Pirá	Sand tilefish	Benthic	Carnivore	Handline
Rachycentridae	*Rachycentron canadum* (Linnaeus, 1766).	Beijupirá*	Cobia	Benthic/ pelagic	Carnivore	Handline
Coryphaenidae	*Coryphaena hippurus* (Linnaeus, 1758).	Dourado*	Common dolphinfish	Pelagic	Carnivore	Handline
Carangidae	*Caranx lugubris* (Poey, 1860).	Xaréu*	Black jack	Pelagic	Carnivore	Handline
	Chloroscombrus chrysurus (Linnaeus, 1766).	Palombeta	Atlantic bumper	Pelagic	Omnivorous	Handline; Gillnet; Set gillnets
	Oligoplites saliens (Bloch, 1793).	Tibiru	Castin leatherjacket	Pelagic	Omnivorous	Handline
	Selar crumenophthalmus (Bloch, 1793).	Olhona	Bigeye scad	Reef-associated	Omnivorous	Handline
	Selene vomer (Linnaeus, 1758).	Galo*	Lookdown	Pelagic	Carnivore	Gillnet; Set gillnets
	Seriola rivoliana (Valenciennes, 1833).	Arabaiana	Longfin yellowtail	Reef-associated	Carnivore	Gillnet
Lutjanidae	*Lutjanus jocu* (Bloch & Schneider, 1801).	Dentão*	Dog snapper	Reef-associated	Carnivore	Handline; Gillnet
Haemulidae	*Haemulon melanurum* (Linnaeus, 1758).	Sapuruna	Cottonwick grunt	Reef-associated	Carnivore	Handline
	Haemulon parra (Desmarest, 1823).	Cambuba	Sailor's grunt	Reef-associated	Carnivore	Handline
	Haemulon plumieri (Lacépede, 1801).	Biquara	White grunt	Reef-associated	Carnivore	Handline; Gillnet
	Haemulon steindachneri (Jordan & Gilbert, 1882)	Macasso	Chere-chere grunt	Reef-associated	Carnivore	Handline;
Sparidae	*Calamus pennatula* (Guichenot, 1868).	Pena	Pluma porgy	Reef-associated	Carnivore	Gillnet
Pomacanthidae	*Pomacanthus paru* (Bloch, 1787).	Paru	French angelfish	Reef-associated	Omnivorous	Gillnet
Labridae	*Halichoeres brasiliensis* (Bloch, 1791).	Budião	Brazilian wrasse	Reef-associated	Carnivore	Gillnet

Table 2. Continued...

Family	Specie	Common name	English name	Environment	Eating habit	Fishing gear
Ephippidae	*Chaetodipterus faber* (Broussonet, 1782).	Paru branco*	Atlantic spadefish	Reef-associated	Omnivorous	Trap
Sphyraenidae	*Sphyraena spp.*	Zambaia	Great barracuda	Pelagic	Carnivore	Handline
Scombridae	*Euthynnus alleteratus* (Rafinesque, 1810).	Bonito*	Little tunny	Pelagic	Carnivore	Handline; Gillnet
Balistidae	*Balistes vetula* (Linnaeus, 1758).	Cangulo	Queen triggerfish	Reef-associated	Carnivore	Handline
Ostraciidae	*Lactophrys trigonus* (Linnaeus, 1758).	Peixe cofre	Buffalo trunkfish	Reef-associated	Omnivorous	Handline

* Species that are traded among fishermen.

The catch per unit effort recorded for the handline gear obtained a median of 0.42 kg/fishermen.hours. In the gillnet fishing, the catch per unit effort median was 0.08 kg/m^2.hours (Figure 8).

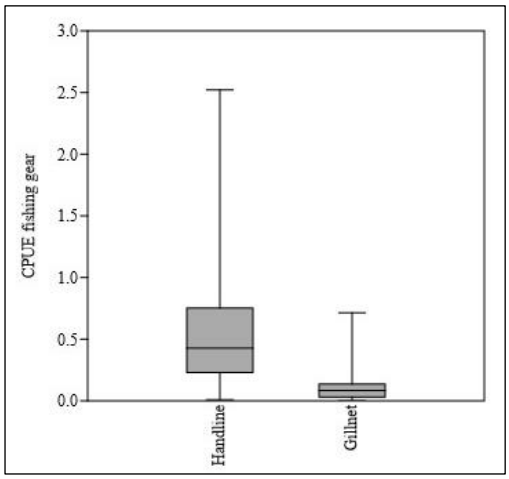


Figure 8. Catch per unit effort (CPUE) by fishing gear of the artisanal fishing practiced in the Prainha do Canto Verde Marine Extractive Reserve, Beberibe, CE from May 2016 to April 2018.

2.3.5 Marketing

Among the target fish species, king mackerel had the highest commercial value, with a median of US$ 3 per kilogram (Figure 9). This species is usually caught with handline fishing, of which individuals showed a weight of over 1kg. An important factor in determining the price of the kg of a species is whether the specimen weighs more or less than 1 kg.

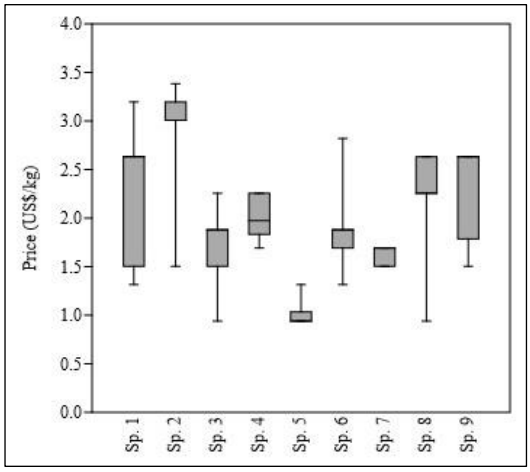


Figure 9. Variation in the marketing price of the target species caught by the artisanal fishing in the Prainha do Canto Verde Marine Extractive Reserve, Beberibe, CE, from May 2016 to April 2018 (Sp. 1: *Scomberomorus brasiliensis*; 2: *Scomberomorus cavala*; 3: *Caranx crysos*; 4: *Caranx bartholomaei*; 5: *Caranx latus*; 6: *Lutjanus synagris*; 7: *Ocyurus chrysurus*; 8: *Lutjanus analis*; 9: *Centropomus* sp.).

2.4. Discussion

2.4.1 Vessels and description of the fisheries

The main economic activity of the MER is artisanal fishing, which is the main source of income for families of the local community. The management agency ICMBio (Instituto Chico Mendes de Conservação da Biodiversidade) in partnership with the deliberative council of the MER prepared a resolution (RESOLUTION n.02 of March 31, 2012) that establishes the administrative procedures for the regulation and planning of artisanal fishing activity within the limits of the reserve. This resolution lists the fishing methods that are permitted and defines artisanal fishing as being only carried out with sailing vessels, whereas motorized vessels are prohibited for any fishing activity (Brazil, 2012). It also has the fishing techniques allowed in the area belonging to MER.

The small sailing raft showed the highest frequency of use in the present study. These boats are built of wood and have flat hulls and a small space for packing the fishing materials and are mobilized with sails. Since the origin of the community in the 1860s, its inhabitants have been fishing in "sail rafts" as the main activity of the local economy (Mendonça, 2012). The small sailing rafts differs from the row-boat by size and availability of space for use such as storing material, containing the catch, and accommodation for the fishermen. Only 10% of fishing fleets in marine waters in Brazil uses medium and large vessels, which constitute the industrial fishing fleets. The majority of fleets is considered as artisanal, composed of small boats such as rafts, canoes, and small sailing rafts. Artisanal fishing generally has a small radius of activity and limited autonomy (Brazil, 2006).

Fewer fishermen and more trips during the week were shown for the "one day trip" fishing with the use of the rowing boats. This is a common feature in fishing communities, where fishermen depend on fishing resources for the livelihood of their families. Therefore, most fishermen are carrying out the activity as many days as possible (Paudel et al., 2016). The number of fishermen was shown to increase according to the type of vessel and fishing gear, which influence the hours of work and number of days in the activity. For example, the small sailing raft has greater autonomy and is used for longer fishing trips and allows more fishermen.

The most frequent fishing grounds are those closest to the coast and at shallower depths that are adequate for the fishing gear, which facilitates the "come and go" trips. It is noteworthy that the choice of fishing location depends on the target fishery resource. The wide variety of fishing grounds used in MER is due to the knowledge that fishermen have regarding the

environment and dynamics of the target resources (Pinheiro & Joyeux, 2007; Ramires et al., 2012).

Each fisher anchors the private artificial reefs (AR) material and maintains the location for their own use, and usually shares the location with only family members. Artificial marine reefs are systems that stimulate natural production and attract several species of fish by providing shelter and food, creating extra habitats that may promote greater fish populations and more productive regions for fishing (Mariano & Rosa, 2010; Lima et al., 2018). In Prainha do Canto Verde, the use of artificial reefs was intended to produce natural food for target species that are mostly the coastal pelagics, such as spanish mackerel (*Scomberomorus brasiliensis*), king mackerel (*Scomberomorus cavalla*) and blue runner (*Caranx crysos*), with only few species caught directly in the artificial reefs.

According to surveys of the fishermen, the following materials have been used to create artificial reefs: car scraps, household appliances (e.g. stoves, refrigerators), and tires. It is known that some decades ago, fishermen of coastal communities of Ceará dropped bales of tree branches in the ocean to stimulate the aggregation of schools of fish by creating refuge and attracting natural food (Conceição & Nascimento, 2009).

In recent years, the fishermen association of the Prainha do Canto Verde Extractive Reserve has encouraged the use of “garajaus”, a kind of artificial reef built with wood from local vegetation and anchored with bricks and concrete. These structures are intended to reduce negative impacts on the marine environment. Brazilian legislation regulates the licensing and installation of artificial reefs in territorial waters and exclusive economic zones of the country through a Normative Ruling n.22 of July 10, 2009 (IBAMA, 2009). However, these artificial reefs can only be used for diving and research.

2.4.2 Fishing gear and techniques

A variety of fishing gear with defined periods of use was observed, which is common in artisanal fishing as the effectiveness of catching equipment varies for different species (González-Álvarez et al., 2016). For example, a particular fish may be more prevalent during a specific time of year. These factors are determinant for the choice of the gear, which still depends on the species to be captured, as well as the sites where they can be found (Begossi et al., 2012).

Handline fishing practically occurs throughout the entire year, which is also common in fishing communities. This fishing gear provides a greater possibility of catching large species

with a high commercial value and is inexpensive (Nóbrega & Lessa, 2007). The diversity of hooks is related to the target species: the hooks of numbers 5 and 6 are intended for fishing larger fish such as spanish mackerel (*Scomberomorus brasiliensis*) and king mackerel (*S. cavalla*), hooks 10 and 11 are for the capture of lane snapper (*Lutjanus synagris*), and the hooks number 14 and 20 are for smaller fish that will generally serve as bait.

Vessels with greater storage capacity are used for gillnet fishing, as extra space allows for storing food for consumption during the trip, ice for preserving the fish, and equipment used for the maintenance. Hence, larger vessels enable longer trips with the greatest number of fishermen. The fishing effort with gillnets is higher, once the nets are extensive and spend more time in the water. In a survey conducted in the municipality of Fortaleza (CE), the average number of nets used for fishing was 64 and varied from 12 to 81 per boat (Carneiro & Salles, 2011). The nets are linked together at their extremities to form a long line and are able to capture between 100 and 800kg, of which the catch shows a high diversity of fish when compared to other fishing gear (Pinto, 2016). Regarding Prainha do Canto Verde, the productions were lower when compared to other landing points on the coast of Ceará state, despite the high fishing effort.

The set gillnet fishing has the same operating characteristics as the traditional gillnets fishing, being used by smaller vessels operating near the coast. The trap fishing to catch fish was first registered in August 2017. Trap fishing has also been used by fishermen from Icapuí (CE) and Areia Branca (RN) (C. V. Feitosa, pers. com.), which are located near the reserve of the present study. The traps have a wooden frame and the covering can be of galvanized wire, shredded polyethylene cable or monofilament polyamide line (Feitosa, 2019). The use of traps has been observed around the world and throughout Brazil and has become common among artisanal fishermen on the northeast Brazilian coast (Sanches & Sebastiani, 2009). In MER, fishermen use bottom traps for capturing lobsters. This fishing gear is the most commonly used for the capture of lobsters and are often used by fishermen on small sailing rafts (Cunha; Silva & Fonteles-Filho, 2014).

2.4.3 Production and catch composition

With regard to the catch production and composition, a greater number of vessels were observed to use gillnets and spend more days at sea for higher production. Captures during the present study mainly consisted of blue runner (*C. crysos*) and the spanish mackerel (*S. brasiliensis*), of which the first is easily captured with the fishing gear due to forming shoals and the latter was prevalent due to the time of year. The months with higher productions when

using the gillnets were during the rainy period. According to the Ceará Meteorology and Water Resources Foundation, the rainy season on the Ceará coast occurs from December to June and more intense rainfall is from February to May. The rest of the year is considered as the dry season with little or no rain (FUNCEME, 2009), which influences the choice of fishing gear (Pinto, 2016). Artisanal fishermen carry out activities according to natural cycles, which determine the periods of abundance for certain fishing resources (Diegues, 2004).

