UNIVERSIDADE FEDERAL RURAL DE PERNAMBUCO
PRÓ-REITORIA DE PESQUISA E PÓS-GRADUAÇÃO
PROGRAMA DE PÓS-GRADUAÇÃO EM RECURSOS PESQUEIROS E AQUICULTURA

Kaio Lopes de Lima

DISTRIBUIÇÃO TEMPORAL, VULNERABILIDADE E USO DE HABITATS DE DUAS ESPÉCIES DE TUBARÃO CARCHARHINIFORMES NA COSTA DE PERNAMBUCO

Recife,
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Tese apresentada ao Programa de Pós-Graduação em Recursos Pesqueiros e Aquicultura da Universidade Federal Rural de Pernambuco como exigência para obtenção do título de Doutor.

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Dedicatória

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Resumo

A presente Tese tem como objetivo descrever a vulnerabilidade em relação a arte de pesca (rede de emalhe de fundo), conhecer a distribuição temporal das capturas destes elasmobrânquios e identificar o uso do habitat das espécies de elasmobrânquios mais abundantes no bycatch do emalhe de fundo (*Rhizoprionodon porosus* e *Carcharhinus acronotus*) na costa de Pernambuco. Entre 2010 a 2015, um total de 176 exemplares de elasmobrânquios foram capturados, sendo 6 espécies (*Rhizoprionodon porosus, Carcharhinus acronotus, Carcharhinus limbatus, Pseudobatos percellens, Hypanus marianae* e *Aetobatus narinari*). As espécies de peixes capturadas pelo emalhe de fundo foram categorizadas em relação a suscetibilidade e a produtividade com base na Análise de Produtividade-suscetibilidade (PSA). Dentre as espécies capturadas, *R. porosus* e *C. acronotus* foram classificados como as mais vulneráveis, obtendo altos indices de vulnerabilidade (2,13 e 1,90 respectivamente). Em relação a distribuição temporal nas capturas as espécies de elasmobrânquios mais abundantes foram *R. porosus* e *C. acronotus,* sendo clasificados como espécies acessórias: 47.45% e 24.38%, respectivamente Segundo constância de Dajoz (1976), sendo a maior parte destes ainda imaturos. *R. porosus* teve distibuição mais costeira, apresentando segregação por fase etária e por sexo (neonatos presentes ate a isóbata de 25m e adultos presentes em áreas mais progfundas), ja *C. acronotus* não apresentou segregação por fase etária ou por sexo. A maior participação de elasmobrânquios no Bycatch ocorreu no período seco. Os dados de captura aliados a modelos logisticos multimodais e binários, confirmaram que *R. porosus* possui uma área de nascimento em regiões costeiras (< 20 metros) de profundidade, diferindo do *C. acronotus* que possui área de nascimento em regiões mais distantes da costa (>30 m). embora os dados de captura indiquem a presença de berçáruios de *R. porosus* em áreas costeiras, estudos ligados e analises de elemetos traços são necessários para identificar possíveis áreas de berçários para *R. porosus* e *C. acronotus*. Estas informações são cruciais para o manejo das pescarias e conservação destas espécies ao largo da costa de Pernambuco.

Palavras-chave: Uso do habitat, fauna acompanhante, Emalhe de fundo.

Abstract

The aim of this thesis is to describe the vulnerability to fishing gear (bottom gillnet), to know the temporal distribution of the captures of these elasmobranchs and to identify the habitat use of the most abundant elasmobranch species in the bottom gillnet bycatch (*Rhizoprionodon porosus* and *Carcharhinus acronotus*) on the coast of Pernambuco. Between 2010 and 2015, a total of 176 specimens of elasmobranchs were captured, 6 species (*Rhizoprionodon porosus, Carcharhinus acronotus, Carcharhinus limbatus, Pseudobatos percellens, Hypanus marianae* and *Aetobatus narinari*). The species of fish captured as bycatch by the bottom gillnet were categorized in relation to susceptibility and productivity based on the Productivity-Susceptibility Analysis (PSA). Among the species captured, *R. porosus* and *C. acronotus* were classified as the most vulnerable, obtaining high vulnerability indexes (2.13 and 1.90 respectively). In relation to the temporal distribution in the catches, the most abundant species of elasmobranchs were *R. porosus* and *C. acronotus*, being classified as accessory species: 47.45% and 24.38%, respectively. According to Dajoz (1976), most of them are still immature. *R. porosus* had a more coastal distribution, with age and sex segregation (neonates present up to 25m isobath and adults present in more prog- nosed areas), and *C. acronotus* did not present segregation by age group or sex. The largest participation of elasmobranchs in the bycatch occurred in the dry period. The catch data, together with multimodal and binary logistic models, confirmed that *R. porosus* has a birth area in coastal regions (<20 meters) in depth, differing from *C. acronotus* that has a birth area in regions farthest from the coast (> 30 m). although catch data indicate the presence of *R. porosus* nurseries in coastal areas, linked studies and trace element analyzes are necessary to identify possible nursery areas for *R. porosus* and *C. acronotus*. This information is crucial for fishery management and conservation of these species off the coast of Pernambuco.

Keywords: Habitat use, bycatch, Botton Gillnet.

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Sumário

1. Introdução

O estado de Pernambuco possui uma pesca bastante diversificada e de carater artesanal, devido principalmente as caracteristicas fisicas e ambientais de sua região costeira, tendo águas bastante oligotróficas (pobre em nutrients), caracteristicas de ambientes tropicais, apresentando uma baixa densidade de estoques pesqueiros e uma alta diversidade de espécies (REVIZEE, 1995).

Devido a alta diversidade de espécies pesqueiras, Pernambuco possui uma grande variedade de petrechos de pesca, dentre estes petrechos, se destacam as redes de emalhe direcionada a pesca da serra (*Scomberomorus brasiliensis*) e da garajuba (*Caranx bartolomaei*) com 27% dos desembarques, a linha de mão 21,7% direcionada a captura de peixes recifais tais como, o sirigado (*Alphestes afer*) o dentão (*Lutjanus jocu*) e a cioba (*Lutjanus analis*), o arrasto de praia 15, 9 % direcionado a pesca do camarão sete-barbas (*Xiphopenaeus kroyeri*), camarão rosa (*Farfantepenaeus subtilis*) e do camarão branco (*Litopenaeus schmitti*)., covo para peixe 13, 4% tendo como espécie alvo o saramunete (*Pseudupeneus maculatus*) (LESSA et al 2009). A maior parte da frota pesqueira atua nas regiões costeiras e estuarinas 65% e 32% respectivamente, muitas vezes não ultrapassando a isóbata de 50 metros de profundidade (LESSA et al 2006).

A variedade de petrechos de pesca e a proximidade de atuação da frota nas regiões costeiras geram uma grande quantidade de fauna acompanhante nas capturas, esta fauna e composta principalmente por peixes (teleósteos e cartilaginosos), crustáceos e moluscos, além de espécies ameaçadas, que compõem a pesca incidental (quelônios, mamíferos aquáticos e algumas espécies de peixes).

Segundo Alverson *et al*, (1994) cerca de 27 milhões de toneladas de fauna acompanhante são descartadas no mundo anualmente, de tal pratica, podem advir graves consequências sobre a fauna acompanhante já que a pesca pode continuar sem que se perceba o declínio de várias espécies (BEVERTON, 1990). Parte da fauna acompanhante capturada no estado de Pernambuco é composta por elasmobrânquios (tubarões e raias) compondo cerca de 4% do total de espécies capturadas (em número de indivíduos) na rede de emalhe de fundo no estado, boa parte destes elasmobrânquios são capturados ainda imaturos (LESSA et al., 2006; MORGAN et al., 1992). Além das redes de emálhe, arrastos de camarão, e pescarias mais recentes, como o espinhel de fundo, são responsáveis pela captura de espécies de elasmobrânquios em diferêntes fases da vida (adultos, jovens e neonates). Embora ocorram com frequência nos desembarques de várias pescarias (industriais e artesanais), dados correspondentes a participação de elasmobrânquios nas capturas de fauna acompanhante (*Bycatch*) são escassos, tornando-se um grande desafio para avaliar e monitorar os impactos causados pela captura desta fauna (STOBUTZKI et al., 2001). Segundo Yokota e Lessa, (2006) a exploração de elasmobrânquios requer cuidados, pois, em geral, são animais de baixa fecundidade, maturação sexual tardia e alta expectativa de vida, atributos que lhes conferem uma baixa taxa de renovação de suas populações, o que os torna vulneráveis a exploração pesqueira.

Neste contexto, métodos baseados em avaliação de Risco Ambiental (Environmental Risc Assessment - ERA) têm sido utilizados no manejo ecossistêmico da pesca (FAO, 2003), por relacionarem dados e informações qualitativas, disponíveis disponíveis sobre as espécies que compõem a fauna acompanhante (bycatch) de uma determinada pescaria, levando em consideração aspéctos da dinâmica da frota a fim de caracterizar a “vulnerabilidade” destas espécies em relação as artes de pesca (VISINTIN e PEREZ, 2016). Estes métodos são conhecidos como “Análise de Produtividade-Sucetibilidade (PSA)”

Desta forma, a PSA (Vulnerabilidade) tem se tornado um método eficiente para avaliar os efeitos da pesca em várias espécies que compõe o Bycatch. Seu poder de previsão potencial ajuda como base para a implementação de políticas de gestão, sendo uma metodologia que pode ser usada para indicar uma possível redução populacional de um estoque, resultante da pesca desordenada (ARRIZABALAGA et al. 2001; GRIFFITHS et al. 2017). De forma geral a Análise de Produtividade- Susceptibilidade (PSA) permite inferir a vulnerabilidade das espécies ao aparato pesqueiro a partir da relação entre os atributos de "produtividade" e "suscetibilidade" (STOBUTZKI et al., 2001, 2002; HOBDAY et al., 2007; VIZINTIN e PEREZ, 2016).

Além da identificação das espécies mais vulneraveis ao esforço pesqueiro estudos relacionados ao uso do habitat por estas espécies, corroboram na elaboração de planos de conservação e manejo.

Dentre as espécies de elasmobrânquios capturadas em Pernambuco o cação-flamengo (*Carcharhinus acronotus*) e o cação-rabo-seco (*Rhizoprionodon porosus*) são as espécies mais frequentes, principalmente nas capturas com redes de emalhe (LIMA K.L., 2014). Por habitarem regiões costeiras, estes tubarões estão mais vulneráveis pesca devido a captura de indivíduos juvenis, bem como, degradação dos seus habitats, principalmente áreas específicas utilizadas por estas espécies para reprodução (berçarios). Esforços para avaliar como esses meso-predadores usam os habitats costeiros durante suas vidas foram desenvolvidos para espécies congêneres em outras partes do mundo (SIMPFENDORFER, et al., 2011), e essa informação é crucial para a construção de planos de conservação, que levam em conta o uso do habitat.

Em 2006, o Serviço Nacional de Pesca Marinha (NMFS-USA) classificou muitas destas áreas costeiras como “Habitats Essenciais de Peixes – EFH”. Segundo Conover et al (2000), a identificação de EFH’s é importante para proteger habitats fundamentais para os recursos marinhos, tais como, locais de alimentação e berçários de espécies comercialmente e ecologicamente importantes. Dentre os vários tipos de EFHs, os berçários exercem grande importância na manutenção de várias espécies de peixes e são geralmente caracterizados por apresentarem grande quantidade de alimento e um menor índice de predação, estando frequentemente localizados em áreas litorâneas e estuarinas (BERGMANN et al., 2004; CARLSON et al.,2002.).

No entanto, existe uma grande dificuldade de identificar com precisão estas áreas, principalmente no caso dos berçários para elasmobrânquios, devido à inconsistência do conceito atual de áreas de berçários. (HELPEL *et al*, 2007) propuseram critérios capazes de definir de forma mais consistente estas áreas de berçário, onde a residência de uma determinada espécie de tubarão dentro de uma região pode ser utilizada para determinar uma área de berçário, sendo estes: a maior frequência de jovens do ano presentes nas áreas de berçário a tendência destas espécies a permanecer ou retornar por períodos prolongados a estes locais, desta forma, a fidelidade local seria maior nestas áreas, outro ponto importante seria a filopatria de algumas espécies a estas áreas de berçário usado repetidamente estes locais ao longo dos anos.

Devido à pesca intensiva em áreas críticas como berçários, várias espécies de tubarões e raias, estão sofrendo declínios populacionais (VOOREN e KLIPPEL, 2005; BARRETO et al., 2015; CAMHI, 1998), o que justifica maiores esforços para entender a participação relativa de cada espécie capturada. (frotas artesanais e industriais) visando a sua gestão sustentável (WALKER, 1998; LESSA et al., 1999; VOOREN e KLIPPEL, 2005). Desta forma, o presente estudo teve como objetivo mensurar a participação dos elasmobrânquios nas capturas com redes de emalhe de fundo, e a vulnerabilidade destas espécies em relação ao aparelho de pesca, além de identificar o uso do habitat do cação-flamengo (*C. acronotus*) e do cação-rabo-seco (*R. porosus*) na costa de Pernambuco.

2. Objetivos

2.1. Objetivos gerais

O presente estudo tem por objetivo avaliar a vulnerabilidade destas espécies em relação as artes de pesca, identificar a composição específica de elasmobrânquios capturados como fauna acompanhante e Identificar os habitats essenciais e a possível existência de áreas de berçário para *Carcharhinus acronotus* e *Rhizoprionodon porosus* no litoral de Pernambuco.

2.2. Objetivos específicos

-Avaliar a vulnerabilidade das espécies de peixes (teleósteos e elasmobrânquios) capturados pelo emalhe de fundo;
-Estimar a frequência relativa e participação de elasmobrânquios nas capturas com rede de Emalhe de fundo e suas variações ao longo do ano;
- Identificar o uso do habitat por *Carcharhinus acronotus* e *Rhizoprionodon porosus*;
-Identificar áreas de berçários, para *Carcharhinus acronotus* e *Rhizoprionodon porosus* na costa de Pernambuco;
Os objetivos acima, serão atendidos no capítulos:
1) Vulnerability of fishes caught in coastal gillnet fisheries off northeastern Brazil;
2) Temporal distribuition of elasmobranchs caugth as bycatch in bottom net fisheries on the norteastern Brazil;
3) Identification of essential habitats of Caribbean sharpnose shark, *Rhizoprionodon porosus* and blacknose shark *Carcharhinus acronotus* in northeastern Brazil.

