ANDREY PAULO CAVALCANTI SOARES

HÁBITOS ALIMENTARES E ASPECTOS POPULACIONAIS DO SARAMUNETE (*Pseudupeneus maculatus* (BLOCH, 1793)) NA COSTA NORDESTE DO BRASIL

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UNIVERSIDADE FEDERAL RURAL DE PERNAMBUCO (UFRPE)
PROGRAMA DE PÓS-GRADUAÇÃO EM RECURSOS PESQUEIROS E AQUICULTURA (PPG-RPAq)

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Andrey Paulo Cavalcanti Soares

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

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Orientador

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Hábitos alimentares e aspectos populacionais do saramunete (*Pseudupeneus maculatus* (Bloch, 1793)) na costa nordeste do Brasil.

Andrey Paulo Cavalcanti Soares

Dissertação julgada adequada para obtenção do título de mestre em Recursos Pesqueiros e Aquicultura. Defendida em 28/02/2019 pela seguinte banca examinadora.

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Dedicatória

Aos meus pais, Cleize Cavalcanti de Melo e Paulo Sérgio de Oliveira Soares

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“If you can believe it, then you can achieve it.”

Resumo

O saramunete *Pseudupeneus maculatus* é um importante recurso pesqueiro no nordeste do Brasil, sendo também um componente crucial da biodiversidade. Existem poucos dados publicados acerca dos aspectos populacionais, distribuição espacial e dieta do saramunete. Assim, este trabalho teve como objetivo estudar aspectos populacionais, hábito alimentar e distribuição do saramunete ao longo da costa do Nordeste do Brasil. Foram feitas amostragens ao longo da costa do nordeste (5°-9°S), entre os estados do Rio Grande do Norte e Alagoas, através de dois cruzeiros científicos. Foram definidos 3 principais hábitats (cobertura de coral, cobertura de algas e cobertura de areia), 2 níveis de posição na plataforma continental (próximo à costa / próximo à quebra) e 4 níveis de gradiente latitudinal. Padrões de distribuição foram estudados usando taxas de capturas CPUE (kg/km^2) e frequências de comprimentos. Para avaliar a composição da dieta foram calculadas a frequência de ocorrência (%FO), frequência numérica (%N) e frequência relativa por peso (%P), além dos índices IRI e IAI. As análises multivariadas MDS, ANOSIM E SIMPER foram utilizadas para avaliar a similaridade das dietas entre os hábitats, posições na plataforma e gradiente latitudinal. O comprimento padrão variou entre 4,4 e 23,8 cm, e a maior abundância ocorreu na classe de 16-18 cm (29%). O tamanho de primeira maturação foi definido como 13,7 cm de comprimento padrão. O fator de condição *k* variou entre o gradiente latitudinal, com maiores valores nos hábitats mais ao norte (< 6°S). A atividade alimentar foi classificada como diurna. O *P. maculatus* se alimentou principalmente de crustáceos e menos frequentemente de poliquetas e teleósteos, classificando-o como um predador zoobentívoro. Foram identificadas diferenças significativas entre as distribuições de frequências de comprimento, com elevada presença de juvenis nos hábitats coralíneos e nas áreas mais ao sul (> 8°S), onde há maior presença de áreas marinhas protegidas que oferecem melhores condições, e indivíduos maiores (> 17cm) mais abundantes nas áreas próximas à quebra da plataforma. Os padrões de distribuição de CPUE indicaram maior abundância no norte de Pernambuco. Altas CPUEs também foram identificadas nos hábitats ao sul (> 8°S) onde há a APA dos corais.

Palavras chave: Padrões de distribuição, ecologia trófica, reprodução, mulídeos

Abstract

The spotted goatfish *Pseudupeneus maculatus* is an important fishery resource in the northeast region of Brazil, as well as an important component for the biodiversity. There are few published data about spatial distribution and feeding habits of the spotted goatfish. Thus, this study aimed evaluate population aspects, feeding habits and distribution patterns of the spotted goatfish along the northeast coast of Brazil. Sampling was performed in two scientific cruises along the northeast coast, between the states of Rio Grande do Norte and Alagoas. 3 major habitats were identified (Sand with coralline rocks, Algae coverage and Sand coverage), 2 levels of shelf position (inner shelf and outer shelf) and the latitude gradient (5-9°S). Distribution patterns were evaluated by using capture rates (CPUE – kg/km²) and length frequency. 291 of the 505 individuals caught were taken to laboratory to further analysis. The length at first maturity was estimated as 13.7 cm of standard length and growth was classified as negative alometric for females, isometric for males and isometric for pooled sexes. Standard length varied from 4.4 to 23.8 cm, and the most frequent length class was 16-18 cm (29%). Condition factor k varied along the latitude gradient, with higher values in the northern areas, especially compared to the southern areas. Feeding activity was classified as diurnal and the feeding intensity FI was higher in the southern areas. P. maculatus feeds mainly by crustaceans (shrimps, brachyurans and stomatopods) but also by polychaetas and Teleostei fish. It classifies the spotted goatfish as a zoobenthic predator. Significant differences were identified in the length frequency distribution, with high presence of juveniles in coralline habitats and larger individuals more abundant near the shelf break. CPUE analysis revealed high abundance in the north of Pernambuco, where is located the largest fisheries for the spotted goatfish. Also, high CPUE was identified in the southern habitats, were is located the MPA “APA Costa dos Corais”, that probably contributes for the high abundance.

Keywords: Distribution pattern, trophic ecology, diet

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Sumário

1. Introdução

A família Mullidae inclui cerca de 88 espécies de peixes, englobados em 6 gêneros. Os mulídeos se diferenciam das outras famílias de Perciformes principalmente pela presença de barbilhões localizados na região hioidea, que são estruturas sensoriais utilizadas principalmente na alimentação, mas também em interações sociais (Filkovsky e Springer, 2010; Gosline, 1984; Krajewski *et al.*, 2006). Os mulídeos estão envolvidos em diversos tipos de associações biológicas, como por exemplo nas associações do tipo "nuclear-follower" (Aronson e Sanderson, 1987), onde os indivíduos de espécies classificadas como seguidoras são atraídos através dos itens alimentares expostos pela atividade dos indivíduos de espécies classificadas como nucleares. Tais associações são comuns para diversos tipos de peixes e outros animais, ocorrendo em vários hábitats (Sazima *et al.*, 2006). Nesse tipo de associação alimentar, os mulídeos em geral são classificados como "nucleares" (Aronson e Sanderson, 1987; Lukoschek e McCormick, 2000), com várias espécies de peixes de relevante importância econômica associados a eles (Sazima *et al.*, 2006).

Mulídeos compõem importantes pescarias em várias regiões do mundo, como por exemplo o *Mullus barbatus* e *Mullus surmuletus*, espécies que ocorrem no Atlântico Nordeste e tem alto valor comercial, sendo alvos de pescarias principalmente nos mares Mediterrâneo e Negro (Fiorentini, *et al.*, 1997; Relini, *et al.*, 1999; Tserpes *et al.*, 2002), com uma produção, no ano de 2016, de cerca de 14.000t e 12.000t respectivamente (FAO, 2018). Outras espécies dos gêneros *Upeneus*, *Parupeneus* e *Mulloidichthys* são importantes componentes de pescarias artesanais nas águas rasas de recifes coralíneos do Mar Vermelho (Kumaran e Randall, 1984). Espécies de mulídeos são consideradas, econômica e comercialmente, as mais importantes do setor norte do Mar Vermelho norte do Egito (Mehanna *et al.*, 2018; Sabrah, 2015).

No litoral brasileiro são registradas ocorrências de quatro espécies de mulídeos, sendo apenas três delas com registros no nordeste (Menezes *et al.*, 2003). Dentre elas, duas apresentam maior representação na pesca. São elas a *Mulloidichthys martinicus*, conhecido como saramunete-guaiúba, que tem menor abundância em relação à outra espécie, e o *Pseudupeneus maculatus*, popularmente conhecido como saramunete ou peixe-trilha. O *P. maculatus* apresenta corpo raso, alongado e fusiforme e cabeça de tamanho médio. Tem como característica peculiar a variação na coloração de acordo com sua atividade, ou seja, enquanto ativo, investigando o substrato à procura de alimento, apresenta três manchas retangulares escuras ao longo da linha lateral, com colorido geral acinzentado claro, e, quando em repouso, sua coloração apresenta-se avermelhada com manchas amareladas nas margens das escamas e linhas diagonais azuladas na cabeça (Cervigón, 1993; Gosline, 1984). É presente em boa parte da costa oeste do oceano Atlântico, desde New Jersey, EUA, até Santa Catarina, Brasil, incluindo o Golfo do México e Caribe, onde habitam áreas de recife de coral em zonas de substrato arenoso, lamoso ou áreas de capim marinho, em uma profundidade média de 35m, mas podendo atingir até 90m de profundidade (Carvalho-Filho, 1994; Cervigón, 1993). *P. maculatus* é capturado em todo mar do Caribe através de armadilhas, e têm alto valor comercial, especialmente na Jamaica (Dooley *et al.*, 2015). Em Porto Rico há uma frota comercial que tem como alvo o saramunete (Dooley *et al.*, 2015) e na República Dominicana é bastante capturado como fauna acompanhante da frota lagosteira (Herrera *et al.*, 2011). Há um considerável número de estudos sobre o saramunete na região do Caribe (Collin e Clavijo, 1978; Filkovsky e Springer, 2010; Munro, 1976), entretanto são relativamente pontuais, em termos espaciais.

No Brasil, a exploração do *P. maculatus* é feita majoritariamente de forma artesanal, através de pequenas embarcações de madeira (Campos e Oliveira, 2001; Lessa, *et al.*, 2004). Apesar de ocorrer em todos os estados da região Nordeste, sua pesca para fins comerciais está praticamente restrita a Paraíba e Pernambuco. Essa pescaria é realizada principalmente na plataforma continental através de armadilhas popularmente conhecidas como covo ou manzuá, lançadas em áreas de fundo rochoso ou de cascalho, com profundidades que variam entre 18 a 27 metros (Campos e Oliveira, 2001), sendo recolhidos manualmente cerca de 48h após o lançamento (Campos, 2000).

Várias espécies de peixes, como é o caso do Saramunete, que antes eram consideradas apenas fauna acompanhante da pesca de covo da lagosta e eram descartadas ou consumidas apenas em escala local, ganharam valor econômico e passaram a ser espécies-alvo desse tipo de pesca, sendo comercializadas inclusive para o mercado externo (Ribeiro, 2006). O saramunete é considerado um pescado de alta importância econômica, além de ser uma das poucas espécies do litoral norte de Pernambuco destinadas à exportação, principalmente para os Estados Unidos e Europa, onde há uma alta demanda por esse pescado (Marques e Ferreira, 2010).