The target species with the highest productions (*C. crysos*, and *S. brasiliensis*) in the present study are among the most important fishing resources for artisanal fisheries in northeastern Brazil (Lessa et al., 2009). The blue runner (*C. crysos*) and other species belonging to the Carangidae family are among the main fishing resources traded in Brazil (Duarte et al., 2017). The spanish mackerel (*S. brasiliensis*) is one of the species with the highest production in landings in the state of Ceará (Gonçalves et al., 2014).

Although legalized, fishermen know that lobster trap is an unproductive fishing gear. Yet, they stated that catches of red lobster *Panurilus argus* and green lobster *Panulirus laevicauda* in the MER have declined in recent years. This was also indicated by the means of production and frequency of using lobster traps during the sampling period. The fishing effort for lobsters was considerably lower when compared to that for fish species. Aragão and Cintra (2018) analyzed the yield of lobster fisheries on the Brazilian coast and observed that catch productions oscillated over the years, but generally show a decreasing trend.

Generally, artisanal fisheries are characterized by high species richness and low specific biomass (Rangely et al., 2010). In the present study, a high species diversity was observed but with a higher occurrence and production of target species. Similar results were found throughout the Northeast region of Brazil, where high species richness was observed from the catches obtained from artisanal fishing fleets.

The fishing effort practiced in the Prainha do Canto Verde extractive reserve is of low intensity but with high frequency. The catch per unit effort (CPUE) is an important indicator of relative abundance. Therefore, it is an effective tool in monitoring plans and is commonly used in fisheries studies to understand the dynamics and nuances of fisheries and consequently, elaborate management alternatives (Hoggarth et al., 2006). A higher CPUE value was recorded for handline fishing in the present study as related to the fishing effort applied. In gillnet fishing, fishermen spent more days at sea (three to four days) and uses several fishing nets of the same size and height. Consequently, there was a decrease in CPUE values when compared to handline

fishing. In the handline fishing, the effort applied is lower since the fishermen spend fewer days at sea, the fisheries are of the come and go type, and operate with fewer fishermen.

In the first year of sampling, the CPUE values were higher, as well as for the handline gear that showed the highest production over the two years analyzed in the present study. Nevertheless, variation in the CPUE occurred since fishing in the MER involves several species and different fishing gears. A decrease in CPUE values over time can be an indicator that stocks are declining. However, other factors should be considered such as the fishing effort employed, fishing gear, changes in fishing areas, environmental conditions and skills of the crew in fishing operations (Morgan & Burgess, 2005).

2.4.4 Trading

The Spanish mackerel (*S. brasiliensis*) and blue runner (*C. crysos*) showed the highest productions and differed in selling prices. The price of the fish caught is classified according to the trade relations determined between fishermen and buyers. Individuals caught with handline and that weigh more than one kilogram have higher commercial values, while fish caught with gillnets and that weigh less than one kilogram have lower prices. Nevertheless, the selling price is most influenced by the specimen having a weight of over 1kg, regardless of the fishing gear. The valuing of the species with the highest weight was established by the intermediaries, which is a practice that has been observed in other coastal communities and may consider other factors in the selling price such as the color of the meat, size and taste (Burda, 2007).

At the landing site, the production is separated and destined for direct sale, intermediaries, or is consumed by the fishermen without the minimum care required to conserve it (Silva, 2010). After sorting, the product is delivered to traditional buyers, which comprise a network that facilitates sales between artisanal fisher (producer) and the final consumer. The only processing observed was evisceration, which occurred on vessels or even on sand at the time of landing. Removal of the scales can compromise the quality of the fish from contamination of microorganisms present in the sand and manipulators. Fish meat can deteriorate quickly and require adequate sanitary conditions, from capture to marketing (Teixeira & Garcia, 2014). For example, autolysis occurs and makes the surface of the fish susceptible to bacteria, and the release of sugars, amino acids, fatty acids, and other compounds promotes bacterial growth (Vieira, 2004).

The intermediary is the main destination for selling the fish and is usually the owner of the fishery within or near the community. Each fisher has a partnership established with the

intermediary for marketing the production. This relationship is traditionally characterized as clientelistic, once the intermediary often provides the necessary inputs for the activity in the lack of resources and the unpredictability of income of artisanal fishermen. Thus, the intermediary is responsible for setting the price of the production (Pasquotto, 2005).

Differences in fishing performance may depend on the effects of the particular fishing characteristics of each locality, such as target species, fishing gear and fishing location. The information obtained in the present study may facilitate the elaboration of a management plan for the MER. As a conservation unit intended for sustainable use, its objective is to protect traditional communities, their livelihoods, the fishing resources and biodiversity (Moura et al., 2009).

2.5. Conclusion

The artisanal fishing in the Prainha do Canto Verde MER is directed to the capture of several species by means of different fishing gear and sailing vessels that mostly carry out the "come and go" fishing. The predominant fishing gear are handline and gillnet which has the blue runner (*Caranx crysos*) and the spanish mackerel (*Scomberomorus brasiliensis*) as the target species. Marine extractive reserves are conservation units for sustainable use and are protected territorial spaces. The consolidation of the areas occurs through the creation and implementation of its management plan, in which all rules for occupation, use, and maintenance of the area must be established. The information in this research is of great importance for the elaboration of the plan, once the management instruments must be developed with the close participation and permanent interaction of all interested parties, resident in the area and control bodies.

3 CAPÍTULO 2: Reproductive biology of *Scomberomorus brasiliensis* (Teleostei: Scombridae): the main target species of artisanal fisheries in a marine extractive reserve in Northeast Brazil

Reproductive biology of *Scomberomorus brasiliensis* (Teleostei: Scombridae): the main target species of artisanal fisheries in a marine extractive reserve in Northeast Brazil

Pedro Florêncio Ribeiro[1]; José Roberto Feitosa Silva[2] & Caroline Vieira Feitosa[3]

[1]Programa de Pós-graduação em Engenharia de Pesca da Universidade Federal do Ceará, Campus do Pici, Fortaleza – Ceará – Brasil. pedro88phb@hotmail.com.

[2]Departamento de Biologia, Laboratório de Histologia Animal da Universidade Federal do Ceará, Campus do Pici, Fortaleza – Ceará – Brasil. jrobertofeitosa@gmail.com.

[3]Instituto de Ciências do Mar da Universidade Federal do Ceará, Fortaleza, CE – Brasil. Carol_feitosa@ufc.br.

ABSTRACT

The Spanish mackerel (*Scomberomorus brasiliensis*) is one of the most important resources in artisanal fisheries in Northeastern Brazil. This study describes the reproductive biology of the spanish mackerel caught in the artisanal fishery of the Prainha do Canto Verde Marine Extractive Reserve, Beberibe, State of Ceará. Monthly samplings were conducted over one year. At each landing, for each fishing gear, individuals were identified, photographed, weighed (kg) and the morphometric measurements were recorded. Still in the field, the gonads of each individual were taken, identified by sex by their color ans hape, weighed (g), and fragments were taken for later histological analysis and confirmation of the stage of sexual maturity. For a total of 360 spanish mackerel sampled, the sex ratio was 1M: 2.42F. The maximum GSI occurred between June and August/17. The first maturity size (L_{50}) for both sexes was 46.8 cm total length (TL), for females, 44.7 cm and for males, 47.5 cm. The individuals caught by handline and gillnet had a median total length of 83 and 50 cm, respectively. Management measures for spanish mackerel fishing are required, as the mean catch size is very close to L_{50} and may compromise the resource in the future by growth overfishing.

Keywords: Reproduction. Gonadal Maturation. Fisheries Management.

3.1 Introduction

Reproduction is an important factor for species maintenance, once recruitment will depend on reproductive success and will be responsible for maintaining populations, which in turn are determinants for environmental stability (Araújo; Araújo & Chellapa, 2012). Knowledge of the reproductive biology is crucial, especially in developing countries such as Brazil, where managers use the first sexual maturity size (L_{50}), as well as the onset and duration

of the spawning season for the implementation of management measures (Dias Neto, 2010; Santos & Freire, 2015).

A key consideration for the sustainability and management of any fishery is the degree of population resistance to exploitation (Pitman; Haddy & Kloser, 2013). The ability of a population to remain sustainable or recover from exploitation can be explained by fishery-induced phenotypic changes in life cycle traits (Rideout & Morgan, 2007).

The Spanish mackerel, *Scomberomorus brasiliensis* (Collette, Russo & Zavala-Camin, 1978), is one of the most important fishing resources for artisanal fisheries in the Northeast region of Brazil (Nóbrega & Lessa, 2007). In the State of Ceará it is one of the species with the largest landings (Gonçalves et al., 2014). It occurs along the Atlantic coast of Central America, the Caribbean, and South America, from Belize to the State of Rio Grande do Sul in southern Brazil. It is distributed in the Northeast Exclusive Economic Zone (EEZ) from the mouth of the Parnaíba River, State of Piauí to the State of Bahia. The species can occur in areas up to 100 meters deep, however, the highest catch frequency is between 10 and 50 meters. It is believed that the largest abundances are in Ceará, as this is where the most significant landings are recorded (Nóbrega et al., 2004). It is a common species in coastal waters in the epipelagic zone. It forms shoals and can also occur in estuarine zones (Collete & Nauen, 1983; Silva; Castro & Gubiani, 2005; Silva et al., 2009). It is ovuliparous with external fertilization and embryonic development, and its eggs are pelagic.

This species has a considerable importance for artisanal fishing due to its commercial value and has been routinely caught on the Brazilian northeast coast (Chellappa et al., 2010). In Prainha do Canto Verde extractive reserve, more than 30 species of fish are caught and exploited and the spanish mackerel (*Scomberomorus brasiliensis*) is among the species with the highest landings (Almeida & Pinheiro, 2002), presenting the highest regularity in the catches. Information on the reproductive parameters of this species may support the establishment of management measures to ensure its rational exploitation. Studies on the population and reproductive biology of the species along the coast of the State of Ceará were carried out some years ago, from the 70 and 80’s (Alcântara-Filho, 1977; Fonteles-Filho, 1988; Gesteira & Mesquita, 1976). Due to the recurrent and intense fishing pressure, it is likely that the parameters have changed as a way of adapting the species to ensure population growth (Fonteles-Filho, 2011). Other studies focusing on reproduction and fishery stock assessment were performed on the Northeast coast with samples from the coast of Bahia to Piauí (Nóbrega et al., 2004), studies of reproductive strategies on the coast of the State of Rio Grande do Norte

(Lima et al., 2007; Oliveira et al., 2015), in the State of Maranhão through population structure and reproductive indicators such as size and age of first sexual maturity (Lima et al., 2009; Silva et al., 2005) and in the State of Pará by population structure, sex ratio (M: F) and size of first sexual maturity (Maia et al., 2015).

Therefore, considering that spanish mackerel is an important fishing resource, being abundant and frequent on the Ceará coast, this study aims to answer the following hypotheses: (1) due to the frequent fishing effort, it is believed that the L_{50} established in this research will different than those recorded in the literature; and (2) its capture in Prainha do Canto Verde extractive reserve is sustainable.

In this context, this study aimed to describe and update information on sex ratio (M: F), size of first sexual maturity (L_{50}) and the time of highest reproductive activity of Serra Spanish mackerel (*Scomberomorus brasiliensis*) caught by artisanal fisheries in the Prainha do Canto Verde Marine Extractive Reserve, Beberibe, State of Ceará.

3.2 Material and Methods

3.2.1 Study area

The Prainha do Canto Verde Marine Extractive Reserve is located in the Paripueira district, Beberibe municipality, on the east coast of the state of Ceará. The reserve has an area of 29,804.99 ha (Galdino, 2012; ICMBio, 2019) (Figure 1).

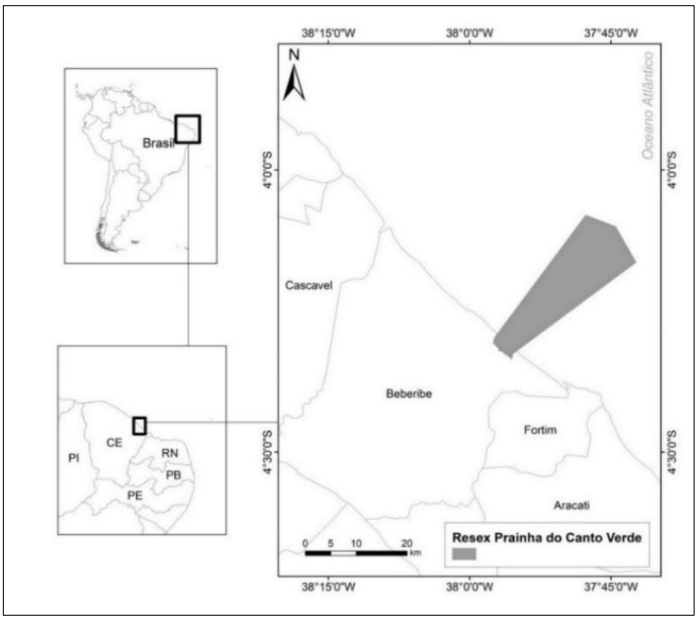


Figure 1. Study area location, Prainha do Canto Verde Marine Extractive Reserve, Beberibe, State of Ceará.