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4. Capítulo I

Artigo científico a ser encaminhado a Revista Ocean & coastal management

Vulnerability of fishes caught in coastal gillnet fisheries off northeastern Brazil

Todas as normas de redação e citações, deste capítulo, atendem as normas estabelecidas pela referida revista (em anexo)

VULNERABILITY OF FISHES CAUGHT IN COASTAL GILLNET FISHERIES OF NORTHEASTERN BRAZIL

ABSTRACT

Little is known about the fish composition of gillnet catches off the northeastern coast of Brazil, although it is one of the most used fishing gear in this region. These gillnets has target the Spanish Mackerel (Scomberomorus brasiliensis), with other species of fish caught as bycatch in Pernambuco, corresponding to 90% of total catch. From August 2010 to December 2012, 65 fishing trips carried out with artisanal boats using gillnets were monitored, where 109 species belonging to 41 families of teleost fish and 4 families of elasmobranchs were captured. To analyze vulnerability, the species caught were categorized according to susceptibility and productivity after a continuous fishing effort. Among the species caught Rhizoprionodon porosus, Carcharhinus acronotus and Lutjanus synagris were classified as most vulnerable. Most elasmobranchs are captured with lengths less than the size of the first maturation. To minimize the negative impacts of gillnet fishing on the accompanying fauna, management measures are suggested in this study.

Keywords: sustainability, bycatch, elasmobranchs, teleosts, management

INTRODUCTION

The gillnet is used by 13% of the artisanal boats in the state of Pernambuco and is responsible for 15.9% of the total weight landed (Lessa et al., 2006). In the fisheries where the spanish mackerel (*Scomberomorus brasiliensis)* is the target species, the volume (kg) of bycatch, which constitutes up to 90% of the catch, presents a high diversity of species.

According to Musick et al., (1999), the utilization of gillnets with small mesh sizes is one of the major causes for the high incidental capture rates and, consequently, the collapse of several stocks worldwide. The less selective fishing techniques causing overfishing in under- developed countries are considered to be a major problem (Pauly, et al., 2005). The consequences of this exploitation on the bycatch can continue without anybody ever noticing the decline of the species that are part of this group – which is due to the effort directed towards the target species (Beverton, 1992). The target species is generally more resilient than the bycatch species which end up declining (Camhi et al., 1998). The scarcity of knowledge available on the bycatch species submitted to excessive fishing efforts contributes to this context (Pina and Chaves, 2009).

In this context Methods based on Environmental Risk Analysis (ERA) have been used in the ecosystem management of fisheries (FAO, 2003), by relating available qualitative and available data information on the bycatch species of a given fishery, these methods are known as "Productivity-Spreadability Analysis (PSA)"

The Productivity-Susceptibility Analysis (PSA) allow to infer the vulnerability of the species to the fishing apparatus based on the relationship between the attributes of "productivity" and "susceptibility" (Stobutzki et al., 2001, 2002; Hobday et al., 2007; Vizintin and Perez, 2016). In this way, the classification of species according to the characteristics of susceptibility and productivity could show the relative capacity of the species to sustain the fishery and, therefore, its priority for management.

In the northeast of Brazil, studies focus on the vulnerability of the bycatch in trap fishing and shrimp trawling (Feitosa et al., 2008; Silva Jr. et al., 2013; Vizintin and Perez, 2016). However, the few studies on gill fisheries available (Reis and Pawson, 1999; Tomás, 2003; Lucena et al., 2004; Alves et al., 2009) provide limited information to quantify the real impact on the bycatch. In the study area, the bycatch is composed of a great variety of species, commercialized as "second-rate fish" and discarded at landing as *Pseudobatos percellens*, *Echeneis naucratus* and *Scorpaena brasiliensis*, among others.

Many species are also vulnerable to anthropogenic impacts because they are coastal species. This makes them more susceptible to fishing because of the capture of young individuals and the general degradation of their essential habitats used for feeding, reproduction and as nurseries (Knip et al., 2010).

The main objective of the present study was to identify the degree of vulnerability of the species caught as bycatch in relation to gillnet fishing– so as to adopt management measures that minimize these catches. For this purpose, the Productivity-Susceptibility Analysis (PSA) will be used. A secondary objective of the study was to present the specific composition of the catches obtained by the use of this fishing gear in the study area and to establish specific measures for the proper management of this fishery.

MATERIALS AND METHODS

Study site

The study area comprised the northeast coast of Brazil in the State of Pernambuco between 07º15 '45' '- 09º 28' 18 "S / 034º 48' 33 " - 041º 19 '54"W, where the continental shelf has an average width of 35 km, a low depth, a gentle slope and a shelf break of between 50 and 60 meters (Manso et al., 2003). The climate of the area is characterized by rainfall, with a dry season that is well defined and relatively short in the autumn (Köppen, 1931). The area is dominated by tropical humid or pseudo-tropical climate and the waters that cover the continental shelf have a surface temperature of 27.0 to 28.7°C. From the surface to the depth of 50 m, the temperature is practically constant, starting a decrease starting at 60-70 m. The oceanic waters are predominantly warm and oligotrophic, presenting a deep thermocline, with low primary productivity (Lessa et al., 2005). The coast is influenced by the SE and NE trade winds throughout the year (CPRH, 1999).

Fisheries were carried out from August 2010 to December 2012, totaling 65 bids between5:00 pm and 10:00 p.m., on boats equipped with gillnets whose stretched meshes ranged from 35 to 45 mm in size. The height of the nets ranged from 1.5 to 1.7 m, and the length from 0.95 to 3.7km. The fisheries occurred at between 7 and 50 meters of depth, in different types of substrate (sand, mud, gravel and coral). Fishing trips took place in Pontas de Pedra, Pau Amarelo, Candeias, Gaibu, Porto de galinhas, Tamandaré and São José da Coroa Grande (Figure 1).

During fishing trips, latitudes and longitudes were recorded at the beginning and at the end of the bids using a manual GPS, and the positions were plotted using the Q Gis 2.12 Software. Depth was recorded – with the use of portable sonar – and also the times of launching and recollection of the nets. The captured specimens were identified with the aid of the literature (Nelson 1994; Menezes et al., 2003; Nóbrega et al., 2009a) and classified as alive or dead at the time the nets were hoisted on board (survival).

During the landings the following was recorded from each specimen: sex, total length (TL), Fork length (FL), interdorsal length (ID) for sharks and disc width (DW) for rays, all in cm. The total weights were recorded in Kg.

For the studies related to Productivity-Susceptibility Analysis (PSA), field data were collected and literature information was used when necessary. In cases where there was no information for the analyzed species, we used existing information from species of the same family.

Adaptations were made to the methodology based on Stobutzki et al., (2001) Hobday et al., (2011) and Patrick et al., (2009). In this sense, "Productivity was defined as the ability of a given species to restore population losses after a continuous fishing effort, based on biological-population attributes, available in the literature." Susceptibility "was defined as the propensity of a species to be captured by a particular fishing apparatus, including attributes that measure how much the species is exposed to the capture power of the fishing apparatus. The attributes were defined based on the availability of information in the literature on the analyzed speciesaccording to attributes listed below:

Productivity index:

(1) Natural mortality index: The recovery capacity of a population is related to calculated mortality (Sparre and Venema, 1992) calculated: mortality index = (Lmax - L med) / (Lmed - Lmin) ;(2) Maximum length (L_{max}): Most length ever record in literature. Large fish tend to have low productivity, replenishing their stocks more slowly; (3) Von Bertalanffy Growth Rate: Growth index as a function to length for the age and growth model. (4) Reproductive strategy: Associated with possible amount of fertilized oocytes. (5) L_{50}/L_{max}: Average life span ratio who specie take to get adult phase. Species that mature with size close to their maximum size would be less likely to reproduce during life (Murua et al., 2009). (Table 1).

Susceptibility index:

(1) Constancy: Percentage of samples which the species was present, based on Dajoz constancy index (Dajoz, 1976), (2) Vertical use of habitat: Strategy vertical use of water to even specie caught by gillnet fleet. Species that use pelagic and mesopelagic zones they are usually more active, raising the caught probability. (3) Favorite substrat: Relationship between the life habits of species and sedimentation type of area. They fleet usually acts above coral reefs and mudbanks because to have high probability of target species capture in this areas. (4) Survival rate: Survival probability after capture of individual. The species that was caught still alive and survive until gillnet gathering are release to the sea. (5) Presence

of fishing sites: Species that have been caught and all places of action suffer more effort from this fishery. (6) Diet: Association with feed strategy and chance to cross with the fishing gear (Table 2).

After defining the attributes, these were classified in relation to three categories (high, medium and low), In addition, "cut-off lines" were established among the attributes based on the adopted criteria (Patrick et al., 2009). For each axis scores were assigned from 1 to 3, in relation to productivity score 1 corresponds to the lowest category of productivity and 3 the most productive category. In relation to susceptibility score 1 corresponds to the least susceptible category and 3 to the most susceptible category. Score 2 corresponds to the intermediate category for both axes. The productivity and susceptibility indices were calculated according to the following equation:

$$(p) \text{ or } (a) = \sum (W * R) / \sum W$$

Where p or a are the average scores of productivity or susceptibility, w is the weight of each attribute and R, is the score received by the species at each attribute.

From the definition of each index (productivity and vulnerability) the data were plotted on a two-dimensional scale, where each species was positioned according to its average productivity score (ordinate axis) and susceptibility (abscissa axis). The productivity being represented in inverse scale, that is, the maximum value 3 positioned at the origin of the axes. Susceptibility was represented on the abscissa axis, being the minimum value 1 positioned at the origin of the axes. In this context, the species were classified as low productivity (value <1.5) and "high productivity" (value> 1.5), and in relation to Susceptibility: high susceptibility (value> 2.5) and low susceptibility (value <2.5). In this way, species presented low vulnerability and high susceptibility are more vulnerable to fishing effort than species that presented high productivity and low susceptibility.

The vulnerability was calculated through Euclidean distance, considering 3 and 1 as focal points, based on the vulnerability index (v) proposed by Hobday et al., (2011):

$$V \sqrt{(p-3)^2 + (a-1)^2}$$

When p is the productivity index and s is the susceptibility index.

RESULTS

During the study, 4,631 individuals were captured from 109 species of fish, of which 103 were teleost and 6 were elasmobranchs (Table 4). The most abundant family among the teleost was Carangidae (1,169 individuals and 13 species), of which the most abundant species was *Caranx bartholomaei* (601 individuals). In descending order of importance, the following families were present: Sciaenidae (700 individuals; 8 species), Scombridae (664 individuals, 5 species), Haemulidae (535 individuals, 9 species), Ariidae (359 individuals, 4 species), and Lutjanidae (189 individuals, 7 species). In relation to elasmobranchs, there were 172 individuals of 3 different species from the Carcharhinidae family. Most catches comprised Perciformes (3.025 individuals, 55 species), followed by Siluriforms (359 individuals, 4 species).

The productivity and susceptibity analysis demostrated that *Rhizoprionodon porosus, Carcharhinus acronotus* and *Lutjanus synagris* are the most vulnerable species to gillnet fishery in Pernambuco. The high susceptibity and the low productivity index to *R. porosus* was the main reason why both species possibly suffer more because overfishing damage. In second moment, *C. acronotus* and *L. synagris* was the second most vulnerable group (Figure 2).

The high longevity and life strategy for *C. acronotus* does it less productivity when compared to the another bony fishes. *L. synagris* is the second bony fish less productive and second most vulnerable.

The relationship between first maturity length and total length mean point *C. acronotus* as the worst situation compared to the others species. *Caranx bartholomaei* shows this bad relationship also worrying but not as much as *C. acronotus.*

For Elasmobranchs, total length ranged from 36 to 100 cm for *R. porosus* and 49.5 to 89 cm for *C. acronotus*. (Table 3). Among the teleosts total lengths ranged from 18.7 to 65 cm for *Cathorops spixii,* and from 17.5 to 40.5 for *L. synagris*.

DISCUSSION

The artisanal fleet of bottom gillnet fishing on the coast of the state of Pernambuco operates in a wide range of habitats and depths capturing a great diversity of fish, both teleosts and elasmobranchs. Information regarding their biology and stock situation is scarce for the majority. According to Stobutzki et al., (2001), the lack of information about the species that make up the bycatch fauna is a great challenge to monitoring the impacts of fisheries, as this information is essential to evaluate the sustainability of this fauna.

Because your huge taxa distance, this species not be calculated in Productivity and Susceptibility Analysis. Nevertheless, the PSA is an important tool for assessing possible fishery impacts that are difficult to quantify. Lucena-Frédou et al., (2016) indicated that the PSA risk assessment for several species converge with the results of IUCN fish stock assessment methods and assessment data. This indicates that even with limitations the PSA is still a fairly robust method for ecological risk assessment.

According to Lucena et al., (2004), the species that compose the bycatch are mainly those that share the same habitat and have a body shape with perimeters similar to those of the target species. In addition, species that feed in the same area and of the same prey as the target species, or prey on these species, will have greater susceptibility to the fishing gear. Wootton (1989) considers that food preference directly influences the position of the species in the water column and consequently the susceptibility to the fishing gear used.

Thus, benthic and benthopelagic species are more vulnerable to the fishing gear, since this fishery acts mainly on species that are distributed closer to the bottom. Most of the captured species are freed from meshes dead, especially teleosts, among which the most resistant specimens were those of the family Ariidae (*Catrorops spixii and Bagre marinus*), followed by the family Scianidae (*Larimus breviceps*)

For the elasmobranchs, the highest survival rate occurred for species *Pseudobatos percellens* and *Rhizoprionodon porosus*. Stobutzki et al., (2001) suggests that in shrimp trawling in Australia most sharks and rays die within the trawls (56%), particularly the smaller ones. Thus, differences of survival rates among species may influence changes in their relative abundance. The benthic species were the most susceptible, suggesting a higher mortality because they are species bound to the substrate.

In addition, their diet is mainly composed of benthic organisms, which increases the possibility to be caught by bottom gillnets. Among the teleosts the most susceptible species were those of families Scianidae, Serranidae, Polynemidae, Elopidae and Ariidae; similar to shrimp fishing in the state of Rio Grande do Norte (Silva Jr. et al., 2013). Among the elasmobranchs the *Hypanus marianae* species was the most susceptible to capture.

Most of the species classified as susceptible to fishing gear feed mainly on crustaceans (shrimp), which also form part of the diet of the target species *S. brasiliensis.* Menezes (1970), when analyzing the brazilian spanish mackerel diet, observed a preference for teleosts and penaeid crustaceans, as is also the case for some elasmobranchs, such as *R. porosus* and *H. marianae*, which feed on small crustaceans and demersal teleosts (Silva and Almeida, 2001; Costa et al., 2015). Besides these, *B. marinus* and *L. breviceps* have benthic eating habits.

The high vulnerability to *S. brasiliensis* and *L. synagris* is a worrisome characteristic for this fishery. For decades, *S. brasiliensis* has been the target specie to many fleets in brazilian northeastern (Rangely et al., 2010; Batista e Fabré, 2001; Fonteles-Filho, 1988). Several authors indicate *L. synagris* as the overexploited in many areas of brazillian northeastern (Freitas et al., 2011; Fredou et al., 2006; REVIZEE, 2006).