Alguns estudos apontam o saramunete como uma das espécies mais capturadas em número e em biomassa no Nordeste do Brasil (Barbosa *et al*., 2009; Lessa, *et al.*, 2004;

Ribeiro, 2004), com registro de 78% de captura no estado de Pernambuco (Lessa *et al.*, 2009). O estado de Pernambuco representava como um dos maiores produtores da espécie, com valores que foram de 18 toneladas em 1994, para 296 toneladas no ano de 2007, atingindo o pico no ano 2000, com aproximadamente 626 toneladas (IBAMA, 2002). Em 2006, o saramunete representou 11% da receita da região Nordeste com 3 milhões de reais (IBAMA, 2008). Seu estado de conservação é, de acordo com a IUCN, pouco preocupante, entretanto um estudo de avaliação de estoques no ano de 2002 concluiu que em Pernambuco os estoques estavam sobre-explotados (Araújo, 2002). Desde então não há nenhuma informação acerca da produção ou estado do estoque da espécie na região.

A gestão pesqueira está sofrendo mudanças ao longo do tempo. Novos conceitos, incluindo os aspectos ecossistêmicos e espaciais, estão sendo desenvolvidos no mundo inteiro (Douvere & Ehler, 2009; Ehler, 2014; Ehler *et al.*, 2019). Neste contexto, precisamos determinar os padrões bio-ecológicos das espécies em termo espaciais a fim de contribuir para um manejo espacializado, sob um enfoque ecossistêmico.

2. Objetivos

2.1. *Objetivo geral*

Estudar aspectos populacionais, hábito alimentar e distribuição do saramunete (*P. maculatus*) ao longo da costa do Nordeste do Brasil, mais especificamente entre os estados de Alagoas e Rio Grande do Norte.

2.2. *Objetivos específicos*

- Descrever os padrões de distribuição latitudinal e longitudinal do *P. maculatus* em diferentes habitats da plataforma continental da região Nordeste

- Descrever os padrões espaciais da distribuição dos indivíduos abaixo do L_{50} e considerados juvenis

- Avaliar os padrões espaciais do hábito alimentar latitudinalmente e ao longo do gradiente de profundidade da plataforma continental

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4. Artigo científico

4.1. Feeding habits and population aspects of Pseudupeneus maculatus (Perciformes: Mullidae) along the Northeastern Brazilian coast

Feeding habits and population aspects of *Pseudupeneus maculatus* (Perciformes: Mullidae) along the tropical Brazilian continental shelf

Andrey Paulo Cavalcanti Soares

Universidade Federal Rural de Pernambuco.

This study provides information about feeding habits and spatial distribution of *Pseudupeneus maculatus* captured along the coast of the Brazilian Northeast. The individuals were caught during two oceanographical campaign entitled ABRACOS (Acoustics Along Brazilian Coast), one from August 2015 to September 2015 and the second from April 2017 to May 2017. There were identified 3 major habitats (Algae, Sand and SWCR) in which *P. maculatus* occurs. The positions on the continental shelf were divided into inner shelf and outer shelf and the longitude gradient were divided in intervals of 1° (5° to 9°S). Distribution pattern were evaluated through analysis of length frequency and CPUE (kg/km^{-2}) distribution. To access the diet composition, numerical frequency %N, frequency of occurrence %FO and weight percentage %W were calculated. Multivariate analysis of MDS, ANOSIM and SIMPER were performed to evaluate similarities/differences of the diet between habitats, shelf break positions and latitude gradient levels. Individuals mature with 13.7 cm (L_{50}). There is a slight trend of ontogenetic distribution along the shelf, with larger individuals tending to live in deeper areas. Also, juvenile abundance and feeding intensity were higher in more southern habitats (>8°S) along the coast. The diet of *P. maculatus* is mainly composed by crustaceans (Decapoda, Stomatopoda) but also by teleostei fish and polychaeta. *P. maculatus* presented as a generalist zoobentivorous predator, with a little degree of specialization over crustaceans. This study shows *P. maculatus* is not only an important fishery resource but also a crucial component of the biodiversity of the northeast coast of Brazil.

Key words: spotted goatfish, distribution patterns, trophic ecology, diet, Brazil

INTRODUCTION

The Brazilian coastline is about 8,000 kilometers long and comprises many different habitats (Costa, *et al.*, 2007). The northeast coast is the largest portion of the Brazilian shoreline and one of the most populated (IBGE, 2011). The fishing activity in this region is mostly composed by small scale fisheries, with artisanal fleets, but it has a high economic impact involving more than 200,000 persons, landing the highest volume of fish of Brazil (Lessa *et al.*, 2009; Lessa, *et al.*, 2004). Also, the northeast coast have many Ecologically or Biologically Significant Marine Areas (EBSA) (CBD, 2014).

The spotted goatfish *Pseudupeneus maculatus* is an important fish resource on the northeast region. Its fishery is consisted by canoes and box-like traps, operating on the continental shelf in areas of rocky or gravel bottoms, and depths varying between 18 and 27 meters (Campos, 2000; Campos e Oliveira, 2001; Lessa, Bezerra Júnior e Nóbrega, 2004). Even if this fishery occurs along all the northeast region, the commercial fishery targeting this resource is almost restricted to the states of Paraíba and Pernambuco. Statistics pointed that the spotted goatfish is one of the most captured species with traps in Pernambuco, Brazil (Barbosa, *et al.*, 2009; Lessa, *et al.*, 2004; Ribeiro, 2004), also representing 11% of the total income stemmed from the fishery production of the Northeast region of Brazil (IBAMA, 2008). It is also considered a highly valuable seafood compared with other categories fishery resources, and one of the few species captured by the artisanal fleet of Pernambuco destined for exportation (Marques & Ferreira, 2010).

The biology of *P. maculatus* has been extensively studied. There are some studies about age and growth, length at first maturity, morphometry and feeding behavior about *P. maculatus*, but these studies rely mostly on underwater visual census or fishery-based data (Campos & Oliveira, 2001; Collin & Clavijo, 1978; Filkovsky & Springer, 2010; Krajewski *et al.*, 2006; Munro; Santana, *et al.*, 2006). Also, there is a lack of studies about *P. maculatus* on a larger scale, with fishery-independent data and correlating with habitat composition and abiotic parameters.

Studies about diet and feeding activity of economically important species in their natural habitats are critically relevant because they can provide valuable information on how the organisms' interactions with the environment contribute on the functioning and management of the water resources (Blaber, 2013; Winemiller, *et al.*, 2008) and how to proceed with managing and monitoring the fishing resources (Whitfield & Elliott, 2002), helping to identify areas with potential to become marine protected areas (MPAs). Also, it is important to help the development of guidelines for aquaculture as well as the creation of new techniques for fish farming. Fishery management is under constant changes and new concepts including ecosystem and spatial aspects of species are being developed around the world (Douvere e Ehler, 2009; Ehler, 2014; Ehler, Zaucha e Gee, 2019) and studies, especially about economically important species, are important since these studies may contribute to future management and conservation actions. In this context, this study has the purpose of describe population characteristics, feeding habits and spatial distribution patterns of *Pseudupeneus maculatus* of Northeast Brazil, aiming to contribute with the development of a spatialized management.

MATERIAL AND METHODS

Study area

Sampling occurred along the Brazilian northeastern coast between the states of Rio Grande do Norte (5°S of latitude) and Alagoas (9°S of latitude) (Figure 1). This region contains a high biodiversity and several areas considered priority for management and conservation (CBD, 2014). The continental shelf is 40km width in average, and the average depth per latitude varies between 40 and 80m (Vital *et al.*, 2010). In general, the oceanographic conditions in this area are oligotrophic with warm waters and permanent thermocline which, allied with other factors, gives the characteristics of a typical tropical marine region, with low levels of primary productivity and abundance, but high biodiversity (Hazin, 2006).

Sampling and sample processing

The samples were collected during Acoustic Along Brazilian Coast (ABRACOS) project, composed by two scientific expeditions (Bertrand, 2015, 2017). The first was carried out on August/2015 - September/2015 and the second on April/2017 - May/2017, both aboard the scientific vessel R/V ANTEA. There were 37 sampling stations along the transect of the continental shelf, between 5°S and 9°S (Figure 1). Trawls were performed in depths between 10 and 60m for 5 minutes with a bottom trawl net (body mesh: 40mm, cod-end mesh: 25mm and mouth aperture: 280m²) with diurnal and nocturnal tows. The geometry of the net was evaluated through the SCANMAR system to give an estimate of height, depth and aperture width of the net. Three major types of habitat were identified and classified as: (i) Sand; (ii) Algae; and (iii) Sand with rocks, coralline formations and sponges (SWCR) (Eduardo *et al.*, 2018a). The continental shelf averages 40km width and it is almost completely covered by carbonate sediments (Vital *et al.*, 2010). This was the basis on which shelf position were classified, according to the distance of the sampling point from the shore: inner-shelf (<20 km to the shoreline) and outer-shelf (>20 km from the shoreline). Also, the latitudinal gradient was stratified in four levels according to the sampling points position: A (<6°S), B (6 – 7°S), C (7 – 8°S) and D (>8°S), according to Eduardo *et al.* (2018) for the same area. Onboard, each fish sample was identified, counted, weighted on a motion-compensating scale and preserved in a 4% formalin solution or frozen until further processing. Later in the laboratory, morphometric data was obtained for each specimen. Stomach were removed through a ventral longitudinal incision and immediately fixed in 10% formalin solution for 48h and subsequently stored in a 70% alcohol solution. Content of each stomach were sorted, counted, weighted (g) and identified to the lowest possible taxonomic level.

The relative index of biomass, defined as the capture per unit of effort (CPUE), was determined considering the weight of fish captured per trawled area ($kg.km^{-2}$). This area was determined by multiplying the tow distance by the mouth opening area, estimated by the SCANMAR system. Distribution patterns were evaluated through the analysis of the length-frequency distribution and CPUE. To test significant differences in the mean standard length between shelf positions, the Mann-Whitney test was performed and the Kruskal-Wallis test for differences between habitats and latitude levels after the basic assumptions of normality and homoscedasticity and homogeneity were proved not enough for a parametric test.