3.2.2 Biological sampling and analysis

Monthly samplings were performed from September 2016 to August 2017. For the collection of data and biological samples, the research was registered in the Biodiversity Authorization and Information System (Number: 52552-1 e 52552-2). It is also submitted and approved by the Research Ethics Committee (CEP) from Federal University of Ceará (CAAE: 79895017.0.0000.5054). At landings, individuals were identified, photographed, weighed (0.01 kg) on a portable digital hook scale, measured for total length with a measuring tape (0.01 cm) and separated by fishing gear, in this case, gillnet or handline.

For macroscopic evaluation, the gonads were removed from the abdomen, weighed (0.001g) on a digital scale, identified by sex, and characteristics indicating the degree of gonadal development were recorded: gonad size in relation to the coelomic cavity, color, vascularization, degree of turgidity, as proposed by Vazzoler (1996) and Bazzoli (2003). The gonads were macroscopically classified into five stages for both sexes: A – Immature; B – Maturing; C – Mature; D – Depleted; and E – Resting.

Gonads were prepared for histological analysis with fixation in 10% formaldehyde (diluted with filtered seawater) for 24 hours. They were then stored in 70% alcohol until dehydration and diaphanization, where a fragment of the gonad was removed for the beginning of the process, followed by paraffin embedding and subsequent microtome sectioning. Histological procedures were adapted from Tolosa et al. (2003).

For histological analysis, gonads were separated according to length classes (cm) of the specimen following Sturges formula (length range of 33 to 98 cm and 34 to 90 cm and eight and five length classes for females and males, respectively) and then a representative sample (of at least five specimens) from each class was drawn (Sturges, 1926).

$$K = 1 + 3.322 \, (\log 10 \, n) \quad (1)$$

where n = number of individuals;

The staining method applied was the Gomori's trichrome (adapted from Behmer, Tolosa & Freitas, 1976), as it facilitates the distinction between intracellular and tissue components. The slides containing the histological sections were analyzed and photographed in a photomicroscope (Leica DM1000 LED with 10x objective lens, 100x magnification) for further characterization of sex cell stages and confirmation of macroscopically established gonadal developmental stages at the time of dissection.

To evaluate the degree of development of the gonads, the gonadosomatic index (GSI) of females was calculated due to the higher occurrence and regularity of ovaries in the samples. To determine the GSI, the individuals and the gonads were weighed (0.001g) on a digital scale and the obtained values applied in the following formula (Vazzoler, 1996):

$$GSI = \frac{gonadal\ weight\ (g)}{fish\ weight\ (g)} \text{ x } 100 \quad (2)$$

The length at first maturity (L_{50}) was estimated considering both grouped and separated sexes, the values were estimated using the package sizeMat (Torrejon-Magallanes, 2020) available in the software R (R Core Team, 2020).

3.2.3 Data analysis

The data were organized in spreadsheets and the Shapiro-Wilk (1965) and Levene (1960) tests were used to analyze the normality and homoscedasticity. The total length data between males and females were compared with the nonparametric Mann-Whitney test. The same test was considered to compare lengths obtained by fishing gear (handline and gillnet). Length data were also analyzed to obtain the percentage of specimens caught above length at first maturity (L_{50}).

The gonadosomatic index (GSI) values per month were compared by Kruskal-Wallis test (H) (Zar, 1984). For the sex ratio (M: F), the values were analyzed by Chi-square test (χ^2). The software PAST® (Hammer; Harper & Ryan, 2001) was used to run the the analysis and the significance level considered for all analyses was 5%.

3.3 Results

3.3.1 Population structure

A total of 451 individuals were sampled, but only 360 individuals had the sex identified, as some were landed eviscerated. The total length of the samples of *Scomberomorus brasiliensis* ranged from 31 to 98 cm with a median of 58 cm, while females varied from 33 to 98 cm and median of 59 cm and males from 34 to 90 cm and median of 51 cm (Figure 2).

A significant difference was observed when total length and sex were considered (U = 10352 and p = 0.0008), where females had the longest lengths. The length median of the specimens captured by the handline gear was 83 cm, while by the gillnet 50 cm, presenting a statistical difference (U = 2238, p = 0.0001).

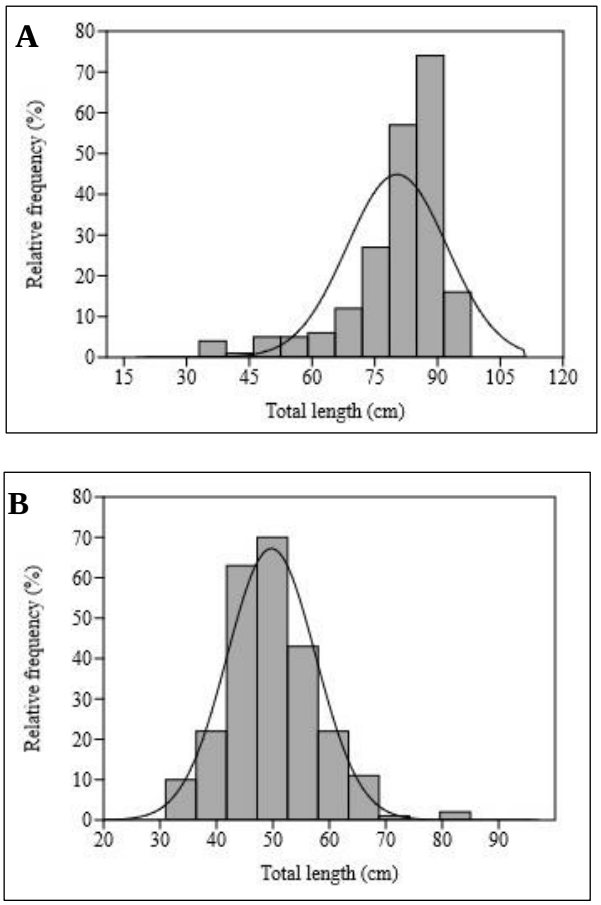


Figure 2. Histogram the total length (cm) of *Scomberomorus brasiliensis* specimens landed in Prainha do Canto Verde – Beberibe, Ceará, from September 2016 to August 2017, captured by fishing gear (2A: Handline; 2B: Gillnet).

Of the total analyzed, 255 were females (70.84%) and 105 males (29.16%), presenting a 1M: 2.42F sex ratio favorable to females (χ^2 = 62.5, p = 0.0001). Over the months analyzed, a larger number of females was found, with a statistically significant difference between the proportions in some months (Table 1).

Table 1. Monthly sex ratio of *Scomberomorus brasiliensis* landed on the Prainha do Canto Verde, Beberibe, State of Ceará, from September 2016 to August 2017.

Month	Male	Female	Sex ratio M: F	χ^2	p-value
Sep 16	11	29	1: 2.63	8.10	0.0072*
Oct 16	11	28	1: 2.54	7.41	0.0104*
Nov 16	4	19	1: 4.75	9.78	0.0035*
Dec 16	6	5	1: 0.83	0.09	1
Jan 17	3	8	1: 2.66	2.27	0.22
Feb 17	18	42	1: 2.33	9.60	0.003*
Mar 17	3	10	1: 3.33	3.76	0.096
Apr 17	19	42	1: 4.75	8.60	0.049*
May 17	3	2	1: 0.66	-	-
Jun 17	13	5	1: 0.38	3.50	0.099
Jul 17	9	53	1: 5.88	31.22	0.0001*
Aug 17	5	12	1: 2.40	3.50	0.099

*****Significant difference (p<0.05).

3.3.2 Reproduction

The highest gonadosomatic index (GSI) peaks for females were recorded from June to August 2017, with medians of 16.66, 7.33 and 6.76 respectively, for males the peaks occurred in the same months with medians of 6.22, 3.38 and 3.7, indicating a larger number of specimens at advanced maturity stage (Figure 3). GSI values in these months where the statistical difference was confirmed by the Kruskal-Wallis test females ($H = 93.1$, $p = 4.127E^{-15}$) and males ($H = 88.7$, $p = 2.859E^{-14}$) (Figure 3).

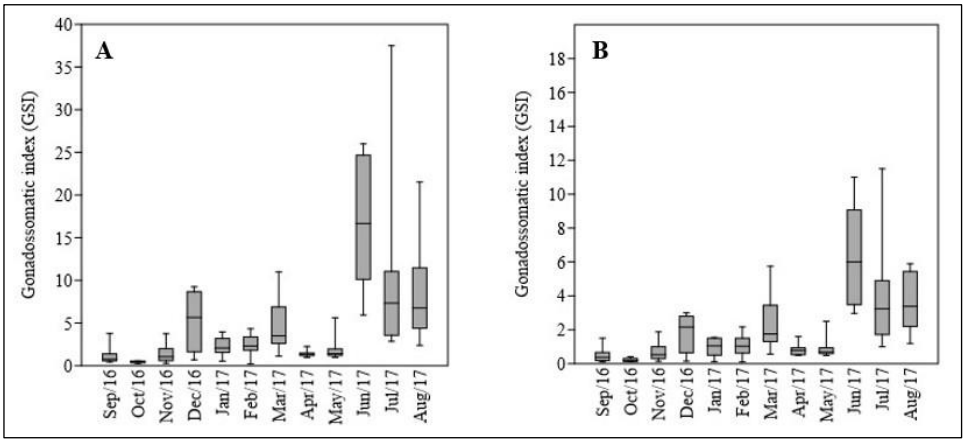


Figure 3. Gonadsomatic index (GSI) of *Scomberomorus brasiliensis* landed on Prainha do Canto Verde, Beberibe, State of Ceará, from September 2016 to August 2017 (3A: females; 3B: males).

According to the results of the histological evaluation, it is possible to observe a higher frequency of females capable of reproduction with predominance of the mature stage in December, March and from June to August, while in the months from January to May, predominated the maturing stage (Figure 4).

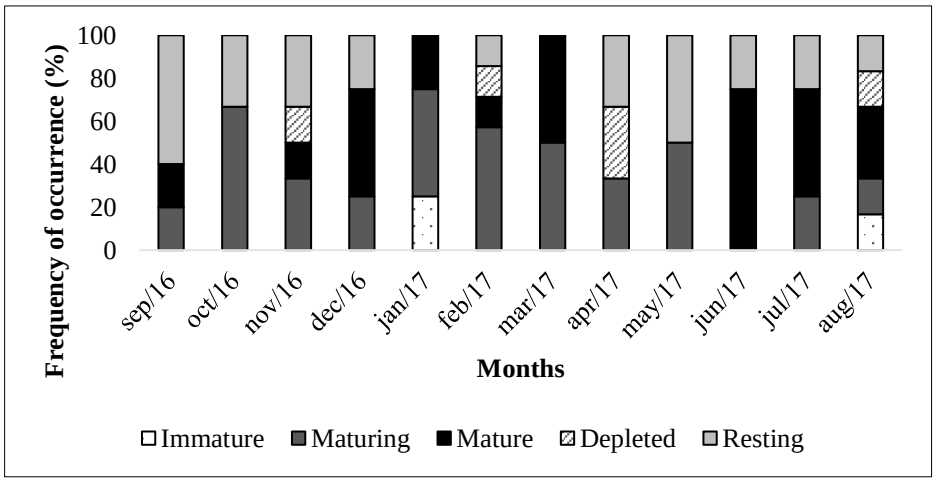


Figure 4. Frequency of occurrence of gonadal stages of *Scomberomorus brasiliensis* females landed on Prainha do Canto Verde, Beberibe, State of Ceará, defined by histology analysis.

Confirmation of the macroscopically evaluated ovarian stages (immature, early maturing, late maturing, mature, depleted and resting) was performed microscopically and also allowed the differentiation of five stages of oocyte development (I-oogonia, II-young oocyte or at protein vitellogenesis, III – oocyte at lipid vitellogenesis, IV- oocyte at lipid and protein vitellogenesis, V- oocyte at complete vitelogenesis (mature) (Figure 5).