Several species of teleosts presented low vulnerability with values above 1.5 that is a relatively high recovery rate and a moderate susceptibility to fishing gear. Only the *L. synagris* saw a high vulnerability with a value above 1.54, tending to a low recovery, which can be explained by the capture of this species being composed mainly by young individuals (Figure 2)

Elasmobranchs were the species with the high vulnerable. Of these, *R. porosus* obtained the higth rate of 2.13, *C. acronotus* obtained a rate of 1.90.

According REVIZEE (2006), *R. porosus* have been caught in significant quantities by gillnet fishery in brazilian northeastern for some time and this present study your situation does not change. Altough it is not the target specie, this elasmobranch show high capture to actual fleet and it is still high vulnerable species. This is a worrying fact taking into account its trophic and ecological importance for the environment.

Despite the fact that the value of 2.13 shows a tendency for recovery, *R. porosus* was the elasmobranch most captured by bottom gillnets, with most catches (54%) being composed of individuals below first maturation. Mattos and Hazin (2001) observed a mean fecundity for *R. porosus* of 4.5 individuals per year, with a first maturation size of 65 cm. The species suffers an annual reduction of 17.1% (Lessa et al., 2006). According to Lessa et al., (2009), the higher probability for recovery is due to the low maturation age for the species (3.3 years).

Although it presented a vulnerability value smaller than *R. porosus*, which may be related to the preference of these species for areas more distant from the coast, thus reducing its successibility. However, the low fecundity values of *C. acronotus* decrease the recovery capacity of its populations (Barreto et al., 2011).

All *C. acronotus* individuals captured were young and below the first maturation size that is 103 cm (Hazin et al., 2002; Barreto et al., 2011), causing reductions of recruits to the adult stock due to capture before reproduction. Thus, fishing with gill nets exclusively removes the young from the population, which threatens the sustainability of the species in the study area.

Considering current fishing levels, *C. acronotus* is already overexploited, with a decrease of 13.6% every 8.3 years (Barreto et al., 2011). Condition that corroborates with the results of the present study, where *C. acronotus* appears as the second species most vulnerable to fishing with gill nets in the background.

The Ariidae family was the fifth most abundant in the catches, the catfish being closest to recovery from the fishing efforts, but having a relatively high susceptibility. However, the family presents a greater tendency towards sustainability, due to the selectivity of the fishing gear for lengths below first maturation size, which allow juvenile individuals to escape. This does not corroborate with Stobutzki et al., (2001), who when analyzing shrimp trawling classified the Ariidae family as species of low recovery and high susceptibility. Such difference may be related to the selectivity of the fishing gear, since shrimp trawling has low selectivity, capturing mainly young individuals.

According to Carvalho-Filho (1999), this type of reproductive strategy diminishes the prolificity of catfish in general, reducing their recovery capacity compared to fish that reproduce by dispersion. Parental care, while reducing the likelihood of juvenile predation, it increases the likelihood of survival and maturation attainment.

Of the six species of elasmobranchs caught, only two (*R. porosus* and *C. acronotus*) obtained expressive values in catches with gill net. *R. porosus* occurred in 43% of the catches contributing with a percentage of 8.6% of the total weight of the landings. *C. acronotus* occurred in 17% of fisheries with a share of 1.42% of the total number of individuals caught, *Carcharhinus limbatus*, *Pseudobatos percellens*, *Hypanus Marianae* and *Aetobatus narinari*, occurred in 3 fisheries representing less than 1% of the total landed. According to some authors (Roberts and Hawkins, 1999; Jennings et al., 1999), Species that have a late maturation like elasmobranchs and some reef teleosts are highly vulnerable to fishing, especially when they are part of the bycatch.

Stobutzki et al., (2001), when studying shrimp trawling, warns that even for species with catches of less than 1% in trawl numbers, if fishing days are multiplied by the number of nets

(2) a significant number could be caught, which in the case in question could reach 733 individuals in a period of one year.

The low catch of *H. marianae* and *A. narinari* may be related to the selectivity of the fishing gear used, since due to the shape of the body of the target species, they do not get trapped in the gear, but may become entangled within it. This may also occur with adult sharks, since these have a larger body perimeter than the body perimeter of the target species (Spanish mackerel), which prevents them from being "caught by the net" through the gills. From all species, the elasmobranchs are the most affected by gillnet fishing, and of these *R. porosus* was the least sustainable with respect to fishing gear. Lessa et al., (2009) recorded *R. porosus* and *C. acronotus* in the landings of the bottom gillnet fleet of Pernambuco and Alagoas, targeting Brazilian Spanish mackerel between January 1998 and March 2000, with a frequency of relative occurrence of 0.47% and 0.17% respectively.

Gillnet fishing was more sustainable for most teleosts, mainly due to the fact that they were caught mostly as adults exhibiting relatively high prolificicy. Most of the catches occurred in areas with a consolidated substrate, composed of coral reefs, reef ecosystems (rocks) with high biological diversity (Connell, 1978). Due to this fact the artisanal fleet targets these specific areas where there are red fish**,** whiting and grouper of high commercial value, which increases the interaction between the gillnet gear and the fish. Thus, bottom gillnet fishing in areas composed of consolidated substrates has a greater impact on elasmobranchs. According to Kotas et al., (1995), this fishery is responsible for large impacts on the populations of sharks and stingrays in the South of Brazil.

The principal limitation for PSA application is the incorporates another effects provides to other fisheries that's operates on the same region. There is also a high sensitivity regarding the inclusion or exclusion of species evaluated since this causes changes in species ranking (Neat et al., 2010). For examole, occasionally not commercially crustaceans comes tangle in gillnet and are returned or discarded for the crew.

The PSA is a efficient method to evaluate the fishery effects in an ecosystem when you have some or majority limited stock data for the caught species. Your potential forecasting power helps as a basis to management policies implementation (Arrizabalaga et al., 2001; Griffiths et al., 2017). The vulnerability index is a methodology that can be used to indicate a possible population reduction of a stock, resulting from disordered fishing (Griffiths et al., 2017).

Bottom gillnet fishing is a multispecies fishery that captures a great diversity of species. This hinders specific management actions for species with lower recovery rates, captured as bycatch. Among them *C. acronotus*, the most affected, is currently listed as near threatened – NT, according to the IUCN (Morgan et al., 2009), due to the intensive pressure inflicted by artisanal coastal fishing., A viable alternative to minimize the mortality of elasmobranchs and species with low resilience affected by bottom gillnet fisheries, would be the creation of marine conservation units (MPA) with exclusion areas for fishing in essential habitats for fish - EFHs (nurseries, feeding areas, etc.) – located mostly near the coast where the artisanal fleet acts.

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FIGURE LEGENDS

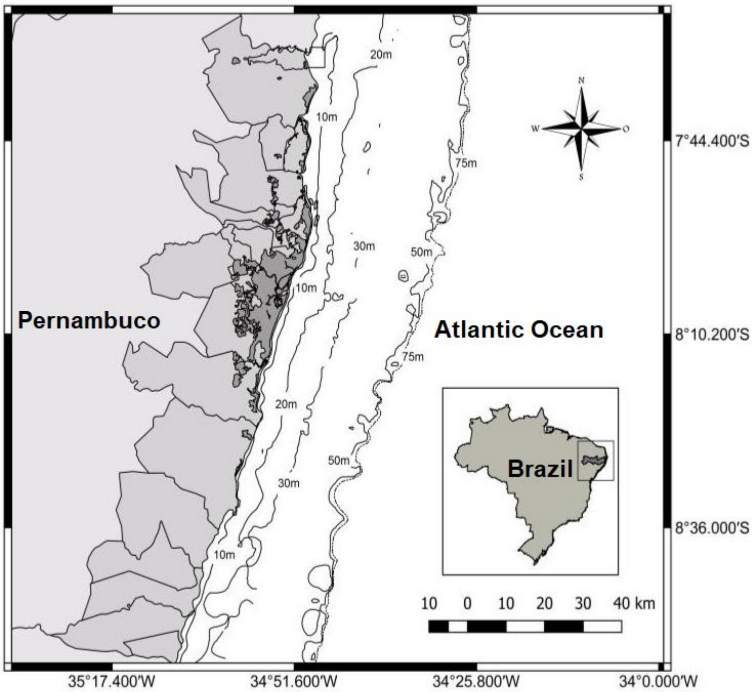

Figure 1. Fishing bids with bottom gillnets from August 2010 to November 2012, at depths of 7 to 50 m in the northeastern region of Brazil.

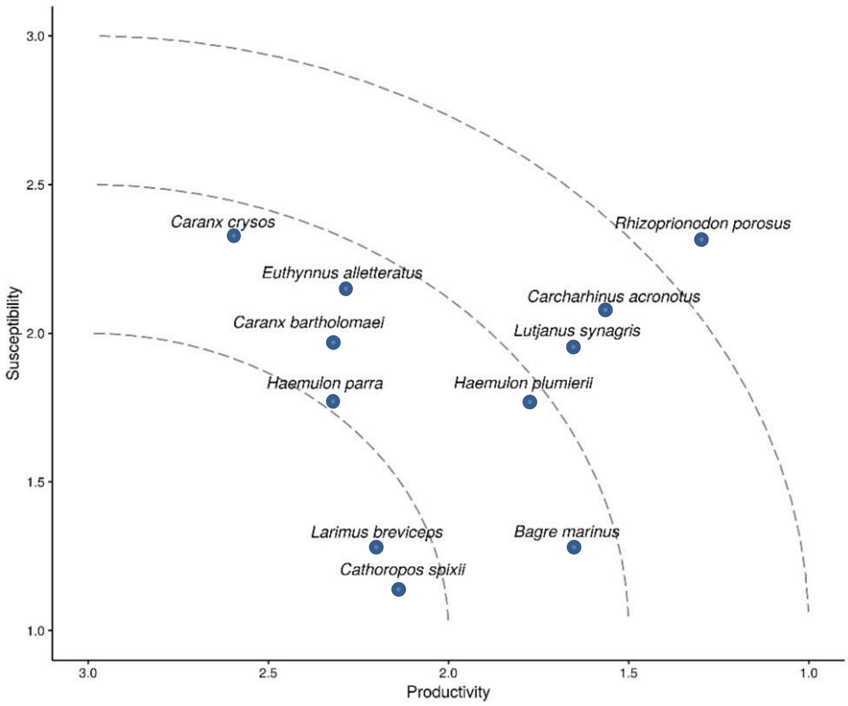

Figure 2. Analysis of productivity and susceptibility of the species fish caugth with botton gillnet in fisheries of spanish mackerel *Scomberomorus brasiliensis* in the Northeast of Brazil.

TABLE LEGENDS

Table 1. Productivity criteria of the PSA based on species behavior and history

Productivity			
	1	2	3
Maximum total length	>50cm	50cm~100cm	>100cm
Reproductivity strategy	External fecundation	External fecundation with parental care area	Internal fecundation
Natural mortality Index	>3.44	3.44~1.88	<1.88
Growth rate (K)	>0.3	0.3~0.2	<0.2
L50/Lmax	<0.3	0.3~0.5	>0.5

Table 2. Susceptibility criteria of the PSA based on fishery strategy, fishing gear and species behavior captured as bycatch in fisheries using botton gillnet direct to Spanish mackerel Scomberomorus brasiliensis, off northeast Brazil.

Susceptibility			
	1	2	3
Vertical use habitat	Benthic	Benthopelagic	Pelagic
Favorite substrate	Habitats outside the fishing area	Other habitats inside the fishing area	Reefs, sandbanks and mudbanks
Survival rate	>66%	33%-66%	<33%
Prsence in Fishing sites	<3 sites	Between 3 and 4 sites	>4 sites
Diet	Feeds outside the fishing area	Feeds ocasionally on fishing area	Feeds inside fishing area
Constancy	<30%	30%-50%	>50%

Table 3. Number of specimens (Sample), Amplitude of lengtn caugth (TL), size of first maturity (L_{50}) obtained from the literature and percentage of specimens with lengths below the first maturation of species of the most constant teleost and elasmobranchs, captured by gillnets on the continental shelf of Pernambuco state.

Species	Sample	Amplitude of lengtn in cm	L_{50} cm (%)	Below the L_{50} (%)	Reference of L_{50}
B. marinus	170	18-48	33	23.5	Pinheiro, et al., 2006
C. bartolomaei	695	21.2-46	32	0.01	Sierra, et al., 1986
C. acronotus	58	49.5-89	115	100	Hazin, et al., 2002
C. crysus	306	23-45	26.7	5	Goodwin, et al.,1985
C. spixii	159	18.7-65	10.4	0	Faváro, et al., 2005
E. alleterattus	121	28-48	41	66.9	Hajjej, et al., 2010
H. parra	133	15.4-35	16	0.6	Froese, et al., 2010
H. plumieri	232	12.5-32	16.9	0.8	Shinozaki-Mendes, et al., 2013
L.breviceps	415	15-30.7	19	5	Vazoller, et al., 1989
L. synagris	110	17.5-40.5	24.5	19.5	Luckhurst, et al., 2000
R. porosus	99	36-100	65	54	Mattos, et al., 2001

Table 4. Species of fish caught by bottom gillnet fishing directed to the capture of Spanish mackerel (*Scomberomorus brasiliensis*) in the Northeast region of Brazil, divided by family and species and quantified as the number of individuals captured by species (N) and represented individually by labels (L).