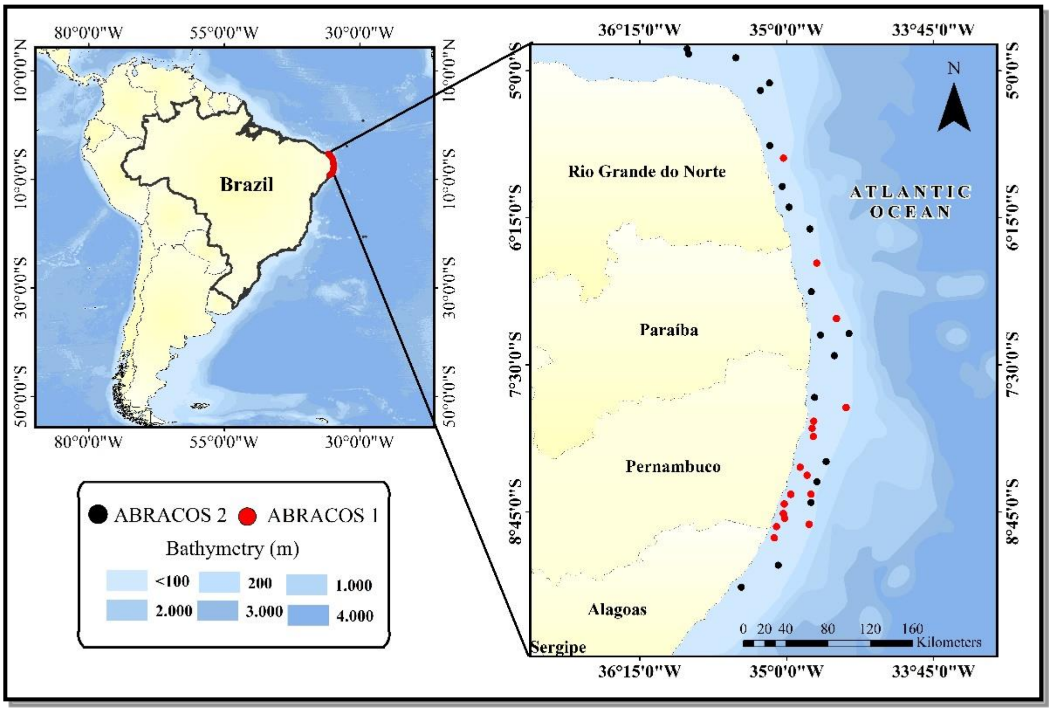

Figure 1: Area of study with bathymetry and sample points along the continental shelf of the Northeastern coast of Brazil

Length-weight relationship (LWR) was determined for grouped and separated sexes by using the log-transformed morphometrical data collected in laboratory. The relationship was expressed by the equation: $TW = aSL^b$, where: TW = total weight in g, SL = standard length in cm, *a* = intercept (constant) and *b* = slope of regression (allometry coefficient). The allometry coefficients were further tested for significant deviations from the expected $b = 3$. The condition factor (K) was determined according to the method proposed by Ricker (1975), adapted by Albieri and Araújo (2010), and is expressed by the following equation: $K = \frac{TW}{SL^b}$, where b is the allometry coefficient of the LWR. The allometry coefficient (*b*) and the condition factor (*K*) were both tested for differences between habitats, shelf positions, latitude levels and sexes.

Gonadal development was assessed by macroscopic evaluation and the gonads were classified in four stages: A = immature; B = maturing; C = mature, and D = spawned or resting. Length at first maturity (L_{50}), which is the proportion of adults (stages B, C and D) by length, was calculated for pooled and separated sexes to determine whether the individuals is juvenile (SL < L_{50}) or adult and considered the standard length as the independent variable. Sex-ratio was determined following the formula total number of males / total number of females (Vazzoler, 1996), and they were statistically tested for significant deviations from the expected 1:1 ratio with a chi-squared test ($\alpha = 0.05$).

Feeding intensity was classified observing the degree of fulness, with degree I – empty, II – partially empty, III – partially full and IV – full (Viana *et al.*, 2010). As an indicative of feeding intensity, the Zavala-Camin (1996) fulness index *FI* was used as an indicative of feeding intensity. *FI* differences between habitats, shelf position and latitude levels were tested using the nonparametric Kruskal-Wallis test.

The contribution of each prey taxon to the composition of the diet was accessed by following three relative metrics of prey quantity: frequency of occurrence (%FO), numerical abundance (%N) and weight percentage (%W) (Bowen, 1996; Hyslop, 1980). All the items collected in the stomach content analysis were considered for subsequent analysis. For a solid assessment of prey importance, two indexes were calculated: the Index of Relative Importance (IRI) (Pinkas, *et al.*, 1971) and the Alimentary index (IAi) (Kawakami & Vazzoler, 1980) adapted by (Oliveira *et al.*, 2004). The IAi is basically based on frequency of occurrence and on the volume of each item, but some authors use this method with modifications, substituting volume by weight, such as Oliveira *et al.* (2004) and Hahn *et al.* (1997). The IRI combines the frequency of occurrence, weight and numerical occurrence of each item. We choose to use these two indexes to have a more robust assessment of the diet.

Niche breadth was estimated by Levin's standardized index *Bi*. This index varies from 0 (species that feed on only one item) to 1 (species that feed on the same proportion of all evaluated items) (Levins, 1968).

The alimentary strategy was characterized through the modified Costello diagram (Amundsen *et al.*, 1996), a graphic representation of prey items, which allow us to infer about the degree of the diet variability of a predator, plotting the prey specific importance of each prey taxa against the frequency of occurrence in 2D diagram, with three axis representing the feeding strategy, prey importance and niche width. In the top right corner of the diagram, a unique prey appears as the most frequent in the most of individuals, meaning that all predators prey on the same item, showing low between/within variability. If most prey are in the bottom left corner, it is both low occurrent and low abundant, meaning the predator displays a generalist habit, with high between/within individual variability.

To assess the degree of similarity in the diet, a multivariate technique of multidimensional scaling (MDS) based on Bray-Curtis similarity matrix, with the stomachs being considered as sampling units. Relative weight of prey (%W) were square root transformed to reduce dominance effect of some prey items. Differences between habitats, shelf position and latitude levels were tested through ANOSIM (Clarke, 1993). The items that discriminated the groups were also evaluated by a SIMPER routine analysis. The R software (R Core Team, 2017) was used for the multivariate analysis.

Stable isotope analysis

Up to ten individuals from each sampled station were selected for isotopic analysis. Fish had white muscular tissue extracted, cleaned with distilled water to remove exogenous material such as scales and bones. Samples were dried in an oven at 60°C for 48h and grounded into a fine powder with a mortar and pestle. Each sample was analyzed for carbon and nitrogen isotope ratios through a mass spectrometer (Thermo Delta V+) coupled to an element analyzer (Thermo Flash 2000, interface Thermo ConFio IV) in the Laboratory of Marine Environment Science, Institute of Research for Development (LEMAR – IRD), France. Results of stable isotope analysis for carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) are derived from the relation of the isotopic value from the sample and a known standard: $\delta^{13}C$ or $\delta^{15}N = [(R_{sample}/R_{standard}) - 1] \times 10^3$; in which R corresponds to the ratio between ^{13}C:^{12}C or ^{15}N:^{14}N. The mean values of $\delta^{13}C$ and $\delta^{15}N$ were tested for differences among habitats, shelf positions and in the latitude gradient.

The trophic position of the spotted goatfish across habitats, shelf positions and along the latitudinal gradient was accessed through the formula proposed by Post (2002): $TP_{si} = [(\delta^{15}N_{consumer} - \delta^{15}N_{baseline})/TDF] + TP_{baseline}$, in which $\delta^{15}N_{consumer}$ and $\delta^{15}N_{baseline}$ are the $\delta^{15}N$ values of the target consumer and the baseline respectively; TDF is the trophic discrimination factor and was considered to be 2.54‰ (Vanderklift e Ponsard, 2003); and $TP_{baseline}$ is the trophic position of the baseline. Assuming there is no long-living filter feeder to be the baseline, the mean $\delta^{15}N$ of zooplankton was used as baseline. To give a more robust response of the trophic level, the analysis of trophic position based on the stomach content analysis was done to compare with the results of the stable isotopes analysis, based on the formula: $TP_{sc} = \sum(W_i T_i) + 1$, in which W_i and T_i are the relative weight and the trophic position of the *ith* prey item, respectively.

RESULTS

Population aspects

From the 505 individuals captured and identified aboard, 291 were analyzed in the laboratory. Standard length (SL) ranged from 4.4 to 23.8 cm $[15.05 \pm 4.01(mean \pm SD)]$, while total weight (TW) varied from 1.04 to 315.01 g (91.38 ± 54.86). From these, 154 gonads were in good condition to be retrieved, being 28% males, 34% females and 38% were juvenile and its gonads could not be sexed. In general, growth was classified as positive allometric $(b > 3; p < 0.05)$ and the length at first maturity was estimated as 13.7 cm SL $(y = \frac{1}{[1+e^{-(13{,}4762+0{,}9759*x)}]})$ for pooled sexes (Figure 2), 14.2 cm SL for females and 14.9 cm SL for males. Significant differences in growth were found between sexes, with females classified as negative allometric $(b < 3; p < 0{,}05)$ and males as isometric $(b = 3; p > 0{,}05)$. When we compared the b values within spatial categories such as shelf positions and habitats, no significant differences were found. However, the *b* values varied among latitude levels, being isometric in the A (<6°S) and B (6 – 7°S) stratum and positive allometric in C (7 – 8°S) and D (>8°S).

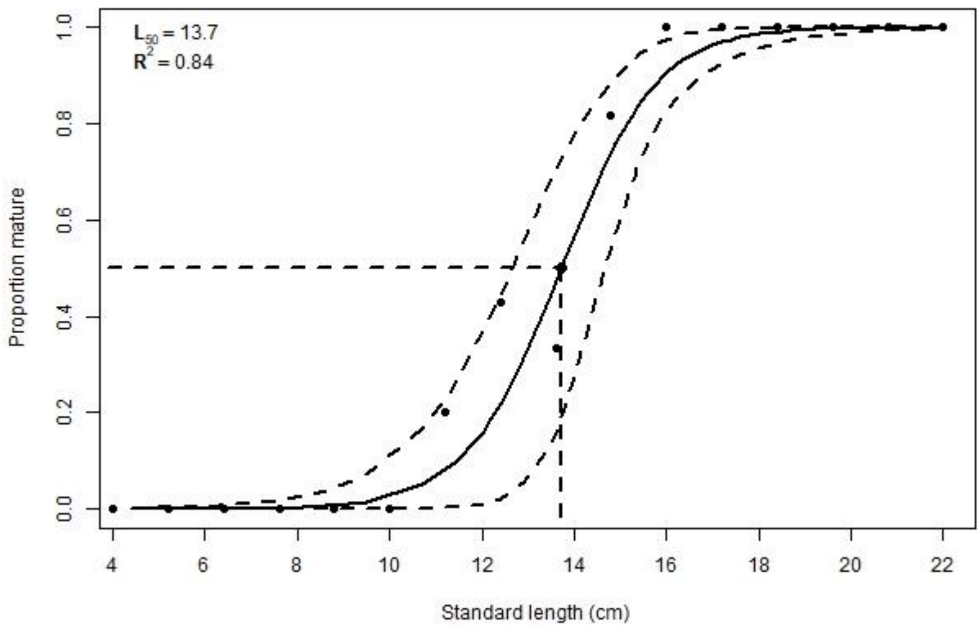

Figure 2: Standard length at first maturity (L_{50}, cm) and confidence intervals (CI, 95%) for pooled sexes of spotted goatfish *Pseudupeneus maculatus*, captured along the northeast Brazil coast.