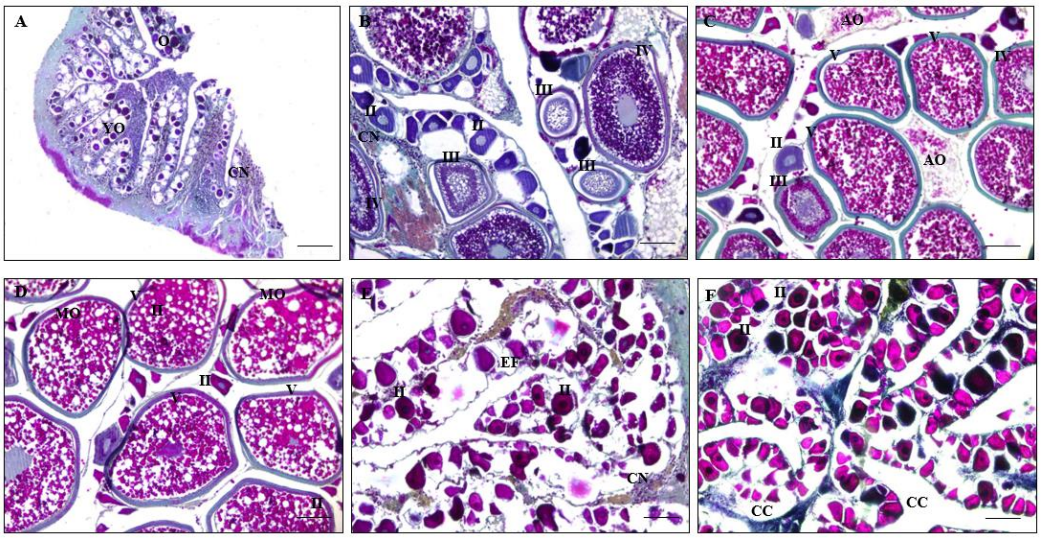


Figure 5. Gonadal stages of *Scomberomorus brasiliensis* females landed on Prainha do Canto Verde, Beberibe, State of Ceará, defined by histology. **A.** immature. **B.** At early maturation. **C**. At late maturation. **D**. Mature. **E**. Depleted. **F.** Resting. **O** (oogonia); **YO** (young oocyte); **CN** (cell nests); **MO** (mature oocyte: at complete vitellogenesis); **AO** (absorbing oocyte); **EF** (empty follicle); **CC** (coelomic cavity). (100µm scale).

Table 2. Characteristics of the predominant gonadal stages and stages of oocyte development for females of *Scomberomorus brasiliensis* landed on Prainha do Canto Verde, Beberibe, State of Ceará, defined by histology.

Gonadal stage	Microscopic characteristics
Immature	Cell organization, cell nests and young oocytes (onset of protein vitellogenesis).
At early maturation	Simultaneous occurrence of phases II, III (lipid vitellogenesis) and IV (lipid and protein vitellogenesis).
At late maturation	Phases II, IV and V (complete vitellogenesis) and occurrence of absorbing oocytes.
Mature	Frequency of oocytes in phase V (complete vitellogenesis), with large volume increase.
Depleted	Empty follicles, cell disorganization, cell nests and oocytes in phase II.
Resting	Larger coelomic cavity (many voids), oocytes in phase II.

The estimate of size at first sexual maturity (L_{50}) for both sexes was 46.8 cm total length (TL) (Figure 6).

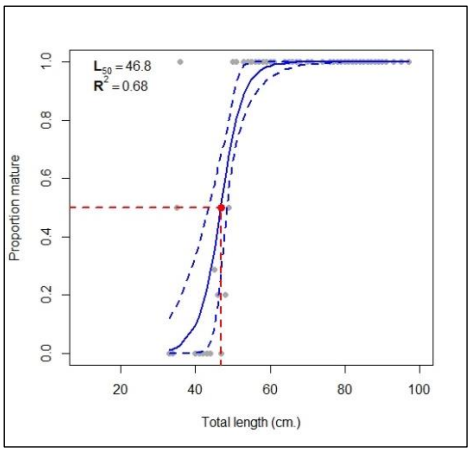


Figure 6. Length at first maturity (L_{50}) for both sexes the *Scomberomorus brasiliensis* landed in the Prainha do Canto Verde, Beberibe, State of Ceará, from September 2016 to August 2017.

When separated by sex, females presented a value of 44.7 and males of 47.5 cm (Figure 7).

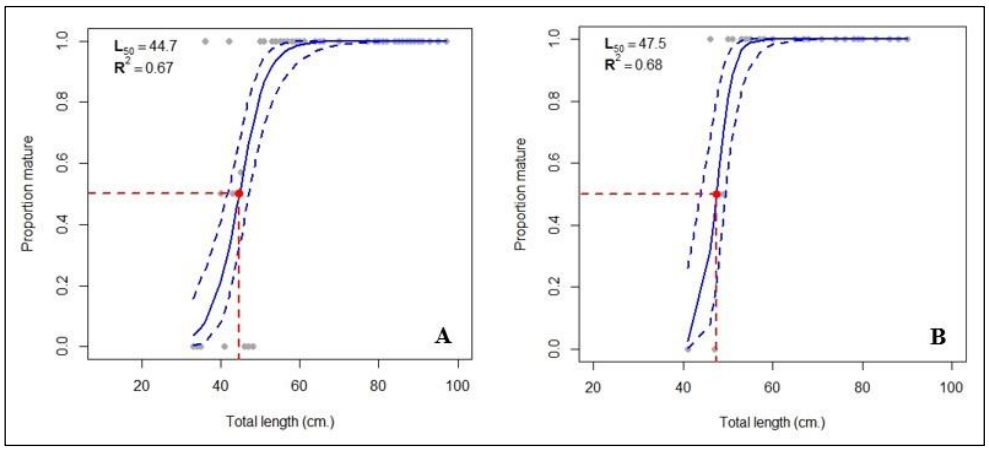


Figure 7. Length at first maturity (L_{50}) separated by sex the *Scomberomorus brasiliensis* landed in the Prainha do Canto Verde, Beberibe, State of Ceará, from September 2016 to August 2017 (A: Females; B: Males).

The specimens caught by handline presented median, for both sexes, above the calculated L_{50}. For the gillnet gear, the median of females was higher than the calculated L_{50} (44.7), but the same is not true for males (Figure 8). Besides this, it is important to reinforce that 21,4% of females and 45,1% of males caught by gillnet gear had the median below the calculated L_{50}.

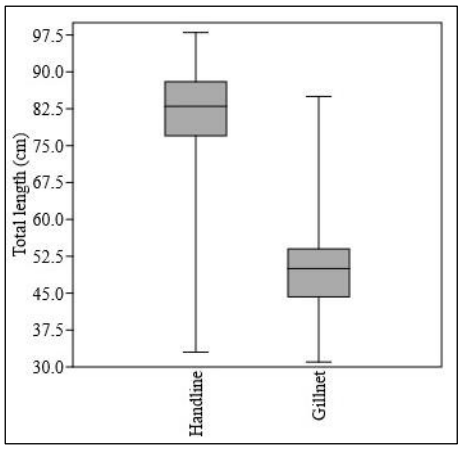


Figure 8. Median of total length (cm) of *Scomberomorus brasiliensis* individuals caught by fishing gear on Prainha do Canto Verde, Beberibe, State of Ceará.

3.4. Discussion

3.4.1 Population structure

Information on sex ratio is basic for assessing reproductive potential and estimating fish stock size, providing important insights into the relationship between individuals and the environment and the general state of the population (Vicentini & Araújo, 2003). In this study, the ratio of the sexes was 1M: 2.42F, favorable to females, a result similar to that found for the species caught in the western coast of the State of Maranhão, which showed superiority of females with 67% and 1M: 2F (Silva et al., 2005). In a study by Nóbrega (2002), a sex ratio of 2.45M: 1F was found, but the samples were obtained from three Northeastern states. For *S. brasiliensis* caught in waters of the State of Rio Grande do Norte, the sex ratio was 2M: 1F, where males also predominated in the population (Oliveira et al., 2015).

This parameter varies over the life cycle according to successive events that act differently on the sexes. In Prainha do Canto Verde, females were more representative and such pattern should be associated with mortality that may act differently on males and females, determining the predominance of individuals of one sex in the different stages of development (Cavalcante; Oliveira & Chellappa, 2012; Oliveira et al., 2015; Vazzoler, 1996). Sex ratio may be related to the size difference between the sexes: small males are more susceptible to predation than females (Araújo; Araújo & Chellappa, 2012). Predation is believed to be the predominant factor for differential mortality between the sexes (Rodd & Reznick, 1997). However, it is noteworthy that more females than males in the environment may be somewhat positive from the point of view of reproductive success (Maia et al., 2015). While the higher

occurrence of males in the samples may be related to the potential of the fishing gear (Nóbrega, 2002).

3.4.2 Reproduction

The use of macroscopic characters of the gonads is an important tool to determine the maturity stage of the individual. Nevertheless, histological characterization is fundamental for a better identification of the developmental stages of the gonads, thus reducing the chance of errors (Esper; Menezes & Esper, 2000; Oliveira et al., 2015). The microscopic characterization of the ovaries of the spanish mackerel females analyzed showed that the species has five stages of gonadal maturation, such as: immature; maturing (early and late); mature; depleted and resting. The oocyte phases identified were I, II, III, IV, V. A microscopic evaluation performed by Chellappa et al. (2010) showed four stages for females of the spanish mackerel caught in the coastal waters of the State of Rio Grande do Norte: immature; in early and late maturation; mature and recovering.

Females showed reproductive peak from June to August. On the northeast coast, Silva et al. (2005), in the State of Maranhão, observed that the species presents reproductive period between March and June. In the State of Rio Grande do Norte, Lima et al. (2007) obtained mean GSI values with three peaks, the highest in December and the other two in April and June. Also, in the State of Rio Grande do Norte, Oliveira et al. (2015) reported a reproductive peak between March and June. Given the regularity of environmental factors, especially surface temperature, it is expected that the species is able to reproduce throughout the year on the Northeast coast. Research in Ceará reports reproductive peaks between September and to March (Gesteira & Mesquita, 1976), as well as from June to August (Fonteles-Filho, 1988). As for the frequency, spawning is periodic (annual). The fact that the collective spawning extends over several months demonstrates that individuals get sexually mature at different times of the year (Mota-Alves & Tomé, 1967). During the sampling period, mature individuals were found in nine of the twelve months, indicating asynchronous development (Vazzoler, 1996), that is, individuals can spawn at different times of the year.

Because reproductive success is so vital to the survival of fish populations, it is important not only to understand how they reproduce, but also to monitor changes in reproductive parameters over time. Regular updates on the reproductive biology of fish species are therefore necessary (Gervasi, 2015). Data regarding the size at first sexual maturity of the spanish mackerel in Prainha do Canto Verde indicate that females reproduce from the total length of 45.75 and males from 49.32. The values obtained were close to those found in the

literature. In the 70's, Gesteira (1972) recorded the size at first maturity of 46.0 cm in zoological length for spanish mackerel on the coast of Ceará, corresponding to the age of 3 to 4 years. Gesteira and Mesquita (1976) estimated for females also from the coast of Ceará the value of 41.0 cm in zoological length (2.9 years), values lower than those in this study. L_{50} estimates for the species in different regions of the Brazilian coast can be observed in table 3.

Table 3. Size at first maturity (L_{50}) values calculated for *Scomberomorus brasiliensis* in different regions of the Brazilian coast and their respective references.

L_{50} (cm)	Sex	Amplitude length (cm)	Location	Reference/year
46.0 ZL	M/F	35.0 – 79.0	CE	Gesteira (1972).
41.0 ZL	F	29.6 – 65.5	CE	Gesteira & Mesquita (1976).
41.9 ZL	F	9.50 – 96.5	PI and BA	Nóbrega et al. (2004).
42.3 ZL	M	9.50 – 96.5	PI and BA	Nóbrega et al. (2004).
28.0 TL	F	13.5 – 80.5	RN	Lima; Fonteles-Filho & Chellappa (2007).
34.5 TL	M	14.0 – 59.8	RN	Lima; Fonteles-Filho & Chellappa (2007).
41.1 ZL	F	27.0 – 79.5	MA	Lima et al. (2009).
44.3 ZL	M	21.5 – 76.5	MA	Lima et al. (2009).
28.0 TL	F	9.30 – 80.5	RN	Oliveira et al. (2015).
34.5 TL	M	–	RN	Oliveira et al. (2015).
52.7 TL	M/F	37.3 – 75.0	PA	Maia et al. (2015).
44.7 TL	F	33.0 – 98.0	CE	Present study
47.5 TL	M	34.0 – 90.0	CE	Present study

ZL- Zoological length; TL- total length; CE – Ceará; RN – Rio Grande do Norte; MA – Maranhão; PA – Pará.

Fluctuations in population size can lead to changes in reproductive sizes. In the present study, the individuals caught by gillnets have mean length close to the estimated L_{50}. Nóbrega et al. (2004) conducted a pseudo-cohort analysis of the lengths of the species found on the Northeast coast and indicated the classes from 31.5 to 76.5 cm (zoological length) as the most exploited by fishing, showing two peaks in catches, one in the class of 44 cm, probably from the gillnet catch and in the 71.5 cm class, indicating the exploitation of the hand line gear.

3.5. Conclusion

Determining the size at first sexual maturity (L_{50}) provides subsidies for sustainable management of fishery resources. According to the results, management measures for spanish mackerel fishing are required, such as establishing a legal minimum catch size and setting mesh size primarily for the gillnet fishing gear, as the mean catch size is very close to L_{50} and may compromise the resource in the future by growth overfishing.