Family	L	Specie	N	Family	L	Specie	N	Family	L	Specie	N
Acanthuridae	Aba	*Acanthurus bahianus*	31	Fistulariidae	Fpe	*Fistularia petimba*	2	Pomacanthidae	Hci	*Holacanthus ciliaris*	10
	Ach	*Acanthurus chirurgus*	53	Gerreidae	Egu	*Eucinostomus gula*	11		Htr	*Holacanthus tricolor*	1
	Aco	*Acanthurus coeruleus*	4		Ebr	*Eugerres brasilianus*	43	Pomatomidae	Psa	*Pomatomus saltatrix*	1
Achiridae	Ali	*Achirus lineatus*	2	Haemulidae	Asu	*Anisotremus surinamensis*	2	Priacanthidae	Par	*Priacanthus arenatus*	1
Albulidae	Avu	*Albula vulpes*	7		Avi	*Anisotremus virginicus*	64	Rachycentridae	Rca	*Rachycentron canadum*	2
Ariidae	Bba	*Bagre bagre*	20		Cno	*Conodon nobilis*	83	Rhinobatide	Ppe	*Pseudobatos percellens*	2
	Bma	*Bagre marinus*	169		Hau	*Haemulon aurolineatum*	23	Scaridae	Sco	*Scarus coelestinus*	1
	Csp	*Catrorops spixii*	158		Hfl	*Haemulon flavolineatum*	3		Sfr	*Sparisoma frondosum*	7
	Spr	*Sciades proops*	12		Hch	*Haemulon chrysargyreum*	5		Sru	*Sparisoma rubripinne*	14
Bothidae	Boc	*Bothus ocellatus*	7		Hpa	*Haemulon parra*	111	Sciaenidae	Cle	*Cynoscion leiarchus*	46
Carangidae	Aci	*Alectis ciliares*	2		Hpl	*Haemulon plumieri*	215		Cvi	*Cynoscion virescens*	10
	Cba	*Caranx bartholomaei*	601		Oru	*Orthopristis ruber*	29		Lbr	*Larimus breviceps*	415
	Ccr	*Caranx crysos*	311	Holocentridae	Has	*Holocentrus ascensionis*	25		Man	*Macrodon ancylodon*	47
	Chi	*Caranx hippos*	12		Mja	*Myripristis jacobus*	6		Mam	*Menticirrhus americanus*	6
	Cla	*Caranx latus*	16	Lutjanidae	Lan	*Lutjanus analis*	17		Mfu	*Micropogonias furnieri*	128
	Cch	*Chloroscombrus chrysurus*	62		Lap	*Lutjanus apodus*	17		Pbr	*Paralonchurus brasiliensis*	47
	Dma	*Decapterus macarellus*	113		Ljo	*Lutjanus jocu*	8		Sra	*Stellifer rastrifer*	1
	Opa	*Oligoplites palometa*	4		Lpu	*Lutjanus purpureus*	1	Scombridae	Ath	*Auxis thazard*	56
	Scr	*Selar crumenophtalmus*	16		Lsy	*Lutjanus synagris*	110		Eal	*Euthynnus alletteratus*	122
	Ssp	*Selene spixii*	25		Lch	*Lutjanus chrysurus*	5		Sca	*Scomberomorus cavalla*	15
	Svo	*Selene vômer*	1	Monacanthidae	Amo	*Aluterus monoceros*	5		Sbr	*Scomberomorus brasiliensis*	454
	Tca	*Trachinotus carolinus*	1		Asc	*Aluterus scriptus*	12		Sre	*Scomberomorus regalis*	17
	Tgo	*Trachinotus goodei*	5		Cma	*Cantherhines macrocerus*	1	Scorpaenidae	Spl	*Scorpaena plumieri*	12
Carcharhinidae	Cac	*Carcharhinus acronotus*	58		Shi	*Stephanolepis hispidus*	1	Serranidae	Aaf	*Alphestes afer*	2
	Cli	*Carcharhinus limbatus*	1	Mugilidae	Mcu	*Mugil curema*	20		Cfu	*Cephalopholis fulva*	7
	Rpo	*Rhizoprionodon porosus*	113	Mullidae	Mma	*Mulloidchthys martinicus*	10		Ead	*Epinephelus adscensionis*	3
Centropomidae	Cpa	*Centropomus parallelus*	12		Pma	*Pseudupeneus maculatus*	3	Sparidae	Apr	*Archosargus probatocephalus*	1
	Cun	*Centropomus undecimales*	5	Muraenidae	Gfu	*Gyminotorax funebris*	1		Aro	*Archosargus rhomboidalis*	13
Clupeidae	Oog	*Opisthonema oglinum*	39		Gvi	*Gyminotorax vicinus*	1		Cpe	*Calamus pena*	17
Dactylopteridae	Dvo	*Dactylopterus volitans*	6		Goc	*Gymnothorax ocellatus*	1		Cpn	*Calamus pennatula*	9
Dasyatidae	Hma	*Hypanus marianae*	1	Aetobatidae	Ana	*Aetobatus narinari*	1	Sphyraenidae	Sgu	*Sphyraena guachancho*	4
Echeneidae	Ene	*Echeneis naucratus*	7	Ostraciidae	Ltr	*Lactophrys trigonus*	3	Stromateidae	Ppa	*Peprilus paru*	2
Elopidae	Esa	*Elops saurus*	8	Paralichthyidae	Cch	*Cyclopsetta chittendeni*	2	Synodontidae	Tmy	*Trachynocephalus myops*	1
Engraulidae	Lgr	*Lycengraulis grossidens*	11		Spo	*Syacium papillosum*	10	Trichiuridae	Tle	*Trichiurus lepturus*	3
	Ced	*Cetengraulis edentulus*	1	Polynemida	Pol	*Polydactylus oligodon*	2	Triglidae	Ppu	*Prionotus punctatus*	1
Ephippidae	Cfa	*Chaetodipterus faber*	3		Pvi	*Polydactilus virginicus*	15				

5. Capítulo II

Artigo científico a ser encaminhado a Revista Ciência Agronômica

Temporal distribution of elasmobranchs caugth as bycatch in bottom net fisheries on the norteastern Brazil

Todas as normas de redação e citações, deste capítulo, atendem as normas estabelecidas pela referida revista.

Temporal distribution of elasmobranchs caught as bycatch in bottom net fisheries on the northeastern Brazil [1]

Distribuição temporal de elasmobrânquios capturados como bycatch na pesca de emalhe de fundo no Nordeste do Brasil.

ABSTRACT - The knowledge of temporal distribution and constance of elasmobranchs in the bottom gillnets along the coast of Pernambuco and crucial to understand how these animals are affected by fishing. The present study was conducted in the coast of Pernambuco between the years 2010 to 2015, and had as objective to know the composition and frequency and the temporal distribution of elasmobranchs captured by the artisanal fishing fleet with bottom gillnet. The total sample was composed by 176 specimens of elasmobranchs divided into 6 species: *Rhizoprionodon porosus* (64.2%), *Carcharhinus acronotus* (32.95%), *Carcharhinus limbatus* (0.57%), *Pseudobatos percellens* (1.14%), *Hypanus marianae* (0.57%) *e Aetobatus narinari* (0.57%). Analysis of muscle tissue of *Rhizoprionodon* spp. confirmed the NADH-2 gene in its entirety (1044 bp), indicating the presence of only the *R. porosus* species in the catches. The most abundant species in the catches were *R. porosus* and *C. acronotus* (113 and 58), respectively, most of them still immature. *R. porosus* and *C. acronotus* were classified as accessory species (> 0.15 <0.50). The association between the catches of immature individuals of *R. porosus* and *C. acronotus* with bottom gillnet fishing may lead to a reduction in the recruitment of juveniles to the reproductive stock.

Keywords: Elasmobranchs; fishing effort; georeferencing; bottom gillnet.

RESUMO - O conhecimento da distribuição temporal e constância de elasmobrânquios capturados nas redes de emalhe de fundo ao longo da costa de Pernambuco e crucial para entender como estes animais são afetados pela pesca. O presente estudo foi realizado ne costa de Pernambuco entre os anos de 2010 a 2015, e teve como objetivo conhecer a composição e freqüência e a distribuição temporal de elasmobrânquios capturados pela frota pesqueira artesanal com redes de emalhe de fundo. A amostra total foi composta por 176 exemplares de elasmobrânquios divididos em 6 espécies: *Rhizoprionodon porosus* (64.2%), *Carcharhinus acronotus* (32.95%), *Carcharhinus limbatus* (0.57%), *Pseudobatos percellens* (1.14%), *Hypanus marianae* (0.57%) *e Aetobatus narinari* (0.57%). Análise do tecido muscular de *Rhizoprionodon* spp. confirmaram o gene NADH-2 em sua totalidade (1044 pb), indicando a presença apenas das espécies de *R. porosus* nas capturas. As espécies mais abundantes nas capturas foram *R. porosus* e *C. acronotus* (113 e 58), respectivamente, sendo a maioria ainda imatura. *R. porosus* e *C. acronotus* foram classificados como espécies acessórias (> 0,15 <0,50). A associação das capturas de indivíduos imaturos de *R. porosus* e *C. acronotus* com pesca na rede de emalhe de fundo pode levar a uma redução no recrutamento de juvenis para o estoque reprodutivo.

Palavras chave: Elasmobrânquios; Esforço pesqueiro; Georreferenciamento; Emalhe de fundo.

INTRODUCTION

Gill net fisheries have been reported throughout time and still remains as one of the most common fishing gears (HOVGARD and LASSEN, 2000), due to its low confection cost and easy usage in artisanal fisheries (VALENTINI and PEZZUTO, 2006). A part of the bycatch fauna of the bottom gill net fisheries comprises elasmobranchs, in which small-sized species are more frequent (LESSA *et al*., 2006; MORGAN *et al*., 2009). Due to intensive fishing in critical areas such as nurseries, several shark species are suffering population declines (VOOREN and KLIPPEL, 2005; BARRETO *et al*., 2015; CAMHI, 1998), which justifies greater efforts to understand the relative participation of each species captured (of both artisanal and industrial fleets) aiming at their sustainable management (WALKER, 1998; LESSA *et al*., 1999; VOOREN and KLIPPEL, 2005).

Although the extinction of target species is unlikely, the least resilient ones captured as bycatch may suffer reductions and continue to be captured while their declines remains unnoticed (CAMHI *et al*., 1998). Therefore, elasmobranch captures require care since they occupy the top of food chains and participate in the energy exchange process within aquatic ecosystems (CORTÉS, 1999; EBERT *et al*., 2007). In Brazil, elasmobranch captures reached 4% of the total nominal landings, which corresponds to 32.000 Ton/year (BONFIL, 1994; FREIRE *et al*., 2015; BARRETO *et al*., 2016). Intrinsic biological features of elasmobranchs imply low fecundity, late sexual maturation, and high life expectation, which lead to a low rate of population recruitment, thus making them more susceptible to fisheries pressures (YOKOTA and LESSA, 2006; BONFIL, 1994).

Despite comprising a group particularly susceptible to overfishing (STEVENS *et al*., 2000), most captured elasmobranchs are also underreported in fisheries statistics (FREIRE *et al*., 2015), usually allocated to the shark and ray categories, thereby hindering the inference about the impact level on the exploited populations (TOMÁS and TUTUI, 1996).

Fishing exploitation with gill nets has developed throughout the Brazilian coast in an uncontrolled fashion without register or management, and led the main target species *Scomberomorus brasiliensis* and *Cynoscion acoupa* to be currently considered as Near Threatened (NT) and Vulnerable (VU), respectively (MOURÃO *et al*., 2014; BETANCUR *et al*., 2015; CHAO *et al*., 2015).

Furthermore, several elasmobranch species captured as incidental catch have declined in Brazil, such as the smalleye hammerhead (*Sphyrna tudes*), the smalltail shark (*Carcharhinus porosus*), sawfish (*Pristis* spp.), and the daggernose shark (*Isogomphodon oxyrhynchus*) (LESSA, 1986; STRIDE *et al*., 1992; LESSA and MENNI, 1994; MENNI and LESSA, 1998; BRASIL, 2004; LESSA *et al*., 2006; BRASIL, 2014), among others. One of the main triggers of this decline is the gill net size, which increased three times in only two decades (Reunião do Emalhe, MMA, 2011) to compensate for the target species productivity decline (BRASIL, 2011).

The gill net fisheries in Northeastern Brazil presents a significant interaction with threatened species such as sea turtles, manatees, and porpoises (GT emalhe MMA, 2011). Regarding the incidentally caught elasmobranchs, the increasing interests in exploration is a factor for stock declines, thus promoting the imbalance of marine food webs (MOURÃO *et al*., 2014). However, beyond the excessive fishing impacts, threats to elasmobranch conservation include anthropic activities, mainly coastal environmental destruction (THORSON, 1982; THORSON *et al*., 1987).

In addition, few studies about the elasmobranchs caught by gill net fisheries elucidating the relative participation of species in the captures exist, especially for Northeastern Brazil. The only studies with such information are Nóbrega and Lessa (2007), Mourão *et al*. (2014), although their focus was not the elasmobranch bycatch fauna.

Bottom gill net is the most used fishing gear in the state of Pernambuco Northeastern Brazil artisanal fishing fleet, corresponding to 13% of participation within the types of gear used and to 15.9% of the total landings yield (LESSA *et al*., 2005). Among those are the fisheries targeting the Brazilian Spanish mackerel (*Scomberomorus brasiliensis*), where there is a significant representation of the bycatch fauna composed of several coastal and semi-oceanic elasmobranch species, such as *Rhizoprionodon porosus*, *Carcharhinus acronotus*, *C. limbatus* and the rays *Hypanus marianae*, *Pseudobatos percellens*, and *Aetobatus narinari*.

Despite these species common occurrence and easy access, as they inhabit coastal areas, knowledge on the gill net fisheries bycatch is scarce. The present study aims at knowing the species specific composition and sizes of the elasmobranchs caught in Pernambuco state's coast (also using molecular techniques), and their temporal and spatial distribution – information not available until now. The study secondarily aims at suggesting conservation measures for this group in this specific exploration.

MATERIALS AND METHODS

Study area

The present study was carried out throughout Pernambuco state's coast (07º 15'45'' - 09º 28'18" S and 034º 48'33" - 041º 19'54" W), which has a 187km long coastline and annual average sea temperatures range from 24ºC (July and August) to 27ºC (february). This coast is characterized by a narrow continental shelf 40 NM wide, with no upwelling, and low primary productivity and fishing yield, but a high species diversity (EKAU and KNOPPERS, 1999). According to these authors, the coastal enrichment caused by mangroves and estuaries fertilize an area restricted to the coastal reefs.

Molecular analysis

Due to the possibility of occurrence of another congeneric *Rhizoprionodon* species in the area besides *R. porosus* (COMPAGNO, 1984; LESSA 1986), muscle tissue samples were collected from the specimens and preserved in 96% ethanol. DNA extraction was performed with the DNeasy, Blood & Tissue Kit (50). Samples with extracted DNA were subjected to a PCR to amplify the mitochondrial gene NADH-2, followed by gel visualization, and sequencing. Subsequently, sequences were edited with the Geneious software and aligned using the MEGA software (Molecular Evolutionary Genetics Analysis) version 7.0. Each sequence was subjected to BLAST available in the GenBank database for alignment.

This dataset was subjected to a Maximum Likelihood analysis with the Geneious software. For that, sequences obtained in the present study and four others from GenBank - *R. porosus* (JQ518648), *R. lalandii* (JQ518646) e *R. terraenovae* (JQ518651) were included.

Fisheries and data collection

In order to obtain catch data, vessels were shipped from the artisanal fishing fleet directed to the fishing of Spanish mackerel (*S. brasiliensis*) with bottom gill nets. The nets had mesh sizes varying from 35 to 45 mm between adjacent nodes (Table 01), with a height of 1.5 to 1.7 m, and 1.5 to 2 km in length. During the fishing the nets were immersed from 1 to 8 hours, being released late in the afternoon and spent (hoisted) in the early evening.

During the shipments were recorded: capture points, average depths of these points, using portable GPS and Sonar. The substrate types of each capture point were verified through bottom samples collected during fishing operations and sediment maps (MANSO *et al*., 2003).

Seasonal variations were adapted in four phases: March through May or the beginning of the rainy season, June to August or rainy season, September to November, beginning of the dry season, and December to February, dry season. This adaptation was based on the monthly precipitation index of the Pernambuco coastal region in 2011 (Instituto Nacional de Meteorologia-INMET).

Upon landing, the specimens were identified (Compagno, 1984) and had their total length (TL, cm) in the natural position (GARRICK,1982) and disc width (DW, cm) in rays, total weight (g) and sex recorded.