In general, the most representative length class was 16-18 cm, with 29% of the individuals, as well as among females (40%). Among males, the most representative class was 18-20 cm (35%) (Figure 3). Differences in size frequency distribution were found between SWCR, with high presence of juveniles, and the other habitats. Although the higher presence of juveniles, the mean SL of SWCR was higher, especially compared to sand habitats, due to the bimodal distribution with high frequency of juveniles and larger individuals (SL>17cm) and a large range of lengths. Mean SL and size distribution were higher in outer-shelf than inner-shelf areas ($p < 0.05$) (Figure 4).

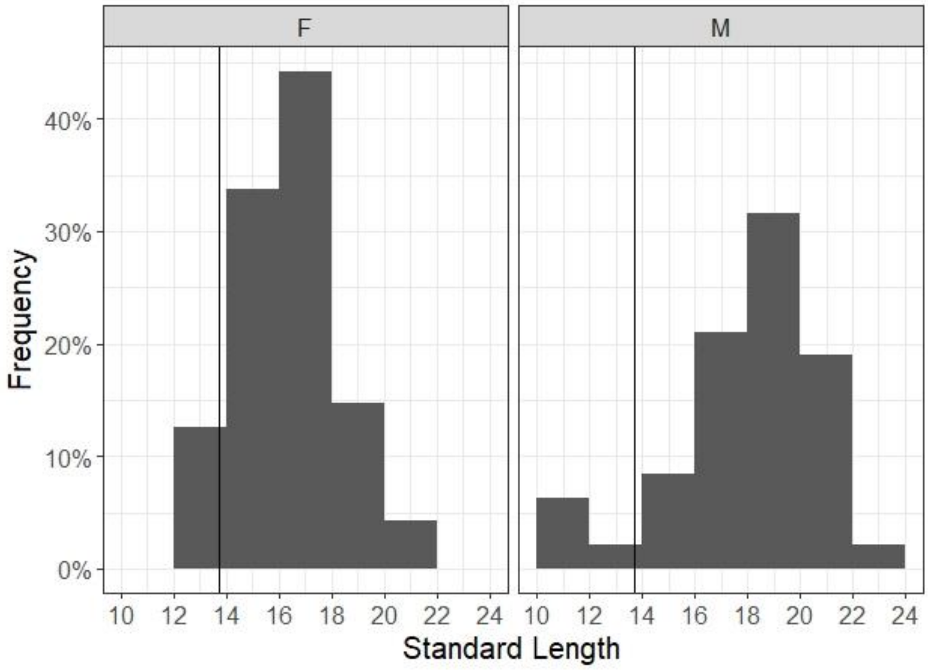

Figure 3: Relative length frequency distribution of males and females of *P. maculatus*. The vertical black line indicates the size at first maturity (L_{50} = 13.7 cm).

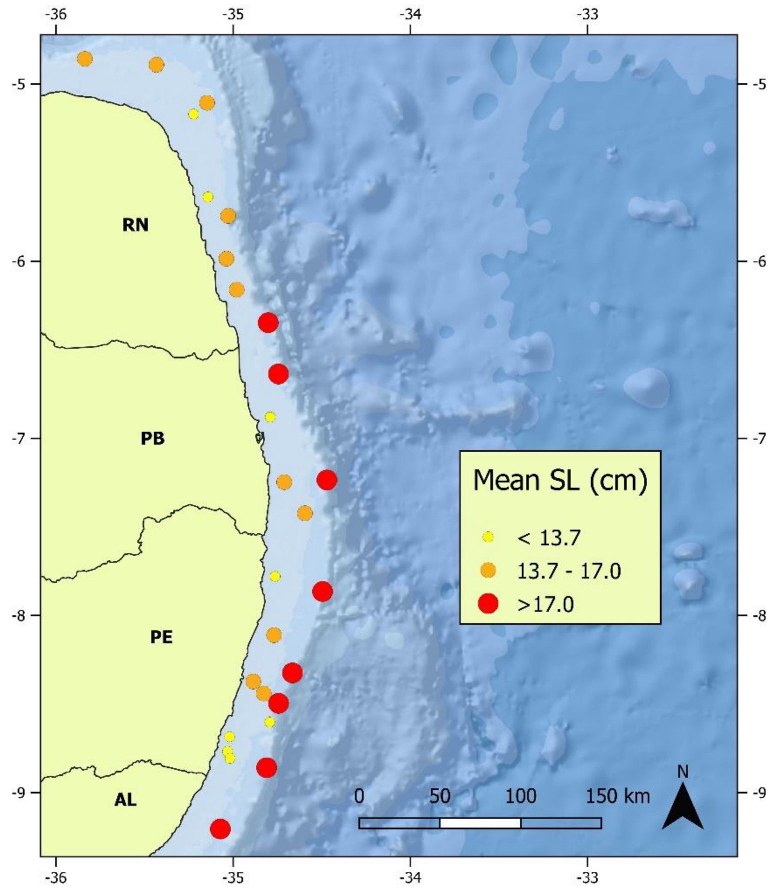

Figure 4: Mean standard length of the *P. maculatus* distributed along the sampling points in the continental shelf of the Northeast Brazil (L_{50} = 13.7 cm).

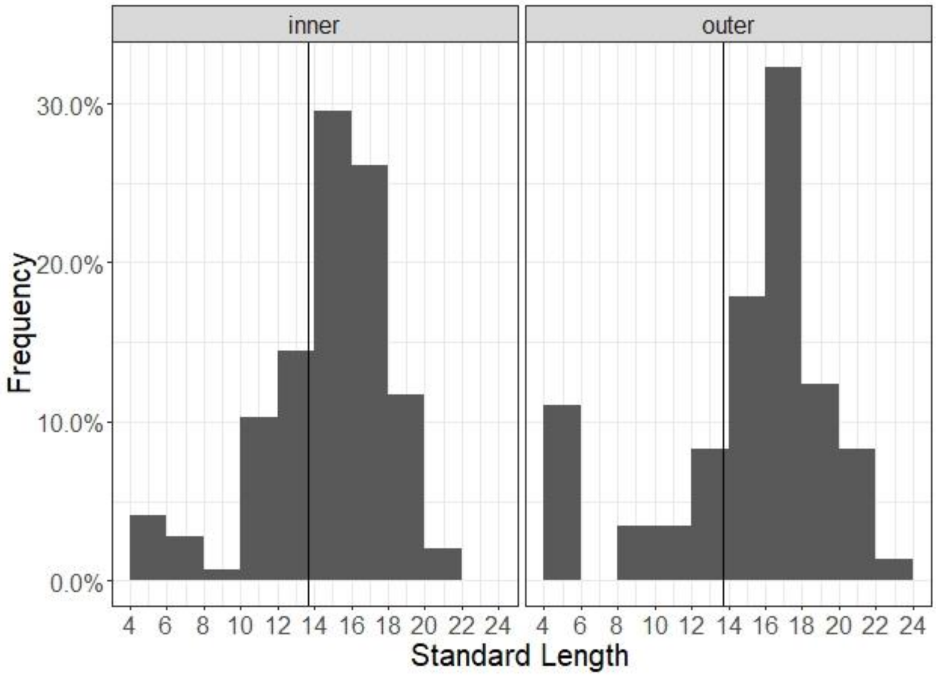

Figure 5: Relative length frequency distribution of *P. maculatus* along the levels of shelf position. The vertical black line indicates the size at first maturity (L_{50} = 13.7 cm).

As the outer-shelf areas are composted mostly by SWCR habitats, the frequency of juveniles in these areas was elevated but also the number of larger individuals. The mean SL did not differ significantly among the latitude levels, but the size distribution of the stratum D differed from the others stratum because of the high frequency of juveniles in this level. The CPUE analysis (Figure 6) showed higher abundance in the southern sampling points (below 8°S), where is located the MPA "APA Costa dos Corais" which plays an important role for the environmental protection and for the management and sustainability of the artisanal fisheries present there. There are also some peaks off the coast of Pernambuco and Paraiba, where fisheries for spotted goatfish is present, and less but not least in the north of the Rio Grande do Norte.

Females and males were equally abundant, with the sex ratio not being significantly different from 1:1 ($p > 0.05$). Mean SL was significantly different between sexes ($p < 0.05$), with males being larger than females. Most individuals with sexes identified were adults (90.6% adult males and 90.3% adult females).

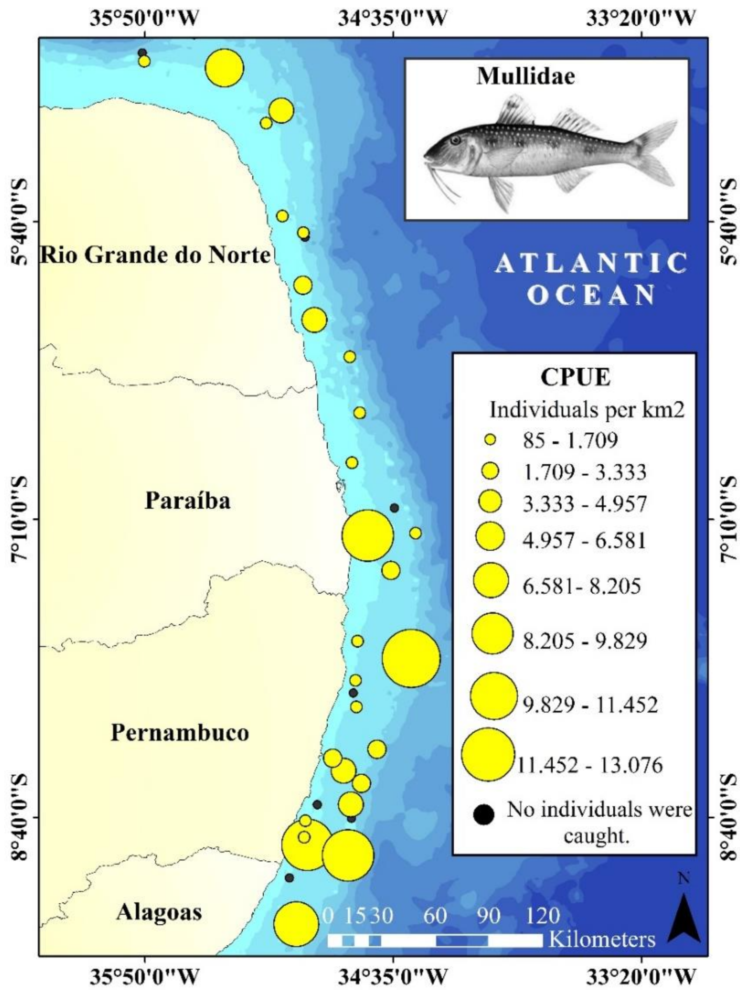

Figure 6: Spatial representation of the catch per unit of effort (CPUE; ind/km²) of *Pseudupeneus maculatus* caught along the northeast Brazilian continental shelf.