4 CAPÍTULO 3: Reproductive biology of Blue runner *Caranx crysos* (Teleostei: Carangidae): one of the target species of artisanal fishing in an extractive marine reserve in the Northeast of Brazil

Reproductive biology of Blue runner *Caranx crysos* (Teleostei: Carangidae): one of the target species of artisanal fishing in an extractive marine reserve in the Northeast of Brazil

Pedro Florêncio Ribeiro[1]; Caroline Vieira Feitosa[2] e José Roberto Feitosa Silva[3].

[1]Programa de Pós-graduação em Engenharia de Pesca da Universidade Federal do Ceará, Campus do Pici, Fortaleza – Ceará – Brasil. pedro88phb@hotmail.com.

[2]Instituto de Ciências do Mar da Universidade Federal do Ceará, Fortaleza, CE – Brasil. carol_feitosa@hotmail.com

[3]Departamento de Biologia, Laboratório de Histologia Animal da Universidade Federal do Ceará, Campus do Pici, Fortaleza – Ceará – Brasil. jrobertofeitosa@gmail.com

ABSTRACT

The objective of this research was to describe the reproductive biology of the Blue runner, *Caranx crysos*, a target species in the artisanal fishery of the Prainha do Canto Verde Marine Extractive Reserve, located in Beberibe, Ceará. The samples occurred from October 2016 to September 2017. At the time of landing, the specimens were identified, separated by fishing gear, photographed, weighed, and morphometric measurements were recorded. Still in the field, the gonads of each individual were removed, identified their sex by the shape and coloration, weighed, and fragments were removed for histological analysis to confirm the stage of sexual maturation. A total of 375 specimens were analyzed and the sex ratio was 1M: 2.86F. The maximum GSI occurred between May and June/17. The L_{50} registered for both sexes was 28.8 cm in total length (TL), while for females was 28.1 cm and for males was 30.7 cm. For individuals caught by handline and gillnet, the median total length was 47 cm and 35.5 cm, respectively. The peak of spawning activity was observed in the months of May to August, where the GSI reached maximum values and a higher frequency of mature individuals. This information is important for the development of fishing management strategies that ensure the sustainable exploitation of this fishery resource.

Keywords: Reproduction. Gonadal maturation. Fishery management.

4.1. Introdução

An accurate assessment of stock parameters related to fish reproduction, such as success and reproductive potential are essential components for effective fisheries management

(Kjesbu, 2009; Lowerre-Barbieri, 2009; Brown-Peterson et al., 2011). In addition, ovarian maturation stage is an important biological parameter for studying reproductive biology and species ecology, as well as for fisheries research (Domínguez-Petit et al., 2017). With the evaluation of maturation stages, it is possible to determine the size of length at first maturity (L_{50}) which provides subsidy for management policy definitions, allowing to delimitate the reproductive stock and thus to establish a minimum catch size for a given species. Therefore, these parameters provide information to assist in the sustainable management of fishery resources (Lima et al., 2009).

The species of the Carangidae family are among the main fishing resources sold in Brazil. The family comprises 4 subfamilies, 30 genera and 147 species. Due to the importance of the species of this family as a fishing resource, there is a lack of precise information on the most frequent species in commercial landings (Duarte et al., 2017; Nelson; Grande & Wilson, 2016; Oliveira et al., 2017).

The Blue runner, *Caranx crysos* (Mitchill, 1815) is a pelagic species that forms shoals near the coast, occurring in depths of up to 100m and often recorded near oil platforms (Herdson, 2010; Platoo, 2015; Oliveira et al., 2017). It is distributed in the Western Atlantic: from Nova Scotia (Canada), to Brazil, including the Gulf of Mexico and the Caribbean, and in the Eastern Atlantic, from Senegal to Angola, and can also be found in the Mediterranean Sea (Herdson, 2010). Many species of Carangidae are important for commercial and recreational fishing. For the Northeast region of Brazil, these species have been cited in research, including 10 adult taxa, among them, the genus *Caranx* (Souza & Mafalda-Junior, 2008). This genus is considered one of the most important based on data published by the REVIZEE/ SCORE-NE program (Lessa et al., 2000). In the Prainha do Canto Verde Marine Extractive Reserve (MER - Portuguese abbreviation) artisanal fishery, the species *C. crysus* is among the most caught resources, as it is considered one of the target species of the gillnet fishery, besides its high incidence throughout the year.

Knowledge of *C. crysos* reproduction is crucial for the development of management strategies that will ensure the sustainable exploitation of this fishery resource. In Brazil, only one study was published on the reproductive biology of this species, where the specimens were caught on the coast of the Rio Grande do Norte state (Northeast, Brazil) (Oliveira et al., 2017). On a global scale, research was conducted in the Gulf of Mexico (north and south coast of Florida and Mississippi Delta in the state of Louisiana, USA) (Goodwin & Finucane, 1985) and

the Caribbean (Puerto Rico) (Figuerola-Fernández, 2008). In the Mediterranean Sea, research was recorded in Egypt (Samira, 1999) and Tunisia (Sley et al., 2012).

This research aimed to describe the reproductive biology of the blue runner *C. crysos* caught in the artisanal fishery of the Prainha do Canto Verde Marine Extractive Reserve, (MER – Portuguese abbreviation) Beberibe - CE by means of macroscopic and microscopic evaluation of the gonads for determination of the length at first sexual maturity (L_{50}), as well as spawning frequency and season.

4.2 Material and Methods

4.2.1 Study area

The Prainha do Canto Verde Marine Extractive Reserve is located in the Paripueira district, Beberibe municipality, on the east coast of the state of Ceará. The reserve has an area of 29,804.99 ha (Galdino, 2012; ICMBio, 2019) (Figure 1).

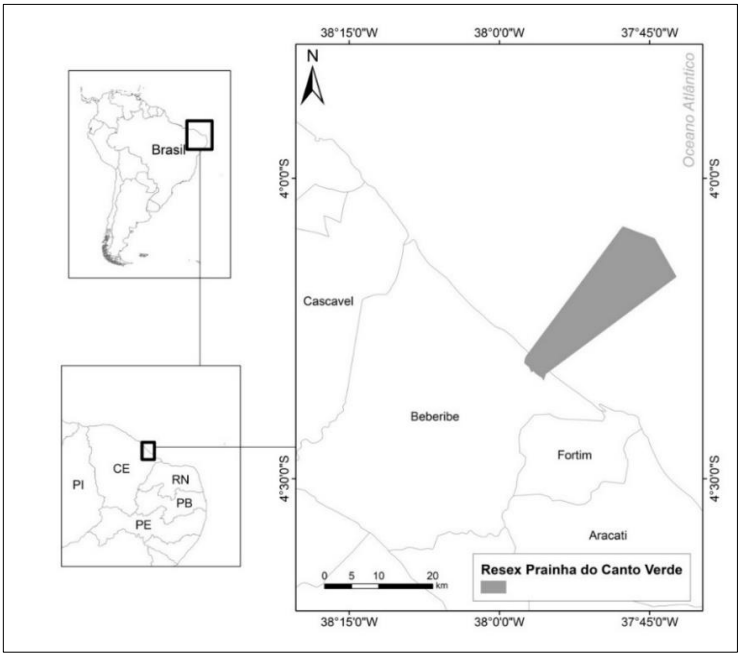


Figure 1. The study area: Prainha do Canto Verde Marine Extractive Reserve, situated in Beberibe municipality, Ceará state, Brazil.

4.2.2 Biological sampling and analysis

The samples were conducted from October 2016 to September 2017. For the collection of data and biological samples, the survey was registered in the Biodiversity Authorization and Information System (SISBIO Number: 52552-1 and 52552-2), also submitted and approved by the Research Ethics Committee (CEP) of the Federal University of Ceará (UFC) (CAAE:

79895017.0.0000.5054). In the landings the specimens were identified, photographed, weighed (0.01 kg) with the aid of a portable digital scale with hook, measured in their total length with a tape measure (0.01 cm) and separated by fishing gear (handline or gillnet).

For the macroscopic evaluation, the gonads were removed, weighed (0.001g) on a digital scale, had the sex registered and the gonadal development stage. The size of the gonad in relation to the celomatic cavity, coloration, visualization of blood vessels, degree of turgidity, and characters of the ovaries and testicles were observed, as proposed by Vazzoler (1996) and Bazzoli (2003). The gonads were classified into five stages, for both sexes: A - immature; B - maturing; C - mature; D - recovering; and E - resting.

The gonads were prepared for histological study starting with fixation in a 10% formalin solution diluted with sea water, where they remained in this solution for 24 hours. Afterwards, they were stored in 70% alcohol until the paraffin inclusion phase and later microtomy. The histological procedures were adapted from Tolosa et al. (2003).

The staining method applied was the Gomori Trichrome (adapted from Bermer, Tolosa & Freitas, 1976), as the result was a greater distinction between intracellular and tissue components. The slides were analyzed and photographed in a photomicroscope (Leica DM1000 LED) with an objective lens of 10, magnification of 100x, and the characterization and confirmation of the gonadal development stages were performed.

For histological analyses, the gonads were separated by length classes (cm) of the specimen according to Sturges' formula (ranging from 13.5 to 61 cm and 7 length classes for females and 20 to 57 cm and 5 length classes for males) and then a representative sample of each class was randomly selected (Sturges, 1926).

$$k = 1 + 3{,}322 \ (\log 10 \ n) \quad (1)$$

where n = number of individuals;

To evaluate the degree of gonadal development, the gonadosomatic index (GSI) of females was calculated. To determine the GSI, the individuals and gonads were weighted, and the values obtained were applied in the following formula (Vazzoler, 1996):

$$GSI = \frac{Gonad\ \ weight\ (g)}{Fish\ weight\ (g)} \text{ x } 100 \quad (2)$$

The length at first maturity (L_{50}) was estimated considering both grouped and separated sexes, the values were estimated using the package sizeMat (Torrejon-Magallanes, 2020) available in the software R (R Core Team, 2020).

4.2.3 Data analysis

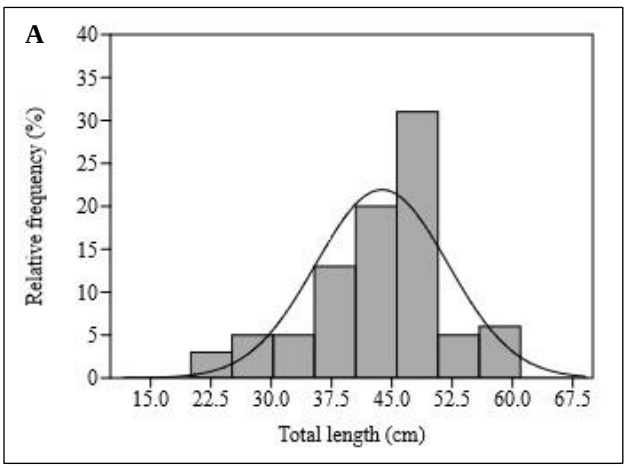
The data were organized in spreadsheets and the Shapiro-Wilk (1965) and Levene (1960) tests of normality and homoscedasticity were applied. The total length data between males and females were compared with the nonparametric Mann-Whitney test (1947). The same test was considered to compare lengths obtained by fishing gear (handline and gillnet). Length data were also analyzed to obtain the percentage of specimens caught above the length at first maturity (L_{50}).

The gonadosomatic index (IGS) values per month were compared by Kruskal-Wallis test (H) (Zar, 1984). For the sex ratio (M: F), the values were analyzed by the Chi-square test (χ^2). The statistical software used for all analyses was PAST® (Hammer; Harper & Ryan, 2001) and the significance level considered was 5%.

4.3. Results

4.3.1 Population structure

A total of 375 specimens were sampled with a median of 37 cm for total length and a maximum and minimum value of 13.5 and 61 cm, respectively. For males, the variation was from 20 to 57 cm and median with 36 cm and the length of females varied from 13.5 to 61 and median with 36.5 cm (Figure 2). However, no significant difference was observed when total length and sex were considered (U = 0.929795 and p = 0.3141). The median length of the specimens caught by the handline gear was 47 cm and by the gillnet was 35.5 cm, presenting a statistical difference (U = 3151.5, p = 0.0001).



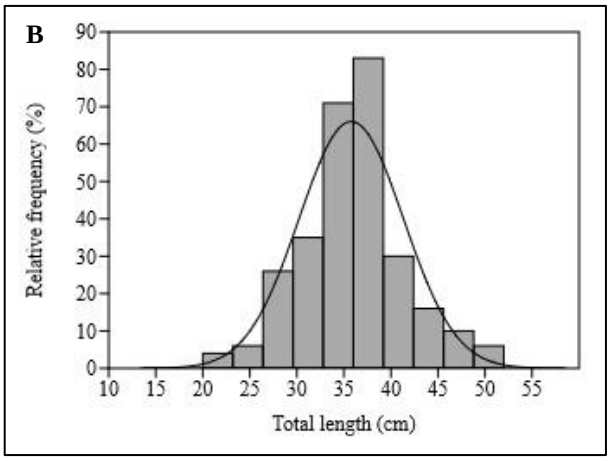


Figure 2. Histogram the total length (cm) of *Caranx crysos* specimens landed in Prainha do Canto Verde – Beberibe, Ceará, from October 2016 to September 2017, captured by fishing gear (2A: Handline; 2B: Gillnet).