Data regarding fishing, morphometry and sexual proportion were systematized in Excel tables and analyzed through the Rstudio program version 3.6.0. (R Core Team, 2019) Then th e data were separated by taxa and distributed by seasons (rainy season, beginning of the dry se ason, dry season and beginning of the rainy season) to associate the occurrence of species to t he seasonality. The sexual ratio was established by the quotient between the number of males and females during the study period. The captured species were classified as constants (> 50%), accessory (≥ 15% to ≤ 50%) and occasional (< 15%), adapted on the constancy of Dajoz (19

73), this constancy measures the frequency with which each species occurs in the environment , relating the number of times the species was captured with the total number of samplings. According to the formula:

$$c = (n \times 100)/N$$

Being: c = catch constancy; n = number of times the species was collected; N = total number of collections made.

RESULTS

Between February 2010 and July 2012, sixty-seven shipments were performed on the artisanal fishing fleet that uses bottom gill nets. Fishing occurred between 0.7 to 50m the deep was measured can be used a deep in different substrates. The wooden vessels measured from 6 to 10 m long operating between 2 and 30km from the coast in both dry and rainy seasons. Fishing was performed in a substrate composed predominantly of sand, mud, gravel and stones.

Table 1. Fisheries carried out on the continental shelf of the State of Pernambuco from february 2010 to july 2012, with knits ranging from 30 to 60mm (between adjacent nodes) in different types of substrates (stone, gravel, mud and sand).

Year	Quarter	Number of fisheries	Mesh	Substrate type
2010	1º	1	45	Stone
	2º	2	45	Sand
	3º	12	45	Mud/Gravel/Stone
	4º	7	45	Gravel/Stone/Mud/Sand
2011	1º	9	45/35	Stone/Gravel/Sand/Mud
	2º	6	45	Stone/Gravel/Mud
	3º	17	35/45	Stone/Gravel/Sand/Mud
	4	2	45/40	Gravel/Stone
2012	1º	4	45	Stone/Gravel/Mud
	2º	4	40/45	Gravel/Mud
	3º	3	40	Stone/Mud
Total		67		

In total, sixty-seven field sampling were conducted between February 2010 and July 2012 (Table 1), in which 176 elasmobranchs were caught correspondin 4.03% of the total individuals fished (teleosts and elasmobranchs). The samples comprised 6 species of elasmobranchs: *R. porosus*, n = 113 (64.2%); *C. acronotus*, n = 58; (32.95%) *Pseudobatos percellens*, n = 2 (1.14%); *C. limbatus*, n = 1 (0.57%); *Hypanus marianae*, n = 1(0.57%), *Aetobatus narinari*, n = 1(0.57%).

R. porosus identifications were verified for each sample using the whole NADH-2 gene (1044bp), which confirmed the unique presence of this species among the sharks captured (figure 1). As shown in the phylogenetic tree, a sample previously identified as *R. lalandii* was, in fact, *R. porosus*, which became evident with its grouping with other *R. porosus* samples and its separation from the *R. lalandii* sequence obtained from GenBank.

Figure 1. Phylogenetic tree obtained by the Maximum Likelihood method, including the sequences obtained in the present study (in red) and GenBank.

Only *R. porosus* and *C. acronotus* was classified as accessories as regarding their participation in the captures. *C. acronotus* was the second most captured species of elasmobranch. Other species of elasmobranchs were also considered as occasional due to the low constancy of catches (*C. limbatos*, 1 specimen). Among the rays, only 4 specimens of 3 species were captured: *P. percellens* (2), *Hypanus marianae* (1) and *A. narinari* (1). (Table 2).

Table 2. Qualitative participation and constancy rate of taxa recorded in bottom gill fishing on the continental shelf of Pernambuco between February 2010 and July 2012.

Species	Total occurrences	Constancy rate (%)	ranking
Rhizoprionodon porosus (Poey,1861)	113	47.45	Accessory
Carcharhinus acronotus (Poey,1860)	58	24.38	Accessory
Carcharhinus limbatus (Müller and Henle, 1839)	1	0.42	Occasional
Pseudobatos percellens (Walbaum, 1792)	2	0.84	Occasional
Hypanus marianae (Gomes, Rosa and Gadig, 2000)	1	0.42	Occasional
Aetobatus narinari (Euphrasen, 1790)	1	0.42	Occasional

The *R. porosus* was the only species with a marked sex ratio dominated by males (Table 3) with two abundance peaks: the greatest between September and November (dry season) and the second between March and April (beginning of the rainy season), (Table 4).

Table 3. Numerical distribution by gender and sex ratio (M: F) of the elasmobranch taxa in gillnet fishing off the coast of Pernambuco between August 2010 and December 2012.

Species	Nº	Males	Females	Sexual reason (♂:♀)
Rhizoprionodon porosus	113	68	45	1:0.7
Carcharhinus acronotus	58	29	29	1:1
Pseudobatos percellens	2	1	1	1:1
Carcharhinus limbatus	1	1	_	_
Hypanus marianae	1	1	_	_
Aetobatus narinari	1	1	_	_
Total	176	101	75	

Table 4. Numerical relative abundance of elasmobranchs species caught in bottom gillnet fishing on the continental shelf of Pernambuco between seasonal variations (values in parentheses represent the percentage of each species in the period).

Species	Beginning of the Rainy season	Rainy season	Beginning of the dry season	Dry Season
	N (%)	N (%)	N (%)	N (%)
Rhizoprionodon porosus	26 (41.9)	13 (41.9)	37 (92.5)	37 (86)
Carcharhinus acronotus	33 (54)	16 (51.6)	3 (7.5)	6 (13.9)
Pseudobatos percellens	1(1.61)	1(3.2)	_	_
Carcharhinus limbatus	1(1.61)	_	_	_
Hypanus marianae	1(1.61)	_	_	_
Aetobatus narinari	_	1(3.2)	_	_
Total	62 (100.00)	31 (100.00)	40 (100.00)	43 (100.00)

Among the specimens captured, 59% had a total length inferior to the size of first maturity 65cm TL (MATTOS, 2001; MEDINA, 2010) (Figure 2).

The individuals of *Hypanus marianae* and *Aetobatus narinari* were captured with 36 and 52 cm DW, respectively. The mature male of *H. marianae* was captured 26 km off the coast, 53 m deep on gravel substrate. The *A. narinari* individual was captured 3 km off the coast, in a 3.5m depth also on gravel substrate.

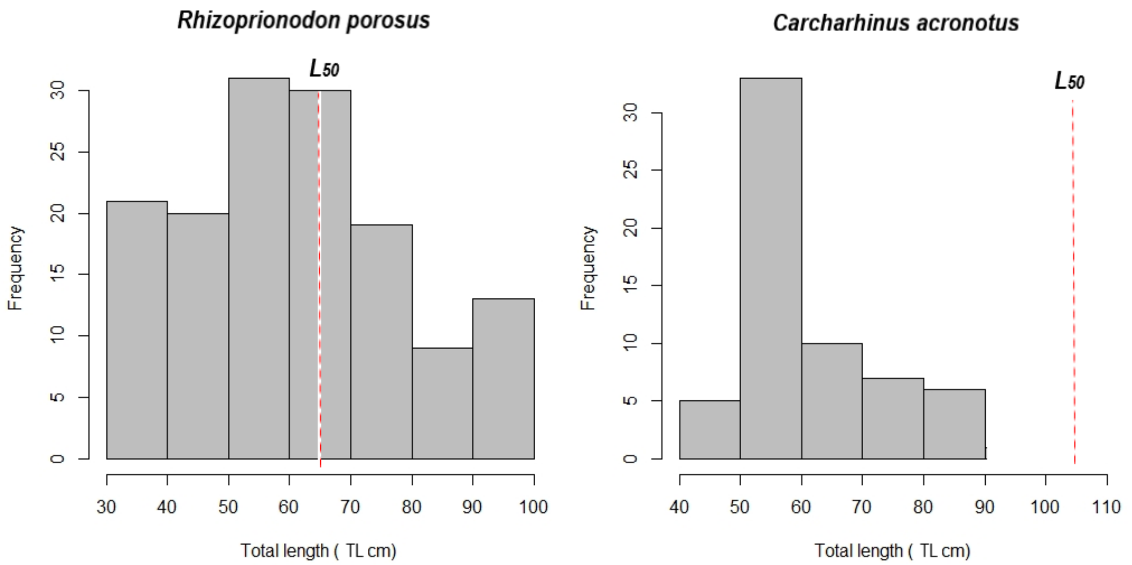

Figure 2. Frequency, total lengths (TL) and length of frist maturation (L_{50}) for *R. porosus* and *C. acronotus* captured on the continental shelf of Pernambuco between February 2010 and July 2012.

Occurrence frequency

The greatest elasmobranch numerical abundance period was the dry period (Table 3), which also presented a greater number of species (5). The rainy season was the period with the least participation of elasmobranchs in the captures. In this period, only the most coastal species, represented by the accessory ones (*R. porosus* and *C. acronotus*), were present.

Substrates

Captures occurred in four kinds of substrates, as follows: stone (corals and stone reefs), gravel, sand, and mud. Most captures occurred in substrates composed of gravel and stone comprising 59.1 and 27.3%, respectively. Sand and mud represented 6.8% of the captures each. Individuals of *R. porosus* and *C. acronotus* were more abundant in habitats composed of gravel, with 48.67% and 77.5% in numbers of individuals, respectively, followed by the habitats composed of consolidated bottoms (stone) corresponded to 34.51 and 15.51% of the *R. porosus* and *C. acronotus* captures, respectively.

Sizes varied according to substrate (Figure 3), in which *R. porosus* neonates were more common in substrates composed of mud, while *C. acronotus* smaller sizes were captured in gravel-dominated substrates. The largest specimens of *R. porosus* and *C. acronotus* were captured in substrates composed of gravel and stones, respectively (Figure 3).

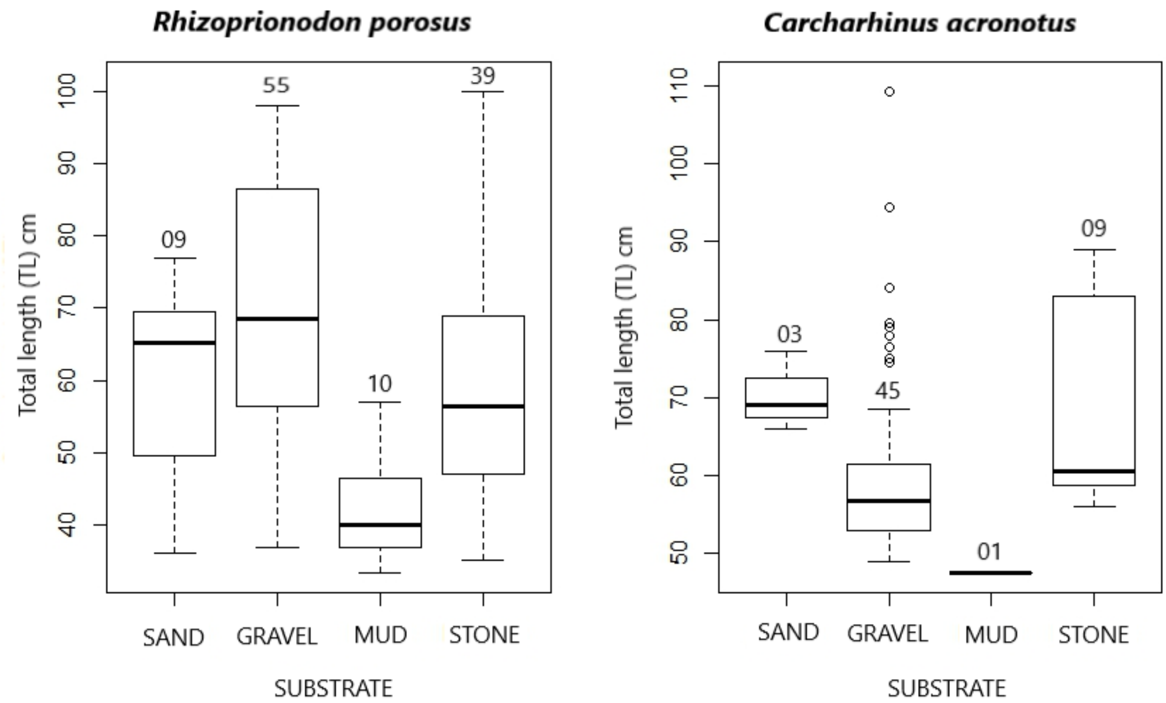

Figure 3. Total lengths and number of individuals of *Rhizoprionodon porosus* and *Carcharhinus acronotus* captured by the handmade bottom gillnet in four types of substrate (sand, gravel, mud and stone), on the continental shelf of Pernambuco.

All specimens of *C. acronotus*¸ *C. limbatus* and *A. narinari* were captured with sizes below the first maturation – 105, 120 and 129.2 cm (TL), respectively. *R. porosus* and *R. percellens* captures were comprised of 54 and 50% of immature individuals, respectively (Table 5). Only the Brazilian large-eyed stingray *H. marianae* capture was composed of 100% of adults.

The greatest portion of the *R. porosus* juveniles were captured in areas closer to the coast up to 25m deep, while adults were captured between 30 and 50m deep (figure 4). *Carcharhinus acronotus* presented a more uniform distribution between the 10 and 30m isobaths near coralline substrates composed of gravel. The only specimen of *C. limbatus* was captured near the 10m isobath. The largest portion of rays were captured near the coast with the exception of *H. marianae*, which was captured in a 50m depth (Figure 4).

Table 5. Number of occurrence, range of lengths (mean and standard deviation - dp) and first maturation sizes of the elasmobranch species captured with bottom gillnet in the continental shelf of Pernambuco.