Significant differences in the condition factor *K* were identified among habitats, with SWCR showing lower values than the other habitats ($p < 0.05$). Algae and Sand showed no statistical differences between them ($p > 0.05$) (*Figure 7* A). Significant differences in *K* were also identified among latitude stratum (*Figure 7* B), with the northernmost areas (<6°S) presenting higher values compared to other areas ($p < 0.05$), while the southernmost stratum showing the lowest values of *K* compared to the others ($p < 0.05$) (*Figure 8*). No statistical differences in *K* were found between shelf positions and different sexes.

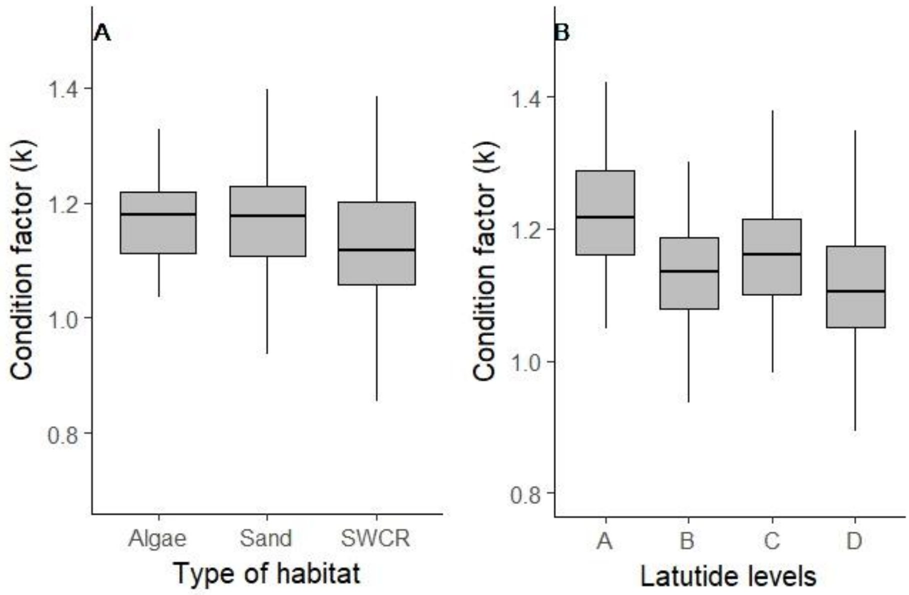

Figure 7: Condition factor (k) in different habitats (A) and in different latitude levels: A (< 6°S), B (6 – 7°S), C (7 – 8°S) and D (> 8°S) (B). The black horizontal line and box represent the median value and the interquartile range, while the vertical lines represent the upper and lower limits. Outliers were not included in the plot.

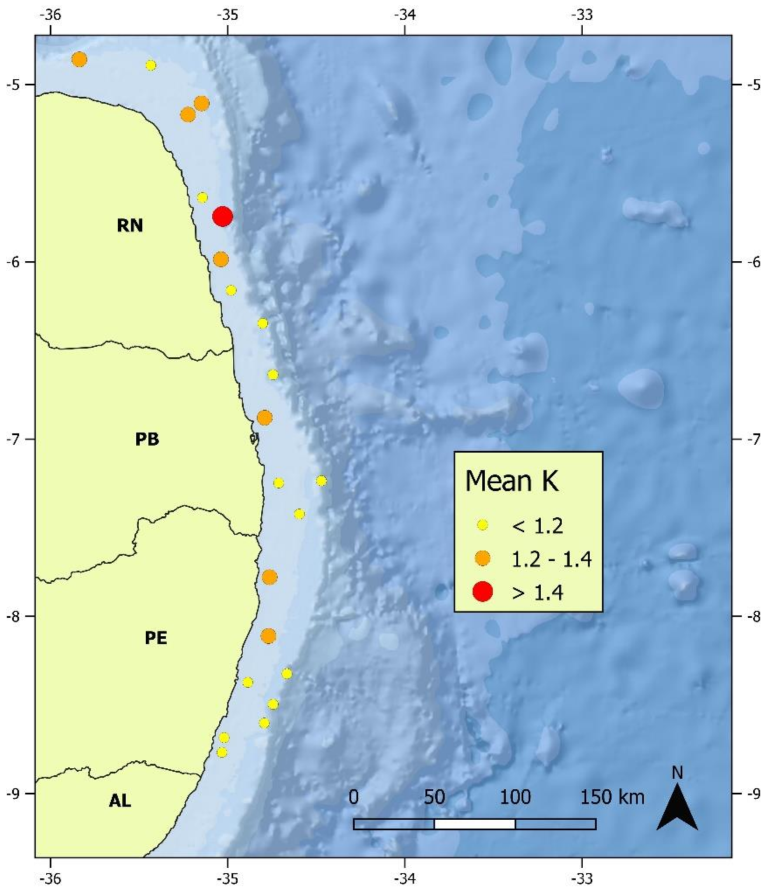

Figure 8: Mean condition factor (k) of the P. maculatus distributed along the sampling points in the continental shelf of the Northeast Brazil.

Diet composition

A high proportion of *P. maculatus* had food content in their stomach (degrees II, III and IV) (63%), mainly in the habitats Algae (88%) and SWCR (85%), compared to Sand (56%). Also, 65% of those fish with no stomach content (degree I) were captured during the night time. From those with food content in the stomach, only 20% of them were collected during night tows, and 85% of these tows were performed earlier than 9 pm.

There was no significant difference ($p > 0.05$) of fulness index between habitats and shelf positions(Figure 9), however differences were found between latitude stratum D and the other levels ($p < 0.05$), with higher FI in this stratum (Figure 10)

The diet of *P. maculatus* was composed mainly by crustaceans, Teleostei fish and polychaeta. In general, crustaceans dominated over the other categories, specially the decapods that were the most abundant. The most frequent items were unidentified shrimp, polychaeta and Teleostei fish (%FO: 34, 20 and 17, respectively). Among decapods, shrimps (%FO: 45) dominated followed by brachyura (%FO: 13) (Table 1). Unidentified shrimp were also the most abundant in number (%N: 31), followed by Caridea shrimp (%N: 18), polychaeta and teleostei fishes (%N: 10 each) whereas Teleostei fishes dominated in biomass followed by shrimps and polychaeta (%W: 28, 23 and 7, respectively) (Table 1). Crustaceans were the most important in general, followed by Teleostei fishes and polychaeta (Table 2). When we analyze deeper, the same five categories figured almost all ranks of indices (IRI, IAI) between habitats, shelf positions and latitude levels (

Table S *4*;Table S 5;Table S 6).

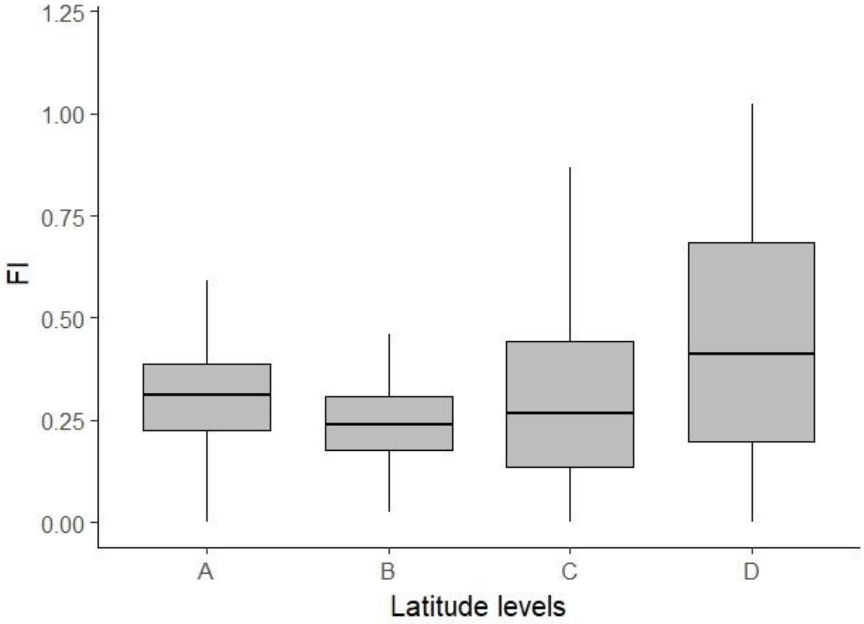

Figure 9: Fulness index values (FI) for latitude levels: A (<6°S), B (6 – 7°S), C (7 – 8°S) and D (>8°S). The black horizontal line and box represent the median value and the interquartile range, while the vertical lines represent the upper and lower limits. Outliers were not included in the plot.

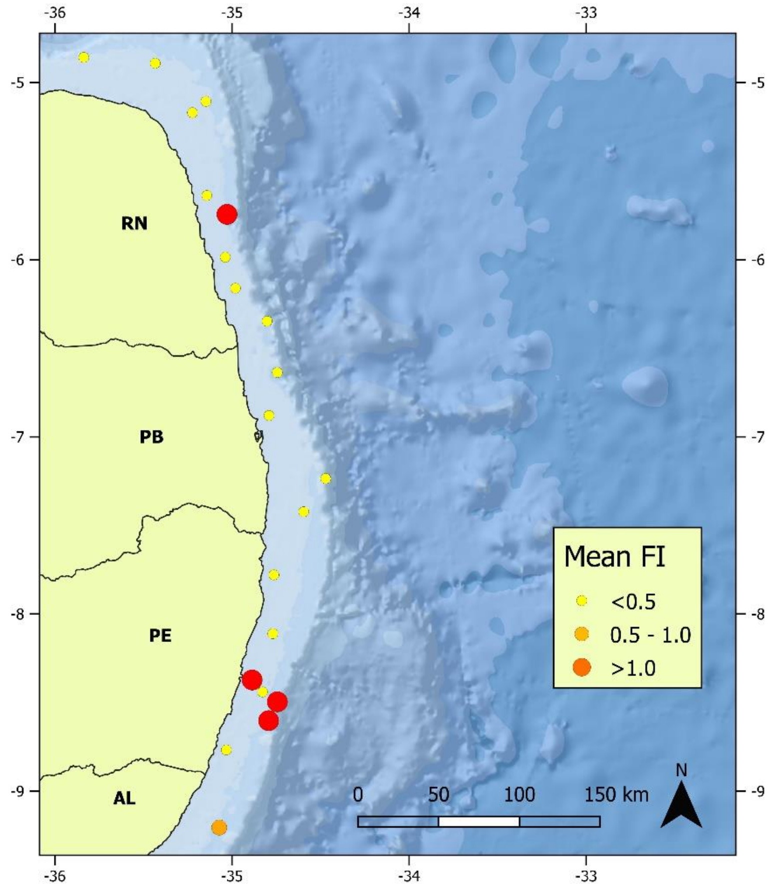

Figure 10: Mean fulness index (FI) of the P. maculatus distributed along the sampling points in the continental shelf of the Northeast Brazil.