Of the total number of individuals sampled, 325 could have the sex identified, since the rest were landed eviscerated. Of these, 241 were female and 84 were male. The sex ratio was 25.85% for males compared to 74.15% females (1M: 2.86F). The sex ratio obtained differs significantly ($\chi^2 = 75.84$; p = 0.0001). During this research, it was observed a predominance of females in the months of October, February, March, April, May, and September with significant differences (Table 1).

Table 1. Monthly sex ratio of blue runner *Caranx crysos* landed in the Prainha do Canto Verde Marine Extractive Reserve, Ceará, Brazil from October 2016 until September 2017.

Months	Males	Females	Sex ratio M: F	χ^2	p-value
Oct/16	15	56	1: 3.73	23,67	0,0001*
Nov/16	8	10	1: 1.25	0,22	0,813
Dec/16	6	8	1: 1.33	0,28	0,789
Jan/17	3	11	1: 3.66	1,47	0,332
Feb/17	9	22	1: 2.44	5,45	0,031*
Mar/17	6	28	1: 4.66	14,23	0,0003*
Apr/17	11	30	1: 2.72	8,80	0,004*
May/17	7	35	1: 5.00	18,66	0,0001*
Jun/17	4	7	1: 1.75	0,81	0,546
Jul/17	5	6	1: 1.20	0,09	1
Aug/17	4	10	1: 2.50	2,57	0,181
Sep/17	6	18	1: 3.00	6,00	0,024*

*****Significant difference (p<0.05).

4.3.2 Reproduction

The minimum and maximum GSI values for females were 0.07 and 6.55, respectively, the males 0.02 and 3.34 with the highest peaks from May to September, where the statistical difference was confirmed by the Kruskal-Wallis test females (H = 113.6, p = 3.503E-19) and males (H = 114, p = 2.873E-19) (Figure 3).

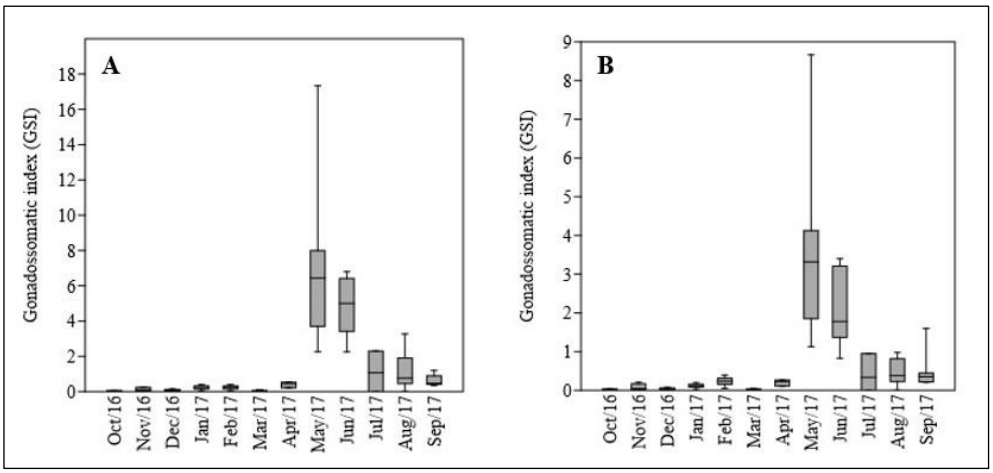


Figure 3. Gonadosomatic index (GSI) of *Caranx crysos* landed in the Prainha do Canto Verde, Beberibe, State of Ceará, from October 2016 to September 2017 (3A: females; 3B: males).

According to the results of the histological evaluation, a higher frequency of mature females can be observed in the months of May and June, while in the months of October to April the maturing stage predominated (Figure 4).

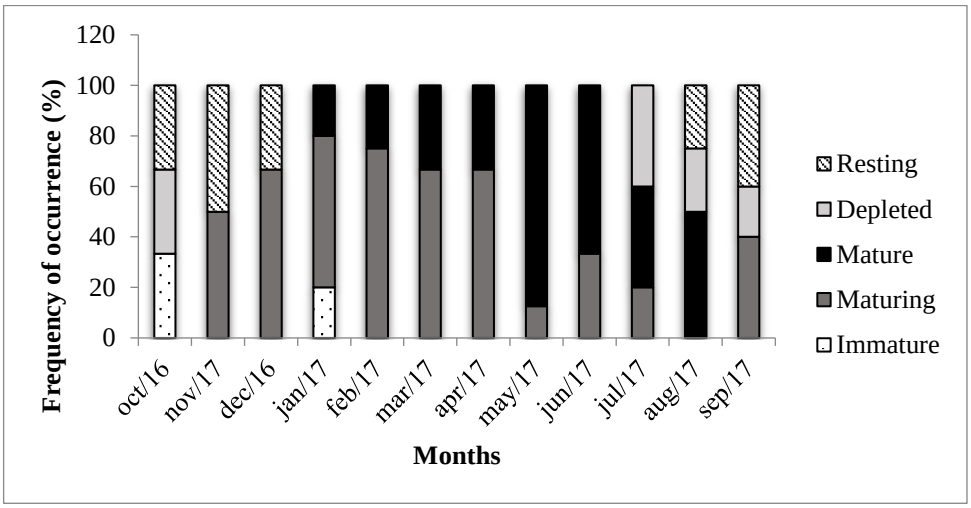


Figure 4. Frequency of occurrence of gonadal stages of *Caranx crysos* females landed in the Prainha do Canto Verde, Beberibe, State of Ceará, from October 2016 to September 2017 defined by histological analysis.

In the macroscopic evaluation of the gonads, the females presented a pair of flattened ovaries, located dorsally in the abdominal cavity. With the development of the reproductive cycle, the ovaries increased in size and presented color variations in shades of pink, red and yellow as the gonadal maturation advanced. The confirmation of the ovarian stages evaluated macroscopically (immature, maturing, mature, depleted and resting) was performed microscopically and also allowed the differentiation of five stages of oocyte cells development (I- oogonia, II- young oocyte, III- oocyte in lipid vitellogenesis, IV- oocyte in lipid and protein vitellogenesis, V- oocyte in complete vitellogenesis - mature) (Figure 5, 6).

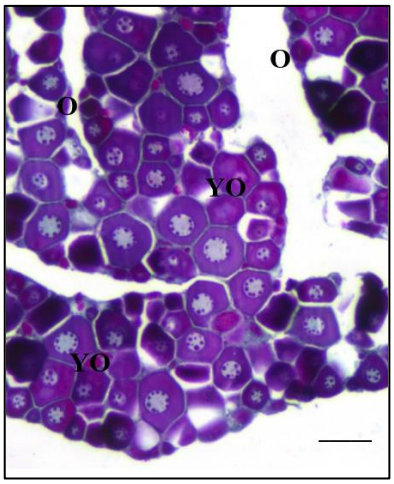


Figure 5. Gonadal stage of immature female *Caranx crysus*, landed in the Prainha do Canto Verde, Beberibe, State of Ceará, defined by histology. O (oogonia); **YO** (young oocyte). (100µm scale).

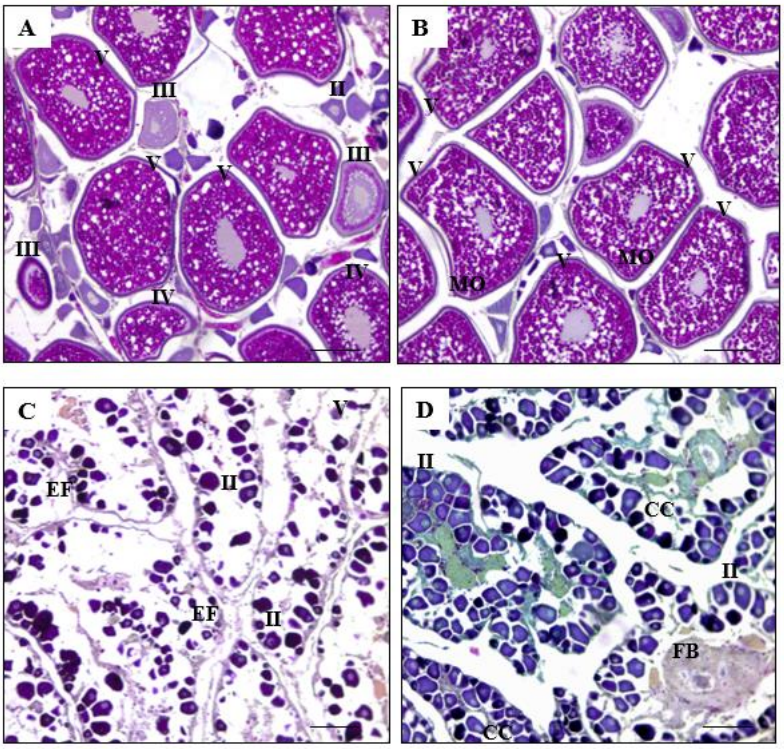


Figure 6. Gonadal stages of *Caranx crysus* females landed landed in the Prainha do Canto Verde, Beberibe, State of Ceará, from October 2016 to September 2017, defined by histology. **A** At late maturation. **B** Mature. **C** Depleted. **D** Resting. **MO** (mature oocyte: at complete vitellogenesis); **EF** (empty follicle); **CC** (coelomic cavity); **FB** (follicular bodies). (100µm scale).

Table 2 describes the characteristics of the gonadal stages of the female of *Caranx crysus*.

Table 2. Characteristics of the predominant gonadal stages and stages of oocyte development for females of *Caranx crysus* landed on Prainha do Canto Verde, Beberibe, State of Ceará, defined by histology.

Gonadal stage	Microscopic characteristics
Immature	Characterized by the presence of oogonia (phase I) and predominance of young oocytes in reserve stock (phase II).
At late maturation	Was characterized by the presence of oocyte cell development in phases II, III, IV, V (complete vitelogenesis).
Mature	Ovaries showed a high frequency of oocytes in phase V with the increase of the volume.
Depleted	Stage characterized by cellular disorganization, empty follicles and oocytes in phase II (reserve stock) were observed.
Resting	The ovaries in rest showed a predominance of oocytes in phase II and a larger cavity cell.

The estimate of size at first sexual maturity (L_{50}) for both sexes was 28.8 cm total length (TL) (Figure 7).

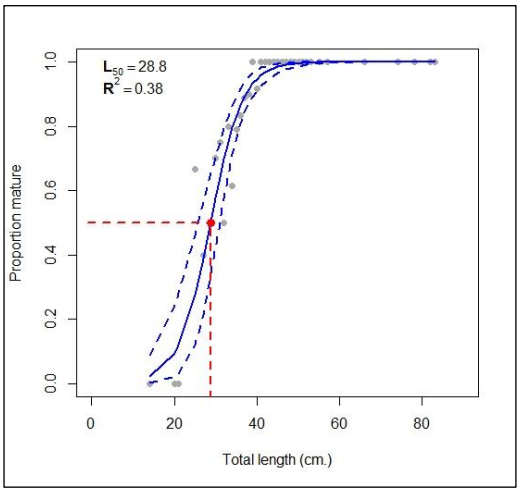


Figure 7. Length at first maturity (L_{50}) for both sexes the *Caranx crysos* landed in the Prainha do Canto Verde, Beberibe, State of Ceará, from October 2016 to September 2017.

When separated by sex, females presented a value of 28.1 and males of 30.7 cm (Figure 8).

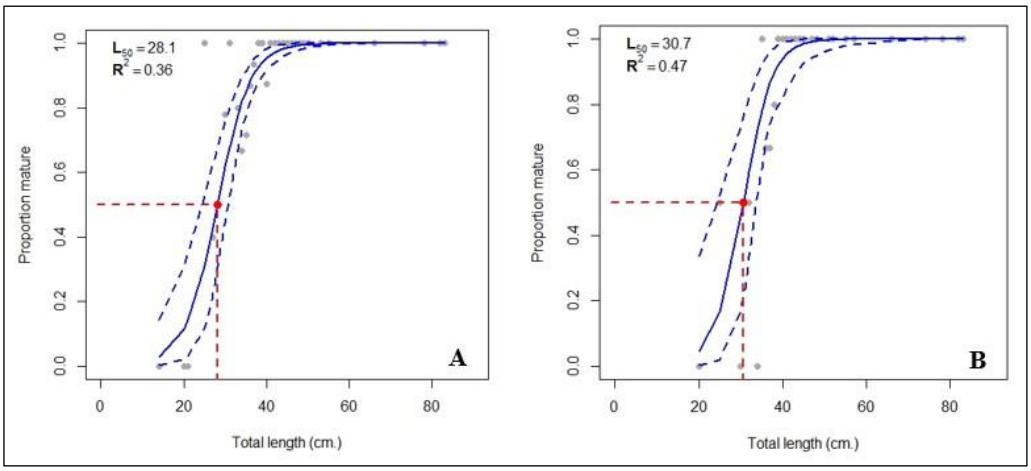


Figure 8. Length at first maturity (L_{50}) separated by sex the *Caranx crysos* landed in the Prainha do Canto Verde, Beberibe, State of Ceará, from October 2016 to September 2017 (A: Females; C: Males).