Species	N	Length range in cm (average ± dp)	L_{50} cm	Below the L_{50} (%)	Reference of L_{50}
R. porosus	113	36-100 (66.6 ± 13.5)	65	54	Mattos, *et al*., (2001)
C. acronotus	58	49.5-89 (62.1 ± 12.8)	105	100	Hazin, *et al*., (2002)
C. limbatus	1	79	120	100	Smith, *et al*., (1998)
P. percellens	2	35-49 (42 ± 15.4)	44,3	50	Ivanoff, *et al*.,(2012)
H. marianae	1	36	30,2	0	Yokota, *et al*., (2015)
A. narinari	1	77.5	129,2	100	Tagliafico, *et al*.,(2012)

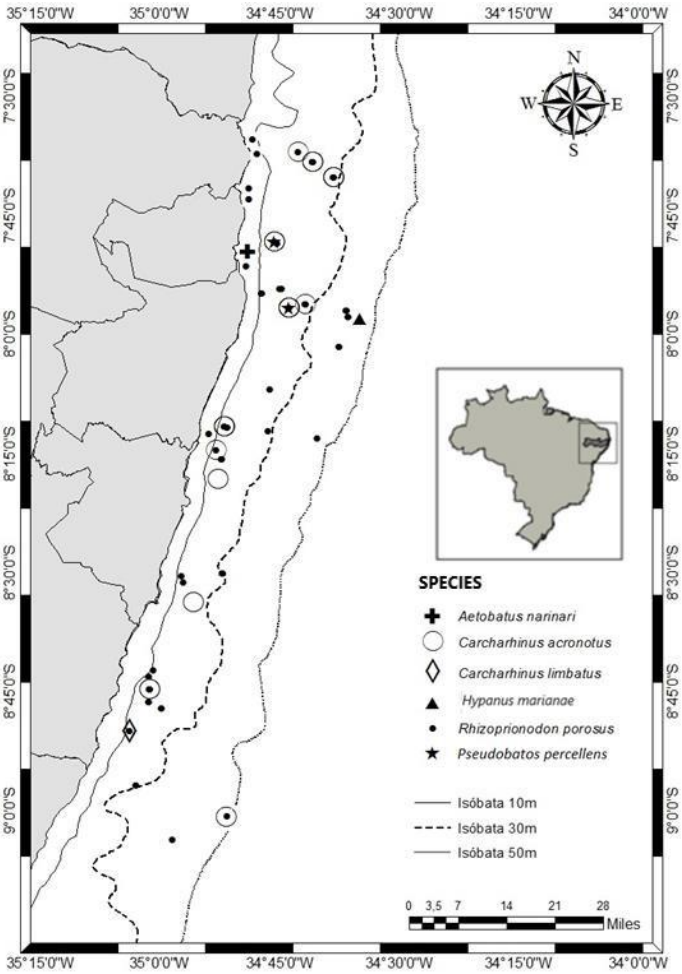

Figure 4. Area of elasmobranch capture in the continental shelf of Pernambuco (•) *R. porosus*, (○) *C. acronotus*, (◊) *C. limbatus*, (+) *A. narinari*, (▲) *H. marianae*, (★) *P. percellens* between the 2 to 50m isobaths.

DISCUSSION

During the present study 6 elasmobranch species were captured, 3 from the Carcharhinidae family (*R. porosus*, *C. acronotus*, and *C. limbatus*) and 3 rays from the Rhinobatidae (*P. percellens*), Dasyatidae (*H. marianae*), and Aetobatidae (*A. narinari*) families. Lessa *et al*. (2009) identified the same Carcharhinid shark species (*R. porosus* and *C. acronotus*) in the gill net fishing fleet for the Pernambuco and Alagoas states' coasts.

Carneiro and Salles (2011) identified 5 elasmobranch species in the same fisheries in Ceará state, with 2 shark species being *R. porosus* and *C. acronotus* and 3 ray species being *H. Americana*, *A. narinari* and *Rhinoptera* sp. Motta (2006), while inspecting the bottom gill net fisheries in São Paulo state's coast between 1997 and 2003, captured 14,087 shark specimens comprising seven families, nine genera, and 18 species. Among those, the Brazilian sharpnose shark (*R. lalandii*) was the most captured species, representing from 56.6 to 64% of the captures, followed by *Sphyrna lewini* (17% of the capture), and the Caribbean sharpnose shark *R. porosus* with 14.9% of the total catch.

The most frequent elasmobranchs in the catches analyzed in this study were *R. porosus* (64.2% of all elasmobranchs caught) and *C. acronotus*. In addition, *R. lalandii* was not recorded in this study, thus corroborating Lessa *et al*. (2009) and Motta *et al*. (2005), which stated that this species distribution is associated to colder waters in comparison to *R. porosus*. The analysis performed with the DNA molecular markers only confirmed the presence of *R. porosus*, and such result contradicts Compagno (1984, 2000) and Lessa (1986, 1997), but also corroborates Mendonça *et al*. (2013), which also used molecular techniques and did not find *R. lalandii* in Northeast Brazil.

Carneiro and Salles (2011) observed a 3% total weight participation of *R. porosus* in Ceará state's gill net fisheries, corroborating the results herein shown. There was a greater presence of male *R. porosus* in captures (male/female = 1:0.7). Furthermore, Medina *et al*. (2010) and Lessa (2009) verified a greater participation of male *R. porosus* in the gill net fisheries off Venezuela and Northeast Brazil coasts (1:0.5 and 1:0.3, respectively), which indicates that this is a pattern for the species.

Mattos *et al* (2001), Yokota (2006), and Medina *et al*. (2010) suggest that there are sexual and size segregations for this species. According to these authors, larger females are in areas further from the coast, thus making their capture by the characteristically coastal artisanal fleet harder, which corroborates the present study, since larger females (>80 cm TL) were captured after the 30 m depth (Figure 5).

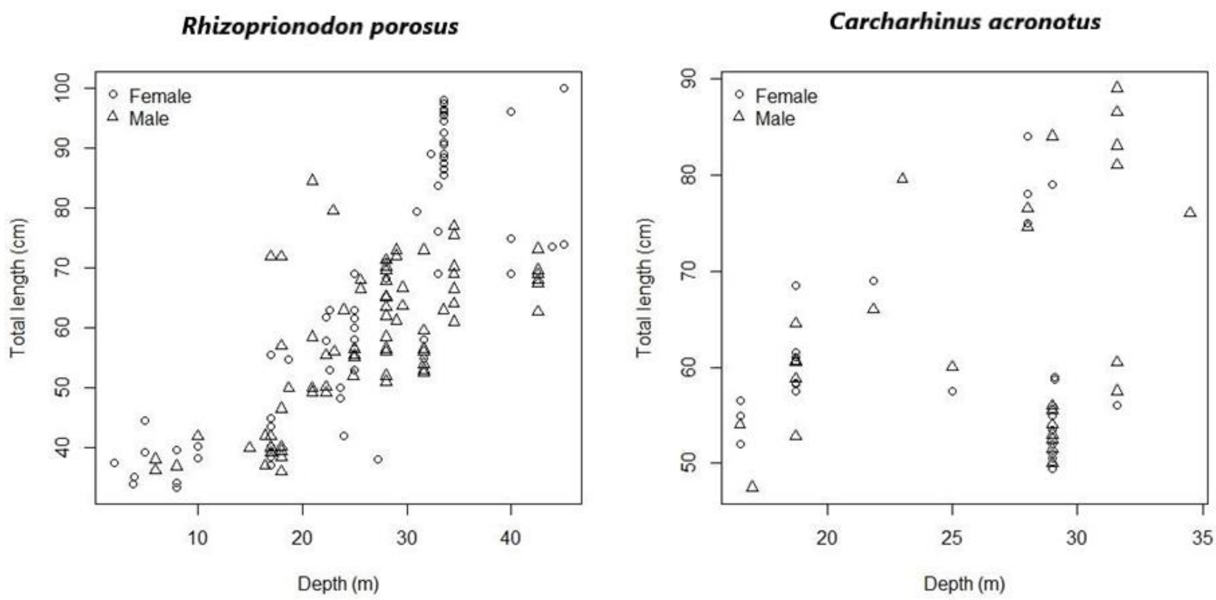

Figure 5. Distribution by sex and length of *R. porosus* and *C. acronotus* in different depth gradients.

In total, 63 females of *R. porosus* were captured, with 12 of those being pregnant and captured in September (austral spring). Therefore, this indicates that this is the parturition period in for this species in Pernambuco state's coast, which coincides with the greatest occurrence of neonates in October. Compagno (1984) also suggests that this species parturition period ranges from september to the beginning of december in Brazil.

On the other hand, the blacknose shark (*Carcharhinus acronotus*) was more abundant in the captures between December and April – period in which the fleet fished further from the coast targeting *Caranx bartolomaei*. For *C. acronotus*, approximately 90% of the captures occurred in areas composed of gravel and stone (corals and stone reefs) substrate, and their preference for these environments might be related to their feeding habits. According to Wooton (1989), the preference for certain prey items will directly influence the position of a certain species in the water column and consequently their susceptibility to the fishing gear.

The greatest occurrence of immature specimens of *R. porosus* and *C. acronotus* (54 and100% of the captures, respectively (Table 5), might be directly related to the fishing gear selectivity and preference of the target species. According to Lucena (2004), gill net captures are composed of species that share similar feeding habits and habitats, besides possessing a similar body shape and perimeter to the gill net mesh sizes. In this way, small sharks are selected by the fishing gear for having similar body diameter and diet to the target species.

Most of the rays were captured in coastal regions (*A. narinari* and *P. percellens*). Only *H. marianae* was captured beyond the 30m isobath. The small number of rays present in the captures (4 specimens) can be justified by their dorsoventrally compressed body, which decreases their vulnerability to this fishing gear.

Silva and Almeida (2001), while studying the feeding habits of *R. porosus* in Maranhão state's coast, observed a predominance of 48% of coastal teleost fishes in their stomach contents. Among those, the most abundant were *Trichiurus lepturus*, *Sphoeroides testudines*, and *Cetengraulis eduntulis*, besides penaeid crustaceans and squids. These items also make up the diet of *Scomberomorus brasiliensis* (FONTELLES, 1988; NOMURA, 1967), thus these shared food items make the young *R. porosus* more susceptible to bycatch of the *S. brasiliensis* gill net fisheries. The same occurs with *C. acronotus* since the species prefers small reef teleost fishes, which are targeted in the bottom gill net fisheries towards *Caranx bartolomaei*.

The greatest portion of the captured elasmobranchs in the present study (*Aetobatus narinari*, *Pseudobatos percellens*, *Carcharhinus acronotus*, and *Carcharhinus limbatus*) are currently considered by the International Union for the Conservation of Nature (IUCN) as Near Threatened (NT). The Caribbean sharpnose shark *R. porosus* is classified as Least Concern (LC). Only *Hypanys marianae* was considered as Data Deficient (DD).

Although the gill net fisheries is considered as a low impact fishing for the target species (ARMSTRONG *et al*., 1990), its activity in coastal regions has been causing impacts in the populations of “small coastal” sharks, since the majority of these species use these areas as nurseries (VOOREN and KLIPPEL 2005), and have a similar body shape and diameter to the species targeted by these fisheries. The capture of neonate and juvenile elasmobranchs is a concerning factor in the gill net fisheries catches since their survival is crucial to the maintenance of elasmobranch populations under intense fishing pressure (BRANDER, 1981).

CONCLUSIONS

Among the elasmobranches captured *R. porosus* and *C. acronotus* were the most constant species and also the most frequent species in the catches. This frequency in the catches can be explained by factors such as: the similarity between the diameter and body shape of these species, feeding habits similar to those of the target species (*S. brasiliensis* and *C. bartolomaei*) and occurring in areas near the coast. Such factors increase the susceptibility of these sharks (mostly neonates and young) to bottom gill fishing. Unlike the rays that have a dorsoventrally flattened body, they are hardly selected (fished) by the mesh of the fishing gear. Although adaptations (increase) in mesh diameter are one of the alternatives for the reduction of catches of juvenile shark specimens, such an alternative becomes impractical, since it leads to a decrease in the catches of the target species, which would generate economic impacts on artisanal fishing communities. A viable alternative to reduce elasmobranch capture in bycatch would be the creation of Marine Protected Areas - MPAs for the protection of these species at critical stages of life cycles. Thus, studies related to habitat use and identification of essential habitats for *R. porosus* and *C. acronotus* are viable alternatives for the elaboration of conservation and management policies for these species.

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6. Capítulo III

Artigo científico a ser encaminhado a Revista Journal of Fish Biology

Identification of essential habitats of Caribbean sharpnose shark, *Rhizoprionodon porosus* and blacknose shark *Carcharhinus acronotus* in northeastern Brazil.

Todas as normas de redação e citações, deste capítulo, atendem as normas estabelecidas pela referida revista

IDENTIFICATION OF ESSENTIAL HABITATS OF CARIBBEAN SHARPNOSE SHARK, *RHIZOPRIONODON POROSUS* AND BLACKNOSE SHARK *CARCHARHINUS ACRONOTUS* IN NORTHEASTERN BRAZIL.

ABSTRACT

The knowledge of the strategies of habitat use by elasmobranchs is fundamental for the conservation and management of the species that suffer direct impacts of the fishing or along the Brazilian coast. The present study recorded fishing data "onboard of artisanal vessels" in operations at sea, collecting an array of environmental data (depth, distance, lunar phase, bottom type, seasons of the year) to describe habitat use and to infer on nursery areas of *Rhizoprionodon porosus* and *Carcharhinus. acronotus*. For *R. porosus* shallower and coastal areas evidenced the presence of neonates all over the year with spatial segregation, by size whereas adults of *C. acronotus* occurred in deeper areas, not attained by gillnets, without segregation between stages of development and sexes for the species. *C. acronotus* occurred in deeper areas and more distant from the coastline; there was no segregation between stages of development and sexes for the species. The analysis showed that the *R. porosus* has a pupping area in coastal regions with depths of less than 20 meters, differing from the *C. acronotus* that has a birth area in regions farthest from coast beyond the 30 m isobath. Information collected here is an important tool for the management of fisheries of both species caught as bycatch in fisheries directed to highly value commercial species caught using gillnets and longline off the Pernambuco coast.

Keywords:

INTRODUCTION

Sharks and rays adopted life strategies with peculiar biological traits, as low fertility, late sexual maturity, slow growth, long gestation periods and site fidelity, which prevent them to cope with sudden shifts in fishing mortality (Hoenig and Gruber, 1990). Fishing is the most deemed outstanding threat due to their overall low resilience (Holden, 1974; Camhi et al., 1998, Dulvy et al., 2014).

The small coastal sharks, however, have a relatively higher growth rate attaining maximum sizes around 1.5-2.0 m (Barreto et al, 2011). Of these, the small carcarhinids sharks of the genres *Rhizoprionodon* and *Carcharhinus* are typical components of the fauna from continental shelves along the western Atlantic (Compagno, 1984; Lessa *et al.*, 2006) in depths < 70 m (Springer, 1964; Compagno, 1984) where habitat degradation and fisheries has burgeoned on the last decades (Lessa et al., 2009; Thorson et al., 1987). Embedded in an overall oligoptrophic coast (Ekau & Knoppers, 1999), these environments encompass mangroves, sea grass and coral areas that may function as foraging and nursery sites (Heupel et al., 2007; Knip et al., 2010; Munroe et al., 2015); the latter identified is not just an area where juveniles occur in higher densities, but also as areas which juveniles live for long periods and which females give birth over several years (Heupel et al. 2007).

From the Caribbean to the southeastern of South America, two carcharhinid species *Rhizoprionodon porosus* and *Carcharhinus acronotus* share coastal areas among others species. These species have been studied in Brazil during the last decades focusing on reproduction (Mattos, 2001; Hazin et al., 2002, Motta, 2006), distribution (Lessa et al., 2009), age and growth (Lessa et al., 2009; Barreto et al, 2011), molecular aspects (Mendonça et al., 2013; Lima et al., submetido) and morphometry (Lucena, 2012). In spite of those studies, the overall level of information is still poor for subsidizing the implementation of conservation measures along the coast, which is unveiled by their IUCN conservation status as data deficient-DD.