The overall niche breadth (*Bi*) was 0.31. The largest niche breadth was observed for outer-shelf over inner-shelf habitats ($Bi = 0.44$ and 0.39 respectively) and among habitat types, algae presented a higher value over sand and SWCR ($Bi = 0.50, 0.37$ and 0.36 respectively).

The Costello diagram (Figure 11) showed there is not a specific species that is targeted mostly by *P. maculatus.* Instead, considering the vertical axis, most prey is in the left side of the diagram, with low frequency of occurrence (*Fi*). Considering the prey importance, the diet of *P. maculatus* consisted mostly by rare prey taxa and present in small proportions (low *Fi/Pi*). Other items were also not often seen but they comprised a high percent mass when present, such as isopods, stomatopods, Teleostei fishes. The most frequent items were unidentified shrimps but also with a low occurrence. Based on the position of the items related to the diagonal axis from top-left to bottom-right, the niche breadth is mostly due to a high between phenotype component (BPC). In brief, the spotted goatfish seemed to be a generalist predator, feeding on many rare prey taxa. On the other hand, the population presented some individuals with some degree of specialization, that fed substantially on infrequent prey (high *Pi* and low *Fi*).

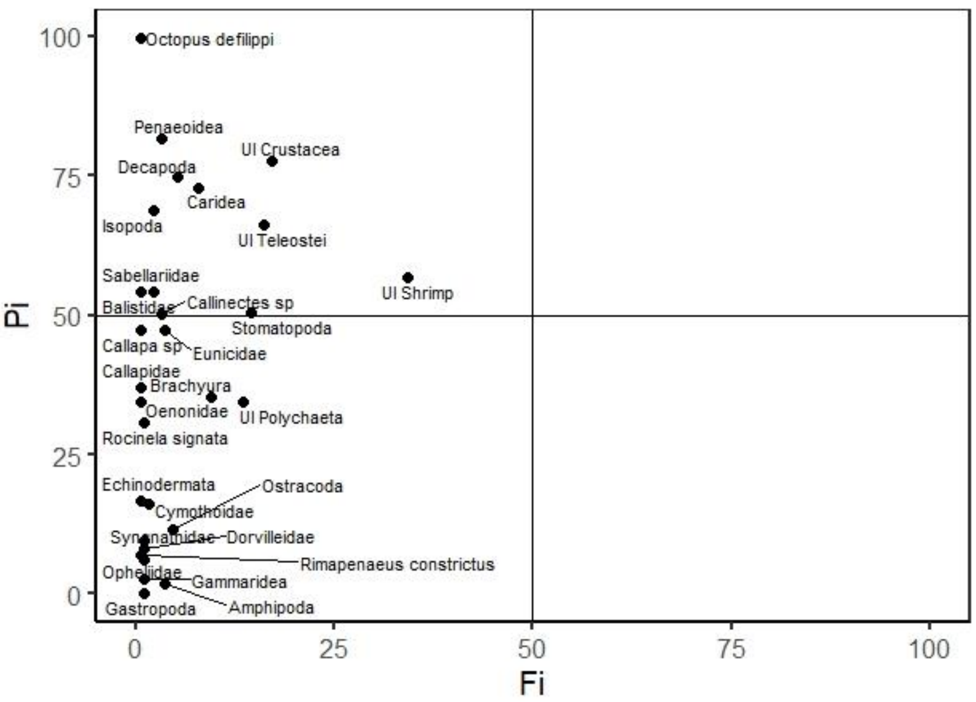

Figure 11: Costello diagram, a scatterplot containing all prey items, showing feeding strategy of the *Pseudupeneus maculatus* captured along the northeast Brazil coast.

The arrangement obtained by the multidimensional analysis MDS showed that there is high overlapping of the diet between habitats (Figure 12 A) with very weak significant differences ($ANOSIM: R = 0.04, p < 0.05$). Also, week significant differences in diet were detected between shelf positions (Figure 12 A) (ANOSIM: $\mathrm{R} = 0.02, \mathrm{p} < 0.05$) and between latitude stratum (Figure 12 B) ($ANOSIM: R = 0.06, p < 0.05$). The simper test indicated mostly shrimps, stomatopods and Teleostei fishes contributed the most for the similarity within habitats, shelf positions and latitude levels (Table S 1;Table S 2;Table S 3).

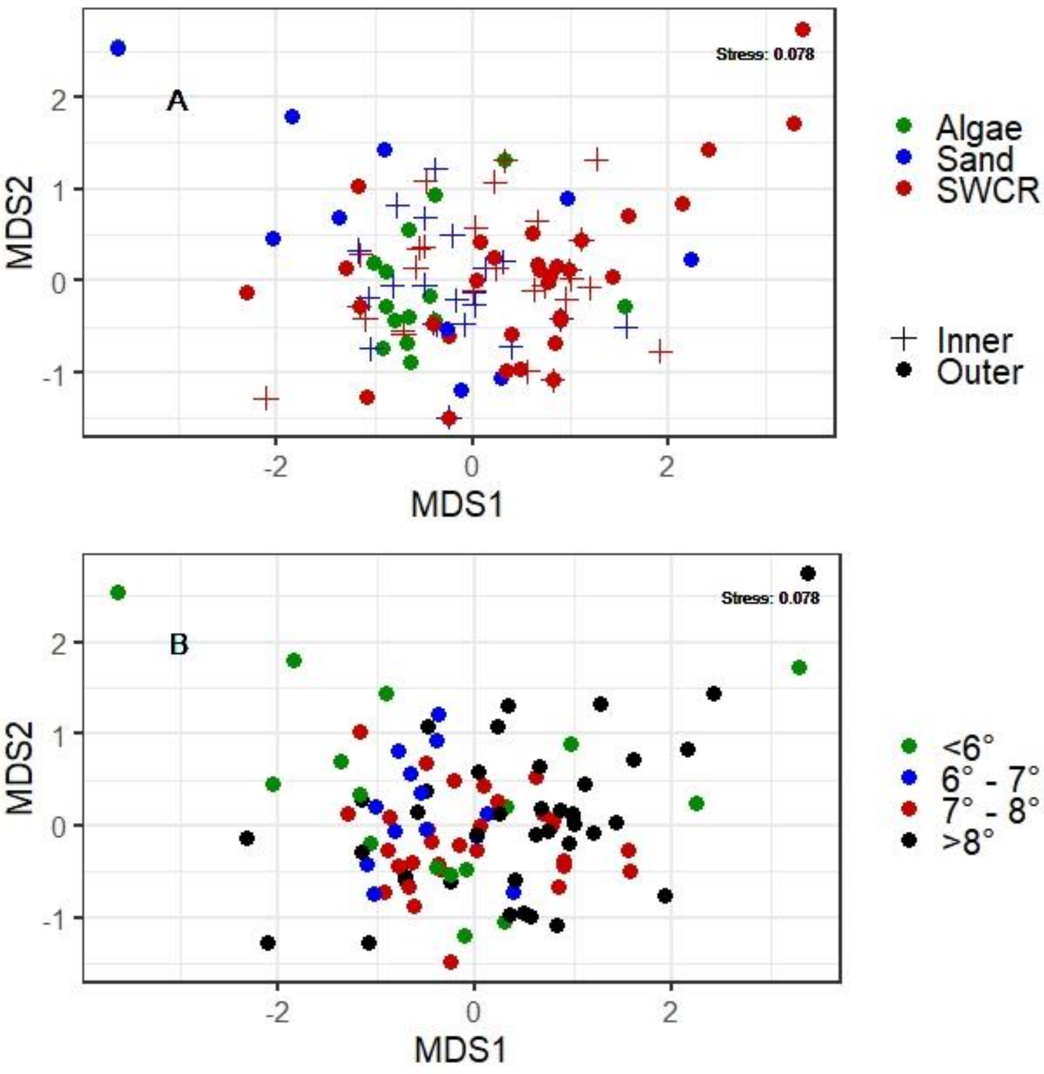

Figure 12: MDS plot of the feed composition of *P. maculatus* in the different habitats (A - colors), shelf positions (A - shapes) in the different levels of latitude (B)

Table 1: Contribution of each prey item for the overall diet of *Pseudupeneus maculatus* by frequency of occurrence (%FO), number (%N) and weight (%W). *UOM: unidentified organic matter.

Prey items	**n = 193**

			%FO	%N	%W
CRUSTACEA			-	-	-
		UI	17.10	-	15.21
DECAPODA			58.55	58.27	26.73
	BRACHYURA				
		UI	9.32	3.66	2.50
		Callapa sp.	1.04	0.29	0.34
		Callinectes sp.	3.11	1.17	1.06
	SHRIMP		45.08	53.15	22.84
	UI		34.20	31.19	14.18
	Caridea		7.77	18.45	4.59
	Penaeidae		3.11	3.51	4.07
		Rincopenaeus constrictus	0.52	0.73	0.07
STOMATOPODA			14.51	7.03	6.75
ISOPODA					
	UI		2.07	0.88	0.68
	AEGIDAE				
		Rocinela signata	1.04	0.29	0.14
AMPHIPODA					
	UI		3.63	1.90	0.03
	GAMMARIDEA		1.04	1.46	0.01
OSTRACODA			4.66	3.07	0.06
TELEOSTEI					
UI			16.06	10.54	27.29
BALLISTIDAE			0.52	0.15	0.40
SINGNATHIDAE			1.04	0.29	0.10
MOLLUSCA			2.07	0.44	1.37
GASTROPODA			1.55	0.29	0.00
CEPHALOPODA					
		Macrotritopus defilippi	0.52	0.15	1.37
ECHINODERMATA			0.52	0.15	0.04
ANNELIDA					
POLYCHAETA					
	UI		13.47	6.44	4.00
	DORVILLEIDAE		1.04	0.29	0.03
	EUNICIDAE		3.63	2.64	2.21
	OENONIDAE		0.52	0.15	0.21
	OPHELIIDAE		1.04	0.29	0.04
	SABELLARIIDAE		2.07	0.73	0.50

OTHERS				
	UOM*	16.06	-	7.65
	DETRITUS	9.84	-	2.26

Table 2: Ranking of importance of each category of prey according to each importance index.

Rank	IRI	IAI
1	Shrimps	Shrimps
2	Teleostei fish	Teleostei fish
3	Polychaetas	Polychaetas
4	Stomatopoda	Stomatopoda
5	Brachyura	Brachyura

Stable isotopes analysis

A total of 101 muscle samples of *Pseudupeneus maculatus* were sampled and analyzed for stable isotopes (δ13C and δ15N). The mean values for δ13C varied between -18.15 and -14.07, and the values for δ15N varied between 6.9 and 11.4. Statistical significances were found in δ15N along the latitudinal gradient. Kruskal-Wallis test revealed differences in δ15N only between stratum D and C ($p < 0.05$). Statistical significances were also found in δ13C along the latitude gradient, with stratum A showing lower values than the other stratum ($p < 0.05$). There were no significant differences in δ13C and δ15N among habitat and shelf position ($p > 0.05$) and these values were not correlated with size (SL) (R^2=0.15). As values of δ13C and δ15N had great variation, any model approach was designed to fit the data. The δ13C and δ15N isotopes of the baseline (zooplankton) were also evaluated and compared between habitat, shelf position and latitude gradient and no statistical significances were detected (Figure 13).