The specimens caught with a hand line showed a median of the total length (cm) above the calculated L_{50}, only 6.81% of individuals with values below. For the gillnet gear, the median was also above the L50, however it was observed that 9.4% of the specimens had total length (cm) below the size of the first sexual maturation (Figure 9).

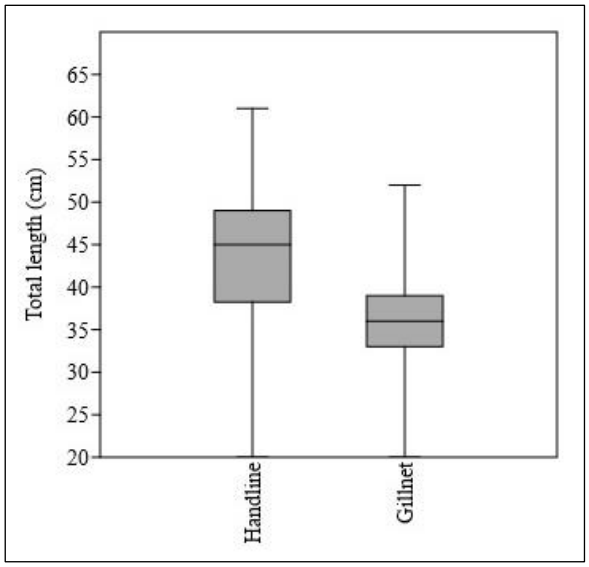


Figure 9. Median of total length (cm) of *Caranx crysos* individuals caught by fishing gear on Prainha do Canto Verde, Beberibe, State of Ceará, Brazil by fishing gear from October 2016 until September 2017.

4.4. Discussion

4.4.1 Population structure

The blue runner *C. crysos* is one of the target species with the highest volume of capture in the Prainha do Canto Verde artisanal fishery. It is important to point out the representativity

of two other species of the same family: yellow jack *Caranx bartholomaei* Cuvier 1833 and horse-eye jack *C. latus* Agassiz, 1831, however, but with less expressivity in the landings.

The sexual proportion registered for *C. crysos* was favourable to females (74.15%). Oliveira et al. (2017) found no difference in the proportion of individuals caught on the coast of the Rio Grande do Norte state (Northeast, Brazil). A similar result to the present study was observed in the research conducted by Goodwin and Finucane (1985) in three areas of the Gulf of Mexico (north and south of Florida and Mississippi Delta, Louisiana, USA). These results differ from those recorded in the research performed by Sley et al. (2012) in the Gulf of Gabes (Tunisia coast), where the number of males (53.4%) was higher than that of females. Such differences may be associated with monthly and seasonal changes in sexual proportions. The predominance of males or females may be related to sample size or feeding behavior of each sex (Sley et al., 2012). In addition, there may be a greater susceptibility of a particular sex to gear selectivity.

4.4.2 Reproduction

The highest peaks of the gonadosomatic index (GSI) were in May and June with a median of 6.55 and 4.78 respectively. Oliveira et al. (2017) in a research performed with samples captured on the coast of Rio Grande do Norte state (Northeast, Brazil), found values for females ranging from 0.02 to 5.89, with highest peaks from April to June and another one in January. In the Gulf of Mexico, the highest GSI values for the species were observed from June to August and another peak in October (Goodwin & Finucane, 1985). In the Caribbean Sea, off the Puerto Rico coast, the GSI values show a spawning period extending from March to October, with a peak in May and June (Figuerola-Fernández et al., 2008). In the Gulf of Gabes, Sley et al. (2012) found the highest GSI peaks from June to August. Based on these results, it is possible to suggest that this species may spawn from January to August, but the spawning peak occurs in the months of May and June, considered a rainy period on the Northeast region coast.

The microscopic evaluation of the ovaries indicated the same spawning period obtained by the variation of the IGS, where the maturing and mature stages were more frequent during the sampling period, indicating that the species caught in Prainha do Canto Verde, can spawn during some months of the year and presents intense reproductive period in some months. This pattern was also observed by Oliveira et al. (2017). Therefore, it can be affirmed that this species presents prolonged reproductive activity, facilitating its population increase.

The length at first maturity (L_{50}) calculated in this study for grouped sex was 28.8 cm of total length (TL). A bigger value (33.1 cm of TL) was recorded for the species caught on the state of Rio Grande do Norte coast, considering both sexes (Oliveira et al., 2017). Both surveys were conducted in Northeast Brazil. In other areas of occurrence, the blue runner reaches sexual maturity at slightly different lengths. In the Caribbean Sea, Jamaican coast, the L_{50} determined for males was 26.0 cm and 28.0 cm of zoological length (ZL) for females (Thompson & Munro, 1974). In Puerto Rico, the values were higher, 36.0 cm for females and 34.0 cm of ZL for males (Figuerola-Fernández et al., 2008). In the Gulf of Mexico, coast of Florida (USA), the length of 26.7 cm of ZL was estimated for females (Goodwin & Finucane, 1985). In the Gulf of Gabes, coast of Tunisia, Sley et al. (2012) found 25.97 cm of TL for females and 24.58 cm of TL for males. These authors comment that regional differences in the length at first maturity among populations of *C. crysos* may be related to ecological conditions. One possibility is the plasticity of its sexual strategy, as a tool to ensure continuity, decreasing the size at which individuals begin to reproduce. This is a commonly observed response when excessive fishing effort occurs. This is justified by the increase in mortality, favouring phenotypes that reproduce before they are killed by fishing (Kokkonen; Vainikka & Heikinheimo, 2015).

The determination of the length at first maturity is necessary for the establishment of management tools, such as the fixing of the minimum capture sizes and for the determination of mesh size (Araújo & Chellappa, 2002; Oliveira et al., 2015).

4.5 Conclusion

The data regarding total length data show that the highest frequency of individuals caught by the handline gear is in length classes above the L_{50} estimated. The opposite was observed for the specimens caught by gillnet, which retains smaller specimens, however the class with the highest number of individuals was close to L_{50}. Due to the lack of information on the reproduction of *Caranx crysus* throughout its distribution, it is essential to conduct studies that provide information that support management tools, such as those of reproduction and age and growth.

5 CONCLUSÃO

Os recifes artificiais (RA) utilizados na Resex Prainha do Canto Verde, funcionam principalmente como áreas de alimentação para os peixes pelágicos (e.g *Scomberomorus brasiliensis*, *Scomberomorus cavala* e *Caranx crysus*) espécies alvo da pescaria na reserva. Nas estruturas ocorre uma diversidade de espécies menores associadas aos recifes que servem como alimento.

Na Resex os conflitos ocorrem desde a sua criação, onde existe um grupo contrário principalmente ao ordenamento do território no continente, pois se interessam pela construção de moradias por não nativos, bem como a venda desses imóveis. Além disto, não cumpre na totalidade as regras existentes no acordo de pesca, como por exemplo, utilizam embarcações motorizadas. Quanto ao grupo favorável, observou-se uma organização e controle da produção desenvolvidos pelos pescadores da comunidade, as estratégias de pesca adotadas, resultado do conhecimento adquirido ao longo dos anos e repassados de geração a geração, garantem a continuação da atividade.

Para a pesca da serra (*Scomberomorus brasiliensis*), medidas de manejo são necessárias, como estabelecer um tamanho mínimo legal de captura e definir tamanho de malha principalmente para a arte de pesca rede de espera, pois o tamanho médio de captura está bem próximo do $L_{50,}$ podendo comprometer o recurso pesqueiro futuramente por meio da sobrepesca de crescimento. Os dados de comprimento total (cm) dos indivíduos de guarajuba branca (*Caranx crysus*) registrados neste estudo mostram que a maior frequência de indivíduos capturados com o petrecho linha/anzol, está em classes de comprimento acima do tamanho de primeira maturação sexual estimado, enquanto que a pesca com rede de espera retém espécimes menores, em que a classe com maior número de indivíduos está próxima do L_{50}. Em reunião devolutiva para a comunidade foi consenso entre os pescadores os impactos potenciais da rede de espera quando comparada à pesca de linha. Os pescadores se comprometeram a aumentar a malha quando fossem trocar as redes.

Dada a importância da pesca artesanal para a Reserva e a diversidade de espécies alvo dessas pescarias, estas informações, como tamanho de primeira maturidade e época de desova, servirão para a elaboração e implementação do plano de manejo com medidas para a pesca artesanal dentro dos limites da reserva.

Acknowledgements

"This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001".

The NGO Rare, through the project “Pesca para Sempre”.

REFERÊNCIAS

ALCÂNTARA-FILHO, P. Sobre a reprodução e fecundidade da serra, *Scomberomorus maculatus* (Mitchill), no Estado do Ceará. **Arquivos Ciência do Mar,** v. 12, p. 117-122, 1977.

ALMEIDA, S. P.; PINHEIRO, J. C. V. A arte da sustentabilidade da pesca na comunidade da Prainha do Canto Verde, Beberibe/CE. **Revista.** s/n, 2002.

ARAGÃO, J. A. N.; CINTRA, I. H. A. Avaliação do estoque de lagosta vermelha *Panulirus argus* na costa Brasileira. **Arquivos Ciência do Mar**, Fortaleza, v. 51, n. 2, p. 7-26, 2018.

ARAÚJO, A. S., CHELLAPPA, S. Estratégia reprodutiva do peixe voador, Hirundichthys affinis Gunther (Osteichthyes, Exocoetidae). **Revista Brasileira de Zoologia**, v.19, n.3, p. 691-703, 2002.

ARAÚJO, G. S.; ARAÚJO, A. S.; CHELLAPPA, S. Tipo de crescimento e aspectos reprodutivos do peixe marinho *Oligoplites palometa* (Osteichthyes: Carangidae), na costa do Rio Grande do Norte, Brasil. **Biota Amazônia**, v. 2, p. 25-30, 2012.

BAZZOLI, N. Parâmetros reprodutivos de peixes de interesse comercial na região de Pirapora. p. 291-306. *In:* GODINHO, H. P.; GODINHO, A. L. (Ed). **Águas, peixes e pescadores do São Francisco das Minas Gerais.** Belo Horizonte, PUC Minas, 2003. 468p.

BEGOSSI, A.; SALIVONCHYK, S. V.; HANAZAKI, N.; MARTINS, I. M.; BUELONI, F. Fishers and fish (Paraty, RJ): time of manipulation, a variable associated to the choice of consumption and commerce'. **Brazilian Journal of Biology,** v. 72, n. 4, p. 973-975, 2012.

BEHMER, A. O.; TOLOSA, E. M. C.; FREITAS, A. G. **Manual de Técnicas para Histologia Normal e Patológica.** Editora da Universidade de São Paulo, 1976. 241p.

BRASIL. Ministério do Meio Ambiente - MMA. Avaliação do potencial sustentável de recursos vivos na Zona Econômica Exclusiva. Relatório Executivo. Programa REVIZEE. 2006. 49p.

BRASIL. Ministério do Meio Ambiente - MMA. Conselho Deliberativo da Reserva Extrativista da Prainha do Canto Verde. **RESOLUÇÃO Nº 02 de 31 de março de 2012.**

BRASIL. Ministério do Meio Ambiente - MMA. **O Sistema Nacional de Unidades de Conservação da Natureza.** Secretaria de Biodiversidade e Florestas, Departamento de Áreas Protegidas. – Brasília: MMA, 2010 16p. WPDA. World Database on Protected Areas. 2010.

BROWN-PETERSON, N. J.; WYANSKI, D. M.; SABORIDO-REY, F.; MACEWICZ, B. J.; LOWERRE-BARBIERI, S. K. A standardized terminology for describing reproductive development in fishes. **Marine and Coastal Fisheries,** v. 3, p. 52-70, 2011.

BURDA, C. L. **Análise ecológica da pesca artesanal e consumo de pescado por quatro comunidades pesqueiras da costa de Itacaré (BA)**. 124f. 2007. Dissertação (Mestrado em Ecologia), Universidade Estadual de Santa Cruz, Ilhéus, BA. 2007.

CARNEIRO, P. B. M.; SALLES, R. Caracterização da pescaria com rede de emalhar derivante realizada no município de Fortaleza, estado do Ceará. **Arquivos Ciência do Mar**, Fortaleza, v. 44, n. 1, p. 69-80, 2011.

CARVALHO-FILHO, A. **Peixes: costa brasileira**. São Paulo. Melro, 3 ed, 1999, 320p.