Both are common species in the *bycatch* of artisanal fleet, mainly targeting the Brazilian Spanish mackerel (*Scomberomorus brasiliensis*) throughout the northeast of Brazil, generating (1998-2004) in assessments of gillnets (REVIZEE Programme) the mean CPUEs of 45 $kg.day^{-1}$ for *R. porosus* and 12.8 $kg.day^{-1}$ for *C. acronotus* (Lessa et al., 2009; Barreto et al., 2011) - which are the first and second most frequent elasmobranch taxons in operations of this gear. Those species are also caught by shrimp trawls, longlines, hand lines and fishing traps, where it is a minor component. In catches along the Pernambuco coast, both adults and the young-of-the-year (YOY) of both species are caught (Barreto *et al*., 2011; Hazin *et al*., 2002; Lessa *et al*., 2009) in consequence of their high susceptibility to fisheries (Rosa *et al*., 2004).

Efforts to assess how such meso-predators use the coastal habitats during their lives have been developed for congeneric species in other parts of the world (Simpfendorfer, et al., 2011), and this information is crucial for building conservation plans, which take into account the habitat use.

This study aims at verifying the general assumption: “these species occur in shallow waters throughout the entire life with juveniles and adults sharing the same habitats” (Barreto et al., 2011; Smith et al., 1998). Through monitored fishing records, we intend to understand the movements for *R. porosus* and *C. acronotus* by size and sex within the studied area of northeastern Brazil aiming at fisheries management of gillnets in the area.

Methods
The study area

The study area is the coast of the state of Pernambuco (8º15’00” - 8º30’00” S/ 34º55’00”

- 35º05’00” W) in northeastern Brazil, where the continental shelf is narrow (10 m) with depths less than 40 m, with temperatures 27 to 28.7°C, from the surface to depth, decreasing from the edge of the shelf (60-70 m), where the thermocline starts (Costa, 1991). Due to the dominance of warm and oligothrophic waters, the area has low primary productivity with low population abundance, characteristic of tropical environments (Roberts *et al*., 2002).

Fishing data.

Specimens of *R. porosus* and *C. porosus* were obtained in fishing operations of artisanal vessels (<12m) in landings from December 2010 to September 2015. Most specimens were captured with gillnets 1.5 to 2km in length, 1 to 1.7 m in height with 30 to 45 mm meshes between adjacent knots. Samples were also collected from gillnets for mullets *Mugil* spp., in hand lines and bottom longline fishing. The distance from the coast of each fishing operation, fishing time, depth (recorded at the beginning and at the end of each set) and the type of bottom (stone/coral, gravel, sand and mud). All specimens were identified according to Compagno, (1984); Nobrega et al., (2009a); Nelson, (1994). During landings the specimens were weighed and sexed, and the total lengths (CT cm; Garrick, 1982), interdorsal lengths (ID cm) were recorded.

Fishing data processing

The sites of capture were related to depth and stage of development of each specimen (neonate <42, Juvenile> 42 cm <65 cm, adult> 65 cm). The specimens of *R. porosus* and *C. acronotus* were categorized in relation to the development as neonates, juveniles, and adults, according to literature (Medina et al, 2009, Mattos, 2001; Hazin, 2002) for *R. porosus* and (neonate <55, Juvenile> 55 cm <100 cm, adult> 100 cm) for *C. acronotus*. Geospatial representations showing the distribution of these species along the coast of the state of Pernambuco were built using QGIS software version 3.2.0 (Sherman et al., 2011).

To describe the habitat, use of *R. porosus* and *C. acronotus*, the total length (TL, cm) allowed specimens to be classified into the above developmental categories. After, the specimens of the two species were differentiated according to sex (males and females). The chi-square test ($\chi 2$) was used to determine the expected ratio of 1♂:1♀ (ZAR, 1996). Correlation analyzes were performed both between sex, developmental categories and attributes (depth, bottom type, etc...) assuming a significance level of 0.05. Developmental categories: Neonate, juveniles and Adult were related to the seasons, lunar phase, depth, distance of the coast and type of substrate.

We used Multinomial Logistic Regression to infer on the habitat use for *R. porosus*, where we tried to understand which attributes (Season, Moon Phase, Depth, Coast Distance and Substrate Type) best explained the presence of species in different stages of development. To evaluate the logistic regression model and to verify the degree of significance of each coefficient of the equation, the Wald test was used.

With the same aim, the Binary Logistic Regression test was employed to analyze the *C. acronotus* species. As it had only one adult and one specimen representing the "mud" in the substrate type variable, these individuals were deleted from the analysis for comparing juveniles and neonates. For presenting results between 0 and 1 the model used was the Nagelkerke R^2 test to explain the variation recorded in the dependent variable.

RESULTS

During this study, 66 fishing trips that used gillnets had catches recorded. Besides, other 25 landings were sampled totaling 206 individuals sampled (*R. porosus*: 143 and *C. acronotus*: 63). Total lengths (CT cm) varied from 33.40 to 100 cm for *R. porosus* and from 47.7 to 109.6 for *C. acronotus*. Of these, 21.6% were neonates, 39% were juveniles and 40% were adults, with a modal class of 56.15 cm for *R. porosus*. Referring to *C. acronotus*, catches were composed of 34% of neonates, 65% of juveniles and 1.5% of adults (only 1 adult specimen was captured).

Most of the newborns of *R. porosus* (60%) were captured on the northern coast of Pernambuco, close to the municipalities of Itamaracá, Igarassú and Paulista; of these, 29% was captured in Itamaracá. The same occurred with *C. acronotus*, of which 85% of the newborns were caught on the northern of Pernambuco, between Itamaracá and Olinda.

Catches of *R. porosus* occurred at depths ranging from 2 to 45 m; being most of them caught between 20 and 30 m depth (n = 81). About 90% of the newborns were caught near the coast in depths up to 19 m (Figure 1A). Specimens of *C. acronotus* occurred between 16 to 34m isobaths; most of these catches were composed of neonates and young (immature) specimens at depths of 16 to 29 m (Figure 1B).

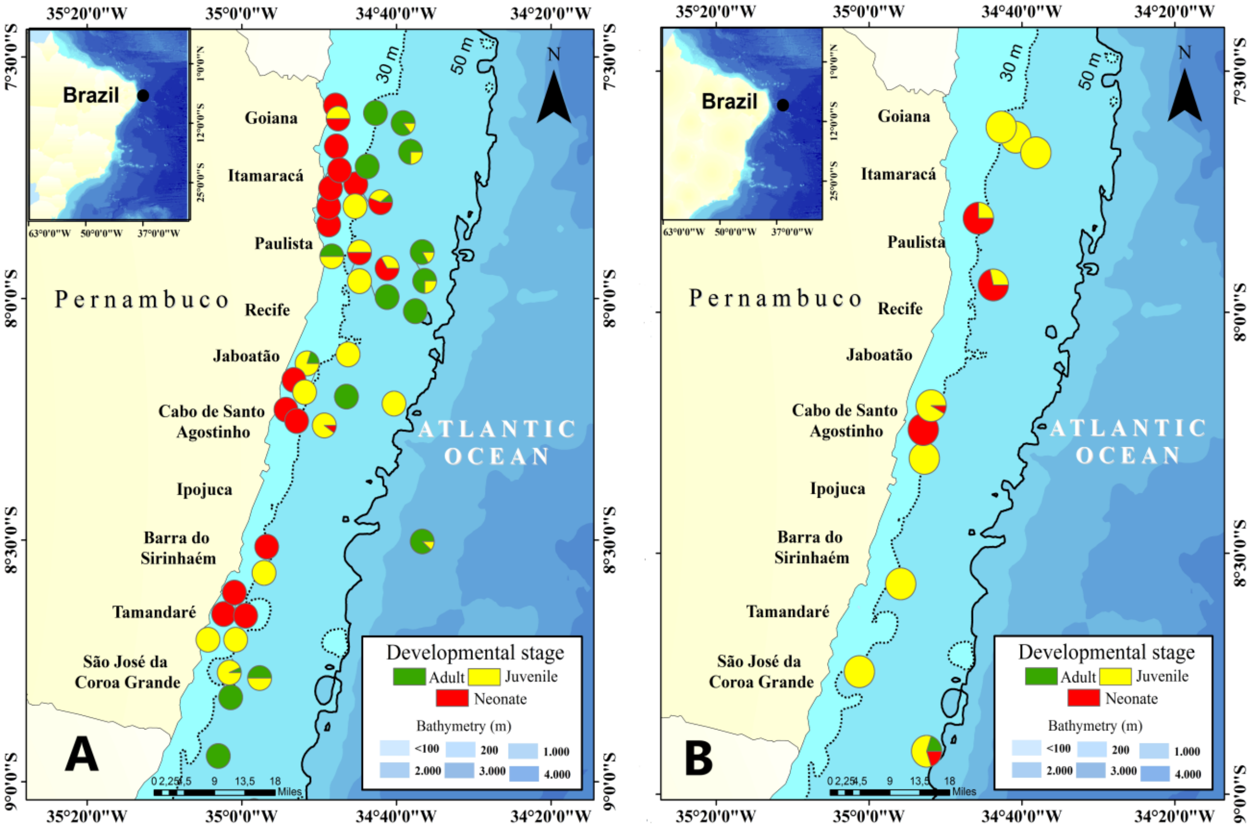

Figure 1. Capture of *Rhizoprionodon porosus* "A" and of *Carcharhinus acronotus* "B". Specimens were classified as: Neonates (red), young (Yellow) and adults (green).

Rhizoprionodon porosus

The majority of *R. porosus* were caught in dry season (n = 69, 48.3%), 59% (n = 85) of these catches were composed of juvenile specimens. About 20% of the catches were of neonates. Although they were present in catches throughout the year, most of the newborns (65%) were caught between September and November (rainy season), mainly in September. Throughout the study, 18 pregnant females were captured in March, July and September, of which 72% were captured in September (Beginning dry season), all in depths from 22 to 45 m. None was caught in shallow areas inhabited by YOY ans small juveniles.

Most catches occurred during the gravel substrate (n = 58, 40.6%). Of these records of highest frequency were adult specimens. The overall mean depth was 25.80 ± 9.49 meters, with an average distance from the coast of 10.92 ± 6.86 km (Table 1).

Table 1. Environmental characteristics relative to developmental phases of *Rhizoprionodon porosus* caught in Pernambuco coast.

Attribute	**Neonate (n = 31; 21.6%)**	**Juvenile (n = 56; 39.2%)**	**Adult (n = 56; 39.2%)**	**Total (n = 143; 100%)**
Season (%)				
Rainy season	7 (22.5)	14 (25)	9 (16.1)	30(20.9)
Beginning rainy season	6 (19.4)	26 (46.4)	4 (7.1)	36 (25.2)
Beginning dry season	16 (51.6)	14 (25)	39 (69.7)	69 (48.3)
Dry season	2 (6.5)	2 (3.6)	4 (7.1)	8 (5.6)
Substrate n (%)				
Sand	3 (9.7)	3 (5.4)	6 (10.7)	12 (8.4)
Gravel	4 (12.9)	22 (39.3)	32 (57.1)	58 (40.5)
Mud	12 (38.7)	5 (8.9)	0 (0.0)	17 (11.9)
Stone	12 (38.7)	26 (46.4)	18 (32.1)	56 (39.2)
Depth (m) mean ± SD	13.8 ± 7.0	25.6 ± 6.3	32.6 ± 6.03	25.8 ± 9.5
Distance of coast (km) mean ± SD	5.5 ± 4.0	9.2 ± 5.2	15.6 ± 6.6	10.9 ± 6.8

Concerning depth attribute, there was only statistical significance between neonates and adults (p <0.05), with the highest frequency of neonates in shallower waters (Wald = 11.728, p = 0.001), displaying a reduction trend of 29.5% (Exp (B) = 0.705) when compared to adults (Figure 2). The "adult" category of *R. porosus* was considered as the reference category (Table 2).

For the coastal distance, significant relationships were observed between juveniles and adults (p <0.05), with a higher occurrence of juveniles in shallower waters (Table 2). There is a trend of 8% reduction at great depths (Exp (B) = 0.920) relative to adults (Figure 2). Dry season was considered the reference season of the year.

When comparing newborn and adults, there was an increase of 14.73% of newborns in rainy season compared to dry season (Wald = 4.348; p = 0.037; Exp (B) = 148.3) and 19.873% in beginning the rainy season (Wald = 4.618; = 0.032; Exp (B) = 199.7). In beginning dry season, there is no difference in the frequency between newborn and adults in relation to dry season.

In the comparison of juveniles and adults, only beginning the rainy showed a trend of 6.99% increase of juveniles in relation to the dry season (Wald = 4.252; p = 0.039; Exp (B) = 70.944) (Table 2).

Regarding the type of substrate, the category "stone" was considered as a reference (REF). For this analysis, only statistical differences (p <0.05) were detected between neonates and adults, with a trend of 106% increase in neonates in the mud substrate in relation to the stone type (Wald = 380.065; p = 0.000; Exp (B) = 2060) (Table 2).

Table 2. Multinomial Logistic Regression model for *Rhizoprionodon porosus* species caught in Pernambuco coast, (B) Regression coefficient, (Wald) degree of significance, (REF) reference category.