Overall, trophic level of the spotted goatfish was between the third and fourth position, classifying it as a carnivore predator. The effects of habitats, shelf position and latitude gradient were virtually inexistent. The results of the trophic position analysis based on the diet (TP_{SC}) were similar to the results reached by the isotopic analysis (TP_{SI}) (Table 3).

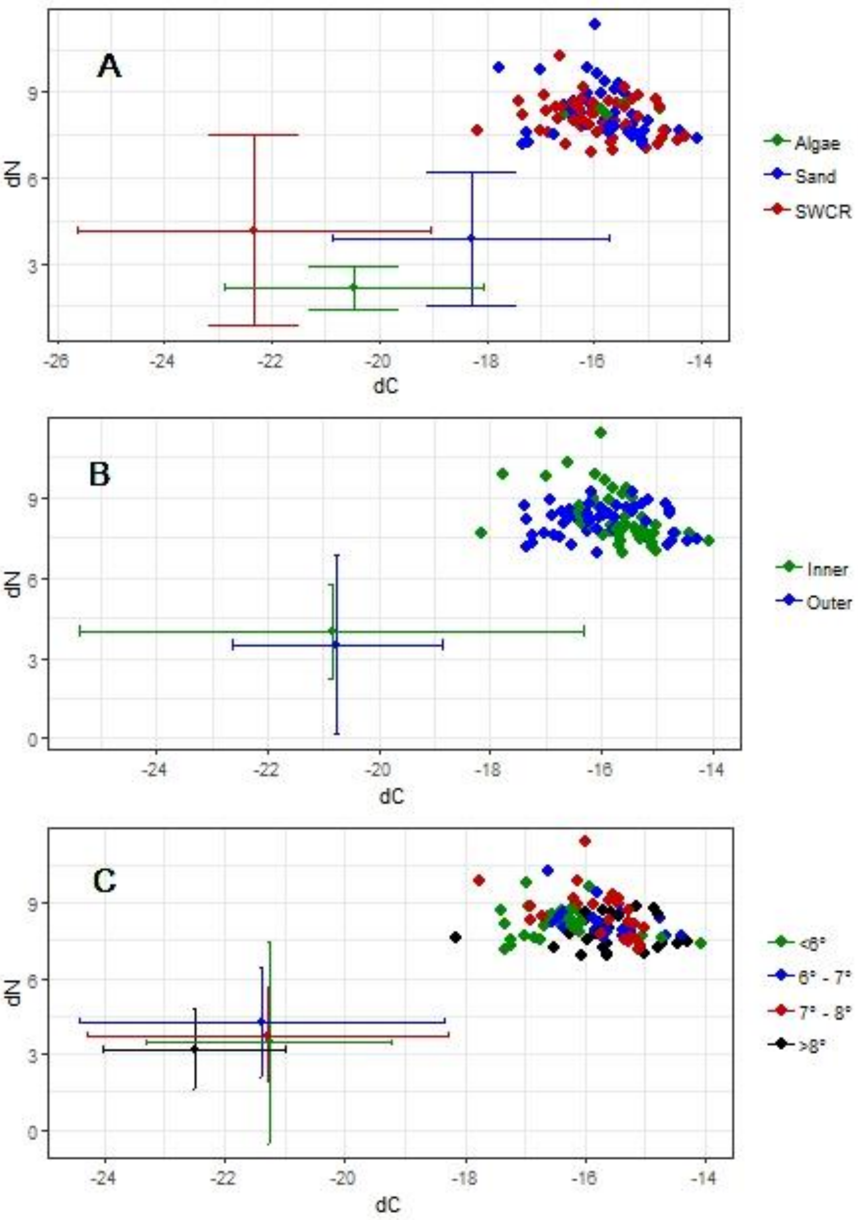

Figure 13: δ13C and δ15N values of *P. maculatus*. Colors represent different levels of habitat (A), shelf position (B) and latitude gradient (C). δ13C and δ15N signatures of zooplankton are also shown (mean ± SD).

Table 3: Trophic level estimates with stable isotopes and its upper and lower limits and stomach content analysis (TP_{SC}) of *Pseudupeneus maculatus* in different habitats, shelf positions and latitude gradient.

Habitat	Mean TP_{SI}	Lower limit	Upper limit	TP_{SC}
Algae	3.84	3.58	4.11	3.75
Sand	3.30	2.87	3.75	3.50
SWCR	3.37	3.12	3.62	3.56
Shelf pos.	Mean TP_{SI}	Lower limit	Upper limit	TP_{SC}
Inner	3.25	2.96	3.54	3.52
Outer	3.54	3.31	3.81	3.57

Lat. grad.	Mean TP_{SI}	Lower limit	Upper limit	TP_{SC}
A	3.61	3.26	3.99	3.52
B	3.28	2.99	3.58	3.59
C	3.41	3.08	3.76	3.40
D	3.36	3.16	3.57	3.27

DISCUSSION

Population aspects

This work provided the first study on feeding habits of *P. maculatus* in a large scale, such as the northeastern coast of Brazil. The spotted goatfish is a key species in many interspecific relations, such as the following behavior, that is a foraging mode commonly reported in reef fish (Krajewski *et al.*, 2006; Sazima *et al.*, 2006, 2010), interacting with, besides many other fishes, endangered species such as *Sparisoma axillare* (Steindachner, 1878) and *Sparisoma frondosum* (Agassiz, 1831) (Krajewski *et al.*, 2006; Sazima *et al.*, 2006, 2007). Adults individuals of *P. maculatus* are usually present in deeper areas with muddy or sandy substratum available for its foraging activity, while juveniles occupies seagrass bed areas (Munro, 1976). Krajevski (2006) also observed an elevated frequency of *P. maculatus* in areas of mixed substratum, composed by algae, sand and coral reef but they were also present foraging over other substratum than sand. In this study, *P. maculatus* showed similar pattern, occupying all sorts of habitats identified.

The condition factor *k* presented different values between habitats and latitude levels, with individuals from SWCR and stratum D showing smaller values. However, these differences seem to be more related to the fact that most habitats in this stratum are SWCR and the most part of the individuals caught in this area came from the first ABRACOS campaign, that occurred in August-September of 2015. Fish from the second campaign (April-May of 2017) were caught during the reproductive season of the spotted goatfish (Campos, 2000; Munro, 1983; Santana, *et al.*, 2006) which can explain the higher values of the condition factor *k* for the specimens caught during this campaign compared to the first campaign.

The size at first maturity (L_{50}) obtained was similar to the results of Santana *et al* (2006) that estimated age corresponding to the first maturity length through the inverted Von Bertalanffy growth curve using fishery based data obtained on the scope of the REVIZEE project (Lessa & Nóbrega, 2000; Lessa *et al.*, 2004). Males were significantly larger than females and this pattern was consistent within spatial patterns. Also, the size at first maturity of males was slightly higher than the females. Sexual dimorphism was reported previously, with males being larger, having “higher arched backs and more angular facial profiles”, while females are more fusiform with more hydrodynamical shape (Caldwell, 1962; Munro, 1976). LWR results differed from Campos and Oliveira (2001), however they only had individuals above the L_{50}, lacking smaller individuals. Also, their study area was restricted to some areas explored by the artisanal fleet of the North of Pernambuco. Similar results were found by Munro (1983), with females showing a negative allometric growth confirming Caldwell’s (1962) observations that males and females have sexual dimorphism.

Feeding habits and diet

Feeding activity of *P. maculatus* is classified as diurnal (Bohlke & Chaplin, 1968; Munro, 1976, 1983) , since most individuals caught at nocturnal period were with low or no content in its guts. Tests about seasonal or annual variations could not be carried out because the expeditions occurred only twice in a period of more than a year between them which limited the potential to investigate the seasonal and annual variations of the diet.

The feeding intensity described as the fullness index (FI), can be influenced by the availability and type of prey, length and season (Mondal & Mitra, 2016; Perelman *et al.*, 2017; Prabha & Manjulatha, 2010). In general, FI did not vary between habitats and shelf position, but it was higher in the southern areas, where is located the MPA “APA Costa dos Corais”. An MPA may provide high diversity of habitat and abundance of prey (Bonaldo *et al.*, 2017; Novaczek *et al.*, 2017).

The presence of several epibenthic organisms in the diet of *P. maculatus*, such as decapods, polychaetas and amphipods, suggests that the spotted goatfish is a carnivore, specialized in zoobenthos. Krajewski *et al.*(2006) described the feeding behavior of *P. maculatus*, as they skim the surface with the barbels, shovel and turn over the substratum seeking its prey. As described by several authors (Aronson & Sanderson, 1987; Gosline, 1984; Krajewski *et al.*, 2006; Lukoschek & McCormick, 2000; Sazima *et al.*, 2010), the spotted goatfish plays an important role in the benthic ecosystem disturbing the substratum, changing the bottom topography and distribution of benthic organisms and, thus, attracting other carnivorous fishes that prey on the small organisms flushed during the substratum disturbance.

The higher spectrum of prey was seen in the SWCR habitats and the least in Algae. Even though there was a higher spectrum of prey in SWCR habitats, the niche breadth in this habitat was lower, suggesting a possible preference for a specific prey in this habitat or a possible low abundance of prey in the Algae habitat, forcing the individuals in this substratum to widen the range of prey. The diet of *P. maculatus* was not significantly different between habitats, shelf positions or latitude levels with a high overlapping over the diets, which can be related directly to the availability of the preferred prey of spotted goatfish. Prey availability is not only dependent of its abundance, but also its size, behavior and relative abundance in the foraged habitats (Labropoulou *et al.*, 1997; Moore & Moore, 1976). Even though the waters of the studied area usually present high diversity of prey and abundance (CBD, 2014; Eduardo *et al.*, 2018a), *P. maculatus* feeds mostly on crustaceans (shrimps, brachyura, stomatopoda), and more rarely but still importantly polychaeta and teleostei fish.

Overall, no relationship between the values of δ13C and δ15N and habitats and shelf positions were found for *P. maculatus*. Little differences between some latitude stratum were observed, but it was biologically insignificant (less than 1‰). Although other studies reported possible positive relationship between the δ15N concentration and growth (Beaudoin *et al.*, 1999; Kolasinski *et al.*, 2009; Overman e Parrish, 2001), we did not find significant increasing with body size. The trophic positions estimated with stable isotopes and stomach content analysis showed *P. maculatus* occupy somewhere between the third and fourth trophic level, confirming the findings of the dietary analysis. These results are endorsed by previous studies based on stomach content analysis for the *P. maculatus* (Gómez-Canchong *et al.*, 2004; Randall, 1967; Sierra *et al.*, 1994) and for other species of the family Mullidae (Golani, 1994; Gómez-Canchong *et al.*, 2004; Hobson, 1974; Hureau, 1986; Kulbicki *et al.*, 2005; Silva Monteiro, da, 1998).