CAVALCANTE, L. F. M.; OLIVEIRA, M. R.; CHELLAPPA, S. Aspectos reprodutivos do ariacó, *Lutjanus synagris* nas águas costeiras do Rio Grande do Norte. **Biota Amazônia,** v. 2, p. 45-50, 2012.

CHELLAPPA, S.; LIMA, J. T. A. X.; ARAÚJO, A.; CHELLAPPA, N. T. Ovarian development and spawning of Serra Spanish mackerel in coastal waters of Northeast Brazil. **Braz. J. Biol.**, v. 70, p. 451-456, 2010.

CLAUZET, M.; RAMIRES, M.; BARRELLA, W. Pesca artesanal e conhecimento local de duas populações caiçaras (enseada do mar virado e barra do una) no litoral de São Paulo, Brasil. **A Linguagem da Ciência**, v. 4, p. 1-22, 2005.

COLLETTE, B. B.; NAUEN, C. E. **FAO species catalogue**. Scombrids of the world. An annotated and illustrated catalogue of tunas, mackerels, bonitos and related species known to date. FAO Fish Synop., v. 125, p. 1-137, 1983.

CONCEIÇÃO, R. N. L.; NASCIMENTO, M. C. Recifes artificiais instalados em Guamaré, Rio Grande do Norte: programa de apoio à pesca artesanal. **Arquivos Ciência do Mar,** Fortaleza, v. 42, n. 1, p. 106-111, 2009.

CUNHA, V. L.; SILVA, A. C.; FONTELES-FILHO, A. A. Características e dinâmica das pescarias de lagosta no nordeste do Brasil. **Arquivos Ciência do Mar**, Fortaleza, v. 47, n. 2, p. 5-18, 2014.

DIAS-NETO, J. **Gestão do uso dos Recursos Pesqueiros Marinhos no Brasil**. Brasília: Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis. 2010.

DIEGUES, A. C. A como mudança como modelo cultural: o caso da cultura caiçara e urbanização. *In:* DIEGUES, A. C. (Org.). **Enciclopédia Caiçara**: o olhar do pesquisador. V. 1, São Paulo: HUCITEC – NUPAUB-CEC/US, 2004, p. 21-48.

DOMÍNGUEZ-PETIT, R.; ANASTASOPOULOU, A.; CUBILLOS, L.; GERRITSEN, H. D.; GONÇALVES, P.; HIDALGO, M.; KENNEDY, J.; KORTA, M.; MARTEINSDOTTIR, G.; MORGADO, C.; MUÑOZ, M.; QUINCOCES, I.; SAÍNZA, M.; THORSEN, A.; VITALE, F. Chapter 3: Maturity. *In:* DOMÍNGUEZ-PETIT, H.; MURUA, H.; SABORIDO-REY, H.; TRIPPEL, E. (Ed.). **Handbook of applied fisheries reproductive biology for stock assessment and management**. R. Digital CSIC. Vigo, Spain. 2017.

DUARTE, M. R.; TUBINO, R. A.; MONTEIRO-NETO, C.; MARTINS, R. R. M.; VIEIRA, F. C.; ANDRADE-TUBINO, M. F.; SILVA, E. P. Genetic and morphometric evidence that the jacks (Carangidae) fished off the coast of Rio de Janeiro (Brazil) comprise four different species. **Biochemical Systematics and Ecology**, v. 71, p. 78-86. 2017.

ESPER, M. L. P.; MENEZES, M. S.; ESPER, W. Escala de desenvolvimento gonadal e tamanho de primeira maturação de fêmeas de *Mugil platanus* Gunther, 1880 da Baía de Paranaguá, Paraná, Brasil. **Acta Biol. Par**., v. 29, v. 255-263, 2000.

FEITOSA, D. L. **Caracterização da pesca com armadilhas para peixes no extremo leste do Ceará**. 2019. Dissertação (Mestrado em Engenharia de Pesca) Universidade Federal do Ceará, UFC, Fortaleza, CE. 2019.

FIGUEROLA-FERNÁNDEZ, M.; PENA-ALVARADO, N.; TORREZ-RUIZ, W. **Aspects of the reproductive biology of recreationally important fish species in Puerto Rico.** Puerto Rico: US Fish and Wildlife Service., 2008. 134p.

FONTELES-FILHO, A. A. **Oceanografia, biologia e dinâmica populacional de recursos pesqueiros.** Fortaleza, CE: Expressão Gráfica. 2011.

FONTELES-FILHO, A. A. Sinopse de informações sobre a cavala, *Scomberomorus cavalla*, e a serra, *S. brasiliensis*, no Estado do Ceará. **Arquivos Ciência do Mar,** v. 27, p. 21- 48, 1988.

FOURNIER, J.; PANIZZA, A. C. Contribuições das Áreas Marinhas Protegidas Para a Conservação e a Gestão do Ambiente Marinho. **R. RA'EGA.**, Curitiba, n. 7, p. 55-62, 2003.

FUENTE, L. G.; VÁZQUEZ, E. F.; CARVAJAL, C. R. A methodology for analyzing the impact of the artisanal fishing fleets on regional economies: An application for the case of Asturias (Spain). **Marine Policy**, v. 74, p. 165-176, 2016.

FUNCEME - Fundação Cearense de Meteorologia e Recursos Hídricos. Para entender melhor a previsão meteorológica para a estação chuvosa no Ceará. (2009). [internet] Disponível em: http://www.funceme.br/produtos/manual/clima/Clima/boletins_clima_alerta/EntenderPrevisaoQuadraChuvosa.pdf Acesso: 11 de maio 2020.

GALDINO, J. W. Reserva Extrativa Marinha (MER) da Prainha Do Canto Verde: A Comunidade Concretizando Um Sonho. **Raízes**, v. 32, p. 154-165, 2012.

GERVASI, C. L. **The reproductive biology of striped bass (Morone saxatilis) in chesapeake bay**. Thesis Master of Science. The Faculty of the School of Marine Science. Virginia, EUA. 2015.

GESTEIRA, T. C. V. Sobre a reprodução e fecundidade da serra, *Scomberomorus maculatus* (Mitchill), no Estado do Ceará. **Arquivos Ciência do Mar**, v. 12, p. 117-22, 1972.

GESTEIRA, T. C. V.; MESQUITA, A. L. L. Época de reprodução, tamanho e idade na primeira desova da cavala e da serra, na costa do Estado do Ceará (Brasil). **Arquivos Ciência do Mar,** v. 16, p. 83-88, 1976.

GONÇALVES, H. F.; GUEDES-FILHO, E. L.; CHAVES, K. C. B.; SANTOS, D. A. A situação da pesca artesanal nas regiões brasileiras. **Teoria e evidência econômica**, ano 20, n. 42, p. 110-138, 2014.

GONZÁLEZ-ÁLVAREZ, J.; GARCÍA-DE-LA-FUENTE, L.; GARCÍA-FLÓREZ, L.; FERNÁNDEZ-RUEDA, M. D. P.; ALCÁZAR-ÁLVAREZ, J. L. Identification and Characterization of Métiers in Multi-Species Artisanal Fisheries. A Case Study in Northwest Spain. **Natural Resources**, v. 7, p. 295-314, 2016.

GOODWIN, J. M.; FINUCANE, J. H. Reproductive biology of blue runner (*Caranx crysos*) from the eastern Gulf of Mexico. **Northeast Gulf Sci**., v. 7, p. 139-146, 1985.

HAMMER, O.; HARPER, D. A. T.; RYAN, P. D. Past: paleontological statistc software Packaged for education and data analysis. Version 1.94b. **Paleontologia eletrônica**, v.4, n.1, p. 1-9, 2001.

HERDSON, D. 2010. *Caranx crysos*. The IUCN Red List of Threatened Species. Version 2014. Disponível em: http://www.iucnredlist.org. Acesso em: 12 de jan. 2019.

HOGGARTH, D. D., ABEYASEKERA, S., ARTHUR, R. I., BEDDINGTON, J. R., BURN, R. W., HALLS, A. S., KIRKWOOD, G. P., MCALLISTER, M., MEDLEY, P., MEES, C. C., PARKES, G. B., PILLING, G. M., WAKEFORD, R. C., WELCOMME, R. L., **Stock assessment for fishery management – a framework guide to the stock assessment tools of Fisheries Management Science Programme (FMSP)**. FAO Fisheries Technical Paper. N 487. Rome, FAO. 2006. 261p.

HUMANN, P.; DELOACH, N. Reef Fish Identification: Florida, Caribbean and Bahamas. 3rd ed. New World Publications, Inc., Jacksonville, FL. 2002.

IBAMA/Brasil, 2009. Instrução Normativa n. 22, de 10 de Julho de 2009. Dispõe sobre o licenciamento ambiental para instalação de recifes artificiais no Mar Territorial na Zona Econômica Exclusiva brasileiros. Brasília: Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis, p. 1-5.

ICMBIO – Instituto Chico Mendes de Conservação da Biodiversidade. MER Prainha do Canto Verde. Disponível em http://www.icmbio.gov.br/portal/unidadesdeconservacao/biomas-brasileiros/marinho/unidades-de-conservacao-marinho/2295-MER-prainha-do-canto-verde. Acesso em: 22 de jan. 2019.

KJESBU, O. S.; HUNTER, J. R.; WITTHAMES, P. R. Report of the working group on modern approaches to assess maturity and fecundity of warm- and cold-water fish and squids, Bergen, Norway, September 2001. **Fisken og Havet,** v. 12, p. 1-140, 2003.

KOKKONEN, E.; VAINIKKA, A.V.; HEIKINHEIMO, O. Probabilistic maturation reaction norm trends reveal decreased size and age at maturation in an intensively harvested stock of pikeperch *Sander lucioperca*. **Fisheries Research**, v. 167, p. 1-12, 2015.

LESSA, R.; BEZERRA-JÚNIOR, J. L.; SANTANA, F. M.; NÓBREGA, F. M. **Peixes marinhos da região nordeste do Brasil.** DIMAR, *In*: Programa REVIZEE / Score-NE, 2009. 209p.

LESSA, R.; NÓBREGA, F. M.; SANTANA, F. M.; SOUTO, G. S. BALENSIFER, P.; DUQUE, P.; CHARLES, W. D. **Guia de identificação de peixes marinhos da região nordeste.** DIMAR, In: Programa REVIZEE / Score- NE, 2000. 138p.

LEVENE, H. Robust tests for equality of variances. p. 278-292. *In*: OLKIN, I. **Contributions to Probability and Statistics: Essays in Honor of Harold Hotelling Stanford studies in mathematics and statistics**, Stanford University Press. California, United States, 1960. 517p.

LIMA, J. S.; ZAPPES, C. A.; BENEDITTO, A. P.; ZALMONA, I. R. Artisanal fisheries and artificial reefs on the southeast coast of Brazil: Contributions to research and management. **Ocean and Coastal Management,** v. 163, p. 372-382, 2018.

LIMA, J. T. A. X.; FONTELES-FILHO, A. A.; CHELLAPPA, S. Biologia reprodutiva da serra, *Scomberomorus brasiliensis* (Osteichthyes:Scombridae), em águas costeiras do Rio Grande do Norte. **Arquivos Ciência do Mar,** v. 40, p. 24-30, 2007.

STURGES, H. A. The choice of a class interval. **Journal of the American Statistical Association**., v. 21, n. 153, p. 65- 66, 1926.

TEIXEIRA, L. C.; GARCIA, P. P. C. Qualidade do pescado: captura, conservação e contaminação. **Acta de Ciências e Saúde,** v. 2, n. 3, p. 62-76, 2014.

THOMPSON, R.; MUNRO, J. L. The biology, ecology and exploitation and management of the Carribean reef fishes. Part V. Carangidae (jacks). **Res. Rep. Zool. Dep. Univ. West Indies**., v. 3, p. 1-43, 1974.

TOLOSA, E. M. C.; RODRIGUES, C. J.; BEHMER, O. A.; FREITAS-NETO, A. G. **Manual de Técnicas para Histologia Normal e Patológica.** 2ª. ed. São Paulo: Manole, 2003. 331p.
TORREJON-MAGALLANES, J. (2020). 'sizeMat': An R package to Estimate Size at Sexual Maturity. R package version 1.1.1. Disponível em: https://www.researchgate.net/publication/306106553 acesso: 21 de Agosto de 2020.

VAZZOLER, A. E. A. M. **Biologia da reprodução de peixes teleósteos:** teoria e prática. Maringá, PR: EDUEM, 1996. 169p.

VICENTINI, R. N.; ARAÚJO, F. G. Sex ratio and size structure of *Micropogonias furnieri* (Desmarest, 1823) (Perciformes, Sciaenidae) in sepetiba bay, Rio de Janeiro, Brazil. **Braz. J. Biol.,** v. 63, n. 4), p. 559-566, 2003.

VIEIRA, R. H. S. F. **Microbiologia, higiene e qualidade do pescado**. São Paulo: Livraria Varela, 2004. 380 p.

ZAR, J. H. **Biostatistical Analysis**. 2nd Edition, Prentice-Hall, Inc., Englewood Cliffs, 1984, 718 p.