Phase of desenvolviment	Attribute	B	Wald	p-valor	Exp (B)
Neonate	**Depth**	- 0.349	11.728	0.001	0.705
	Distance of coast	- 0.229	2.575	0.109	0.795
	Season				
	Rainy season	4.999	4.348	0.037	148.304
	Beginning rainy season	5.297	4.618	0.032	199.703
	Beginning dry season	3.307	1.769	0.183	27.310
	Dry season	REF	REF	REF	REF
	Bottom type				
	Sand	0.983	0.077	0.782	2.672
	Gravel	0.433	0.119	0.730	1.542
	Mud	21.446	380.065	0.000	2.060
	Stone	REF	REF	REF	REF
	Intercept	4.552	3.404	0.065	-
Juveniles	**Depth**	- 0.084	1.919	0.166	0.920
	Distance of coast	- 0.124	4.165	0.041	0.883
	Season				
	Rainy season	3.061	2.305	0.129	21.349
	Beginning rainy season	4.262	4.252	0.039	70.944
	Beginning dry season	1.074	0.263	0.608	2.928
	Dry season	REF	REF	REF	REF
	Bottom				
	Sand	1.066	0.952	0.329	2.905
	Gravel	-0.854	1.658	0.198	0.426
	Mud	19.450	-	-	2.798
	Stone	REF	REF	REF	REF
	Intercept	2.186	1.037	0.309	-

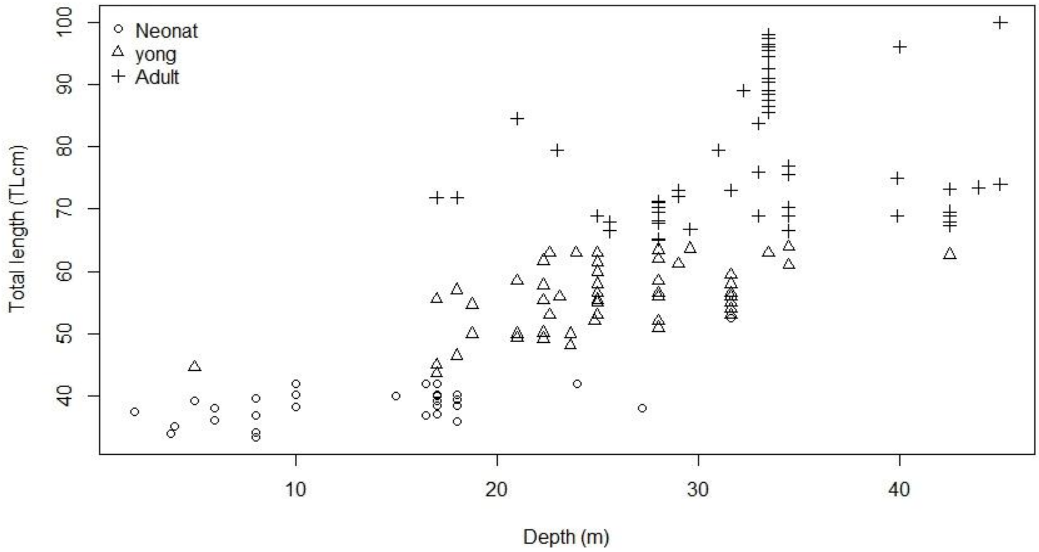

Figure 2. Vertical distribution of *R. porosus* at different depths. Catches were categorized according to the stages of development: neonates (○), juveniles (Δ) and adults (+).

Carcharhinus acronotus

In relation to the attributes for *C. acronotus*, the highest records were in the summer (n = 33; 52.4%), in the new moon phase (n = 26, 41.3%) and in the gravel substrate (n = 50; %). The most frequent developmental range in these records was that of juveniles. The average overall depth was 25.72 ± 5.133 meters (Figure 3), with an average coast distance of 12.46 ± 7.59 km (Table 3).

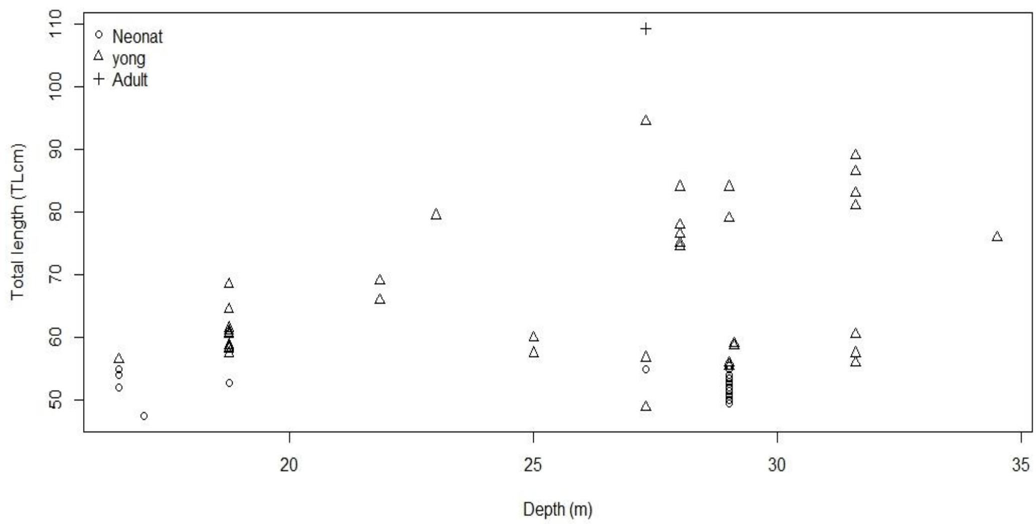

Figure 3. Vertical distribution of *C. acronotus* at different depths. Catches were categorized according to the stages of development: neonates (○), juveniles (Δ) and adults (+).

Table 3. Environmental characteristics for the *blacknose shark* (*Carcharhinus acronotus*) according to developmental phases.

Attribute	Neonate (n = 21; 33.3%)	Juvenile (n = 41; 65.1%)	Adul (n = 1; 1.6%)	Total (n = 63; 100%)
Season n (%)				
Rainy season	0 (0.0)	3 (7.3)	0 (0.0)	3 (4.8)
Beginning rainy season	5 (23.8)	15 (36.6)	1 (100)	21 (33.3)
Beginning dry season	0 (0.0)	6 (14.6)	0 (0.0)	6 (9.5)
Dry season	16 (76.2)	17 (41.5)	0 (0.0)	33 (52.4)
Substrate n (%)				
Sand	0 (0.0)	3 (7.3)	0 (0.0)	3 (4.8)
Gravel	20 (40.0)	29 (70.7)	1 (100)	50 (79.4)
Mud	1 (4.8)	0 (0.0)	0 (0.0)	1 (1.6)
Stone	0 (0.0)	9 (21.9)	0 (0.0)	9 (14.3)
Depth (m) mean ± DP	26.07 ± 5.20	25.49 ± 5.209	27.30	25.72 ± 5.133
Distance of coast (km) mean ± DP	10.67 ± 5.31	12.87 ± 7.92	33.00	12.46 ± 7.59

Due to the low number of adults and specimens in the "mud" category within the substrate type, these categories were not considered in the analysis in the Binary Logistic Regression model, thus demonstrating comparisons between neonates and juveniles. The variation of the observed data was explained in 66%; no significant differences were detected (p> 0.05). Thus, none of the listed attributes interferes in the occurrence of neonates and/or juveniles of *C. acronotus*, these parameters being similar between these developmental phases (Table 4).

Table 4. Binary Logistic Regression Model for blacknose shark *C. acronotus* species caught in Pernambuco coast. (B) Regression coefficient, (Wald) degree of significance, (REF) reference category.

Attribute	B	Wald	p-value	Exp (B)
Depth	- 6.502	0.000	0.999	0.002
Distance coast	1.998	0.000	0.999	7.375
Season				
Rainy season	-66.663	0.000	0.999	0.000
Beginning rainy season	-102.964	0.000	0.998	0.000
Beginning dry season	-42.806	0.000	0.998	0.000
Dry season	REF	REF	REF	REF
Tipo de substrato				
Sand	-	-	-	-
Gravel	43.539	0.000	0.999	8.103
Stone	REF	REF	REF	REF
Constant	215.6	0.000	0.998	4.384

DISCUSSION

The present study is the first to analyze the distribution and habitat use of the Caribbean sharpnose shark (*R. porosus*) and the Blacknose shark (*C. acronotus*) in northeastern Brazil. Specimens of *R. porosus* were monthly caught in different numbers, sized from 33.4 to 100 cm CT, thus encompassing all developmental stages (neonates, juveniles and adults). However, in relation to *C. acronotus*, the greater numbers were of neonates and juveniles from 47.7 to 94.5cm CT, with only one adult measuring 109.3 cm CT, caught near the break of the continental shelf.

The neonates and juveniles of *R. porosus* and *C. acronotus* corresponded to 60% and 98% of the overall sample respectively, a result that corroborates with Medina et al. (2010), which studied *R. porosus* in Venezuela (80% of juveniles) and also with de Silva and Almeida (2001), which studied the species in the northern Brazilian coast (Maranhão, 57% of juveniles). In these sites, fishing fleets was restrained to a narrow band of shelf due to preferential distribution of the target species (~30 m) (Fonteles-Fo, 2007), and the low autonomy of vessels. Different developmental stages of both species were present throughout the area all over the year; however, the ontogenetic distribution with larger and older specimens in deeper waters was first recorded in the current study (see Fig 3).

Referring to the Blacknose shark, a number of authors have reported the existence of segregation by size and sex, with smaller specimens (juveniles) generally found at depths of ~10 m, while adults were caught at greater depths (Compagno, 1984; Schwartz, 1984). A newly longline fishing modality established off Pernambuco, aiming at Lutjanidae species, regularly capture large blacknose sharks in the upper slope (beyond 50 m isobath), corroborating on the ontogenetic distribution pattern on the gradient of depths (RPL**,** personal communication). Such an information confirms results presented by Barreto, et al (2011) showing that fishing exploitation using gillnets off Pernambuco - which target the Brazilian-Spanish-mackerel - catch only juveniles, whereas experimental deeper longlines catch subadults and adults specimens up to 146 cm TL in size. According to Carlson (2002) and Parsons & Hoffmayer (2005), *Carcharhinus acronotus* sharks have productive life-histories, is a relatively fast-growing species (Barreto et al., 2011), have early maturity and annual reproduction (Cortés 2002), and do not use discrete nearshore nursery areas, which has been also noted for this species in the current study.

It's important to highlight that the whole exploited area is under highly oligotrophic conditions derived from the warm Brazilian Current, where the fertilization effect is restricted to a very nearshore band (Schwamborn, 1999) with low impact on the shelf waters (Ekau and Knoppers, 1999). Thus, in such a poor environment, the smallest specimens of *R. porosus*, (neonates and small juveniles) seem to take advantage of enrichment provided by estuaries, mangroves and seagrass for growing fast in the shallowest areas, mostly nearby the reef line (Figs 2 and 3).

Juveniles and neonates were captured in several months, suggesting that births occurred throughout the year, as suggested by Yokota et al., (2006). The highest frequencies of newborn catches occurred in September and October (winter - spring).

All pregnant females were found from 22 to 45 m depth, in gravel (82%) and stone bottoms, without zero records in shallower waters, where the neonates and juveniles prevailed. It's assumed that pregnant females are distributed in the area by reaching the shallow areas for giving birth and immediately (unrecorded so far) leaving the area, remaining in deeper waters where they prey on the available larger items.

Information on the diet of this species is still fragmented due to samples caught by gillnets, in which most entangled species regurgitate their stomach contents, and has so far impeded to detail the ontogenetic shift - which supposedly would show distinct preys by developmental stages, as was found in other small coastal species exploited by the same gear, as *Carcharhinus porosus* and *Rhizoprionodon lalandii* (Lessa and Almeida, 1997; Bornatowsky et al, 2012).

Overall, the probability of *R. porosus* occurrence is driven by a set of environmental variables (depth, coast distance, substrate and season) that can summarize the ecological niche of this shark. Based on the presented data, it can be inferred that the use of the area changes according to body size and, subsequently, its sex. The deeper waters were exclusively inhabited by adult sharks (> 100 cm| CT), while neonates and juveniles occurred in shallow (<25 m depth). This may indicate that small individuals use shallow habitats to escape predators, as observed in other species by De Angelis, et al. (2008); Heupel, et al. (2007). Escaping predators may not be the sole factor causing depth segregation; for example, prey availability may also influence their preference on the habitats, as inferred by Munroe et al. (2015) for *Rhizoprionodon taylori* which use shallow areas to capture small teleosts, crustaceans and squids.

Of the two studied species, the neonates of the Blacknose shark were regularly found farther from the coast and beyond the reefs (> 15 m), in gravel or stone prevalent bottoms, and was different when compared to the Caribbean Brazilian Shark, which were always caught (~10 m) on a large array of bottoms (mud, gravel, stone). Other differences may also be pointed, in the way that those species share the area with the highest numbers for the first species in autumn and summer whereas the second are more numerous in spring. It's known that the Blacknose shark reaches deeper areas (Compagno, 1984; Barreto et al., 2011) on the shelf and slope - which has not been shown for Caribbean Brazilian shark due to constraints of fleet.

Knip et al (2010) proposed a theoretical model to encompass smaller bodied species, such as the blacknose shark *Carcharhinus acronotus* and Rhizoprionidae sp, postulating that the overall pattern followed by these sharks indicates that they can occur in nearshore waters (continental shelf) for their life-span, with immature and mature individuals of both sexes utilizing the same regions and habitats (Simpfendorfer & Milward 1993, Heupel et al. 2006, Ulrich et al. 2007).

In the current study, although our data agree with the general theoretical context by Knip et al (2010) in a broad sense, shows that an array of patterns is displayed by the two species within the continental shelf, which exploit near shore areas in distinct manners. In this way, they establish different habitats in a finer scale in order to avoid the overlap of niches needed to maximizing protection and food resources in different stages, allowing them to get high quality prey and growing faster.

Summing up, information presented in the current study is potentially useful for fisheries management, which should be implemented in a precautionary way, protecting small coastal sharks from the excessive fishing pressure. Accurate monitoring fisheries directed to commercial species should be triggered, as it is currently catching significant (and unrecorded) volumes of small sharks (mainly *C. acronotus*), and with that action, prevent them from suffering the same fate as the other sharks in Brazil.

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7. Considerações finais

No presente estudo ao se análizar suscetibilidade-produtividade (PSA) das espécies capturadas como bycatch na pesca de emalhe de fundo, identificamos como espécies mais vulneraveis ao aparelho de pesca os tubarões: *Rhizoprionodon porosus* e *Carcharhinus acronotus*, estas espécies também foram as mais constantes e também as mais freqüentes nas capturas, (principalmente neonatos e jovens) Essa freqüência nas capturas pode ser explicada por fatores como: a semelhança entre o diâmetro e forma do corpo dessas espécies, hábitos alimentares semelhantes aos das espécies-alvo (*Scomberomorus brasiliensis* e *Caranx bartolomaei*) e a ocorrência destas espécies em áreas próximas ao litoral, onde o esforço da frota artisanal e mais intenso. Este estudo demonstrou que estas espécies de tubarão usam os habitats de forma distinta, com segregação temporal (seasonal, vertical e horizontal) por tamanho e sexo. No caso do cação-rabo-seco (*R. porosus*) pôde-se observer uma distribuição impulsionada por uma combinação de fatores ambientais como a profundidade do habitat e o tipo do substrato. O conhecimento a cerca da forma como estes elasmobrânquios utilizam o habitat são fundamentais para o desenvolvimento de ações de manejo e conservação destas espécies. Embora adaptações (aumento) no diâmetro da malha sejam uma das alternativas para a redução das capturas de juvenis de tubarões no bycatch, tal alternativa torna-se impraticável, pois leva a uma diminuição das capturas das espécies-alvo, o que geraria impactos econômicos na produção das comunidades pesqueiras artesanais. Uma alternativa viável para reduzir a captura de elasmobrânquios como bycatch seria a criação de Áreas Marinhas Protegidas - AMPs para a proteção dessas espécies em estágios críticos dos ciclos de vida. Embora o presente trabalho tenha demonstrado a probabilidade da existência de berçários para *R. porosus* na costa de Pernambuco, estudos relacionados a análize de microelementos (microquímica) presentes nas vertebras destes animais são escenciais para confirmação da existência destes berçários, o que possibilitaria a definição de áreas de exclusão da pesca como alternativa viável para conservação e manejo destes elasmobrãnquios.