Distribution pattern

Munro (1976) affirms there are no migratory movements of *P. maculatus*, which means they do not move much further from the areas they settle. In fact, juveniles were found well distributed along the continental shelf, including in areas near the shelf break, but a slight difference in size distribution was noted due mainly to the fact that larger individuals seemed to be more related to deeper and further from coast areas. Eduardo *et al.* (2018) stated these areas had the highest values of biodiversity, which can provide habitat and resources for the resident species.

The CPUE patterns indicated that this species is more abundant in the northern Pernambuco and southern Paraíba, where is located the largest fishery fleet that targets the spotted goatfish in the region (Barbosa, *et al.*, 2009; Lessa, *et al*., 2004; Ribeiro, 2004), and in the area below 8°S. Also, size distribution indicated most juveniles were found in SWCR habitats, mainly in the southern areas. The differences between the allometry coefficient (*b*) between latitude levels confirmed the higher presence of young individuals in the southern areas of the study, since juveniles have higher growth rates pushing the *b* of that areas toward to the positive allometry. These higher values may be correlated to the presence of a great extension of coral reefs in this region (Costa *et al.*, 2007; Leão *et al.,* 2016). Also, this area is mostly included in two MPAs (APA Costa dos Corais and APA Guadalupe), which may be a possible reason for the highest CPUEs (Eduardo *et al.*, 2018a; Floeter, Ferreira e Gasparini, 2007; Steiner *et al.*, 2015). Floeter (2007) stated the protection of this area granted the maintenance of higher abundance of many species, including those economically important. Many studies have reported fishing activity affects marine ecosystems by modifying habitats, depleting fish populations and consequently altering its structures and affecting its abundance (Agardy, 2000; Dayton *et al.*, 1995; Garcia *et al.*, 2003; Goni, 1998; Jennings e Kaiser, 1998; Kaiser *et al.*, 2003; Kenchington, 2015; Worm *et al.*, 2006). Therefore, an MPA, such as APA Costa dos Corais, is critical to the conservation and the sustainable use of marine resources, by protecting reproductive, nursery and feeding areas.

CONCLUSION

Anthropic pressures may cause changes in the environment and consequently affects the biodiversity, threatening many critical species that are key elements for the ecosystem and vital for the humankind. In this context, the development of knowledge about the marine biodiversity and its component species is essential to minimize these impacts and the data provided by this study, plus many others around the world, is an improvement towards the conservation and the sustainable use of the oceans and its resources. The results of the present study elucidated some points on *P. maculatus* ecology. Our findings provided valuable information about the distribution of the spotted goatfish, as well as trophic relationships with different habitats. These results are useful for future management and conservation purposes of this species. In fact, our results endorses Eduardo’s results (2018b) that identified several potential areas for implementation of MPAs. The study of the diet is a particularly important tool to comprehend aspects of biology and ecology, specially allied with spatial marine planning, aiming a sustainable management of fishing stocks and the development of conservation measures (Kitsos *et al.*, 2008; Mesa, La, *et al.*, 2007). The spotted goatfish in the northeast Brazilian coast is classified as generalist benthic predator but showing some degree of selectivity. This study highlighted the fact that *P. maculatus* is an important fishery resource but also crucial component of the biodiversity of the northeast coast of Brazil performing a key ecological role.

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5. Considerações finais

O saramunete é uma espécie com alto grau de afinidade com ambientes de substrato não-consolidado e hábito alimentar estritamente bentônico. A maioria dos indivíduos capturados estavam abaixo do comprimento de primeira maturação sexual, que mostra que, apesar do efeito da seletividade do aparelho, há grande abundância de indivíduos adultos. De modo geral, nossos resultados mostram que houve uma tendência de migração ontogenética em que durante as fases iniciais de vida ele se associa mais a hábitats coralíneos e mais próximos a costa. Com o aumento do tamanho, a tendência é de os indivíduos procurarem zonas mais profundas, mais próximas à quebra da plataforma. O saramunete foi classificado como um predador zoobentívoro. O tipo de hábitat, posição na plataforma continental e o gradiente latitudinal não influenciaram na diferenciação da dieta do saramunete. Essa não diferenciação da dieta nos diferentes fatores pode ser explicada pelo seu hábito alimentar generalista, com pouca seletividade sobre as presas. A maior abundância e distribuição de indivíduos juvenis foi encontrada em áreas de grandes extensões de recife de coral e/ou com a presença de áreas marinhas protegidas.

Hoje se sabe que as pressões antrópicas provocam mudanças nos ambientes, consequentemente na biodiversidade, ameaçando grande parte da fauna que são importantes peças para a manutenção de serviços ecológicos importantes para o homem. Nesse contexto, a geração de conhecimentos sobre as espécies que compõem a biodiversidade marinha é essencial para minimizar esses impactos. Tais descobertas podem ser de grande valia na criação de medidas de manejo eficientes, aliados ao desenvolvimento de estudos futuros sobre efeitos da geomorfologia do ambiente e da pesca sobre as populações, não só do saramunete, mas de todos os recursos pesqueiros disponíveis, de forma que sirvam como contribuição na conservação e uso sustentável dos oceanos e dos recursos pesqueiros para que as gerações futuras possam desfruta-los.

6. Anexos

Table S 1:SIMPER analysis: breakdown of average similarity within groups of habitats (SWCR; Sand; Algae) and the contribution of each prey item for each index.

Group SWCR
Average similarity: 17.40

Species	Av. Abund	Av. Sim	Sim/SD	Contrib %	Cum. %
UI Shrimp	2.93	7.60	0.36	43.68	43.68
UI Teleostei	2.12	3.47	0.25	19.95	63.63
UI Crustacea	1.99	3.28	0.22	18.87	82.50

Group Sand
Average similarity: 21.84

Species	Av. Abund	Av. Sim	Sim/SD	Contrib %	Cum. %
UI Crustacea	3.79	11.74	0.45	53.76	53.76
UI Shrimp	2.74	6.54	0.33	29.94	83.70

Group Algae
Average similarity: 37.83

Species	Av. Abund	Av. Sim	Sim/SD	Contrib %	Cum. %
UI Crustacea	6.57	35.55	0.96	93.97	97.97

Table S 2: SIMPER analysis: breakdown of average similarity within groups of shelf position (Inner and Outer) and the contribution of each prey item for each index.

Group Inner
Average similarity: 24.38

Species	Av. Abund	Av. Sim	Sim/SD	Contrib %	Cum. %
UI Crustacea	4.15	14.39	0.50	59.01	59.01
UI Shrimp	2.54	5.67	0.32	23.25	82.27

Group Outer
Average similarity: 15.02

Species	Av. Abund	Av. Sim	Sim/SD	Contrib %	Cum. %
UI Shrimp	2.44	5.30	0.29	35.30	43.68
UI Crustacea	2.52	5.22	0.28	34.72	70.02

Table S 3: SIMPER analysis: breakdown of average similarity within groups of latitude levels (A: <6°S; B: 6~7°S; C: 7~8°S; D: >8°) and the contribution of each prey item for each index.

Group A
Average similarity: 20.83

Species	Av. Abund	Av. Sim	Sim/SD	Contrib %	Cum. %
UI Shrimp	3.58	11.38	0.40	54.63	54.63
Caridea	2.44	5.16	0.25	24.79	79.42

Group B
Average similarity: 42.03

Species	Av. Abund	Av. Sim	Sim/SD	Contrib %	Cum. %
UI Crustacea	6.68	38.65	0.97	91.96	91.96

Group C
Average similarity: 23.78

Species	Av. Abund	Av. Sim	Sim/SD	Contrib %	Cum. %
UI Crustacea	4.19	14.28	0.51	60.06	60.06
UI Shrimp	2.41	5.24	0.32	22.04	82.11

Group D
Average similarity: 14.60

Species	Av. Abund	Av. Sim	Sim/SD	Contrib %	Cum. %
UI Shrimp	2.26	4.38	0.31	30.02	30.02
UI Teleostei	1.97	2.90	0.23	19.89	49.91
UI Crustacea	1.83	2.57	0.19	17.63	67.54
Stomatopoda	1.79	2.53	0.20	17.30	84.84

Table S 4: Ranking of importance according to each importance index of each category of prey for each level of type of habitat (SWCR – Sand With Coraline Rocks, Sand and Algae)

SWCR

Rank	IRI	IAI
1	Shrimp	Teleostei fish
2	Teleostei fish	Shrimp
3	Polychaeta	Polychaeta
4	Stomatopoda	Stomatopoda
5	Brachyura	Brachyura

Sand

Rank	IRI	IAI
1	Shrimp	Shrimp
2	Polychaeta	Brachyura
3	Brachyura	Polychaeta
4	Teleostei fish	Stomatopoda
5	Stomatopoda	Teleostei fish

Algae

Rank	IRI	IAI
1	Polychaeta	Polychaeta
2	Brachyura	Brachyura
3	Stomatopoda	Stomatopoda
4	Shrimp	Shrimp

5	Teleostei fish	Teleostei fish

Table S 5: Ranking of importance according to each importance index of each category of prey for each level of shelf position (Outer and Inner)

Outer

Rank	IRI	IAI
1	Shrimp	Teleostei fish
2	Teleostei fish	Shrimp
3	Polychaeta	Polychaeta
4	Stomatopoda	Stomatopoda
5	Brachyura	Brachyura

Inner

Rank	IRI	IAI
1	Shrimp	Shrimp
2	Teleostei fish	Teleostei fish
3	Polychaeta	Stomatopoda
4	Stomatopoda	Polychaeta
5	Brachyura	Brachyura

Table S 6: Ranking of importance according to each importance index of each category of prey for each level of latitude levels (A: <6°S; B: 6~7°S; C: 7~8°S; D: >8°).

A

Rank	IRI	IAI
1	Shrimp	Shrimp
2	Isopoda	Polychaeta
3	Amphipod	Stomatopoda
4	Polychaeta	Isopoda
5	Stomatopoda	Teleostei fish

B

Rank	IRI	IAI

1	Shrimp	Stomatopoda
2	Stomatopoda	Brachyura
3	Brachyura	Shrimp
4	Polychaeta	Polychaeta
5	Teleostei fish	Teleostei fish

C

Rank	IRI	IAI
1	Shrimp	Teleostei fish
2	Teleostei fish	Shrimp
3	Polychaeta	Brachyura
4	Brachyura	Polychaeta
5	Stomatopoda	Stomatopoda

D

Rank	IRI	IAI
1	Shrimp	Teleostei fish
2	Teleostei fish	Shrimp
3	Stomatopoda	Stomatopoda
4	Polychaeta	Polychaeta
5	Brachyura	Brachyura