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DIVERSIDADE, DISTRIBUIÇÃO E ABUNDÂNCIA DA ICTIOFAUNA DERMERSAL DO NORDESTE DO BRASIL.

RECIFE,

2017

UNIVERSIDADE FEDERAL RURAL DE PERNAMBUCO

PRÓ-REITORIA DE PESQUISA E PÓS-GRADUAÇÃO PROGRAMA DE PÓS-GRADUAÇÃO EM RECURSOS PESQUEIROS E AQUICULTURA

DIVERSIDADE, DISTRIBUIÇÃO E ABUNDÂNCIA DA ICTIOFAUNA DERMERSAL DO NORDESTE DO BRASIL.

Leandro Nolé Eduardo

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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Recife,

Agosto/2017

Ficha catalográfica

Setor de Processos Técnicos da Biblioteca Central - UFRPE

Nolé, Leandro Nolé Eduardo
Diversidade, distribuição e abundância da ictiofauna dermersal do Nordeste do Brasil.
N de folhas :53
Orientadora: Flávia Lucena Frédou
Co-orientador: Thierry Frédou
Dissertação (Mestrado em Recursos Pesqueiros e Aquicultura). Departamento de Pesca e Aquicultura.
Inclui bibliografia

UNIVERSIDADE FEDERAL RURAL DE PERNAMBUCO
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Dissertação julgada adequada para obtenção do título de mestre em Recursos Pesqueiros e Aquicultura. Defendida e aprovada em 07/08/2017 pela seguinte Banca Examinadora.

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À minha mãe, *Lídia Helena Menezes Nolé*.

AGRADECIMENTOS

Primeiramente a Deus, por tornar tudo possível e sempre me abençoar muito mais do que eu mereço.

Agradeço a minha mãe, *Lídia Helena Menezes Nolé*, por não medir esforços para que este sonho se concretizasse. A minha família, *Carlos Eduardo Filho (in memoriam), Djaira Otaviana de Almeida*, *Beatriz Nolé*, *Barbara Nolé*, *Ruryky Souza*, *Rodrigo César*, Tia *ngela* e *Tio Waldir (in memoriam)*. Amo vocês.

Aos meus orientadores Flávia Frédou e Thierry Frédou. Por toda paciência, ensinamentos e conselhos. Vocês sempre foram mais que orientadores.

A Arnaud Bertrand, pela oportunidade única de fazer parte do projeto ABRACOS.

Agradeço ao meu amigo *Alex Souza*. Por compartilhar de tantos momentos e estar sempre disposto a ajudar e tornar os sonhos realidade. Mais que um amigo, um irmão.

A todos os componentes do BIOIMPACT, principalmente *Andrey Soares*, *Mondrian Sales, Ray, Valdimere* e *Júlio*. Junto nós somos capazes, juntos nós somos imbatíveis!

A todos meus amigos da Rua José Mariano, com vocês tudo é mais divertido. Vocês fazem parte da minha história.

A minha namorada *Manuella Nery*. Por me fazer sonhar, sentir melhor, acreditar, querer mudar e ir em frente.

A Arnold Schwarzenegger e São Anabolino, por sempre servir como fonte de motivação e mostrar que tudo é possível para aquele que batalha.

"No matter how you fell…Wake up, show up and never give up"

Leandro Nolé

Abstract

Despite the social, ecologic and economic importance of the Brazilian northeast coast, knowledge regarding to biodiversity, assemblage structure and fish species distribution are still scarce, especially when related to environmental factors, which make difficult the implementation of ecosystem-based and sustainable management strategies. In this study, we describe the fish demersal assemblage along the continental shelf of the northeast Brazilian cost, specifically the ecological descriptors and the distribution and spatial abundance of the fish fauna. Sampling was conducted at 37 stations on board the R/V ANTEA, Between the latitudes 5°S-9°S. Fish species were described considering abundance (N° of individuals), biomass (weight) and frequency of occurrence. Community structure was investigated through ANOSIM and SIMPER analysis, while a DISTLM was performed to evaluate the influence of physical-chemical factors on the variability of fish data. Diversity was expressed as a series of indices and represented through maps. A total of 7.340 individuals (830 Kg), distributed in 24 orders, 49 families and 120 species, were collected. Haemulidae, Mullidae and Holocentridae were the most abundant families. The most frequent species were *Hypanus marianae*, *Lutjanus synagris* and *Pseudupeneus maculatus.* Higher abundance values were found in the central and south part of Pernambuco; however, considering biomass, higher values were also found in Rio Grande do Norte. Regarding to richness, higher values were found in Paraiba (PB) and south of Pernambuco (PE), while, considering diversity, high values were found along the entire study area. Comparatively with other regions in Brazil and around the world, the Brazilian northeast continental shelf can be described as an area of high fish species richness and diversity. DistLM analyses identified that depth, latitude and temperature explained 20% of the variation in the fish assemblage. Considering information found in this study, we consider the south of Pernambuco (8°30’S - 9°S), north of Rio Grande do North (5°S - 5°30’S) and the state of Paraiba (6°30’S - 8°S) as priority areas for the development of management plans and conservation of marine ecosystems.

Key-words: Ecology; Demersal habitat; Biodiversity.

Resumo

Apesar da importância social, ecológica e econômica da região costeira do nordeste do Brasil, informações sobre a biodiversidade, estrutura populacional e distribuição das assembléias de peixes ainda são escassas, principalmente quando relacionadas com fatores ambientais, dificultando a implementação de estratégias de manejo sustentáveis e fundamentadas em uma abordagem ecossistêmica. Neste estudo, descrevemos a assembléias de peixes demersais ao longo da plataforma continental do Nordeste do Brasil, considerando descritores ecológicos, distribuição e abundância da ictiofauna. Um total de 37 estações foram amostradas a bordo do ANTEA R/V, entre as latitudes 5°S- 9°S. A ictiofauna foi descrita considerando abundância (N° de indivíduos), biomassa (peso) e frequência de ocorrência. A estrutura da comunidade foi investigada através de análises ANOSIM e SIMPER. A análise DISTLM foi realizada para avaliar a influência de fatores físico-químicos na composição da comunidade de peixes, enquanto, a diversidade, foi expressa através de uma série de índices ecológicos representados através de mapas. No total, foram coletados 7.340 indivíduos (830 Kg), distribuídos em 24 ordens, 49 famílias e 120 espécies. As famílias mais abundantes foram Haemulidae, Mullidae e Holocentridae; enquanto as espécies *Hypanus marianae*, *Lutjanus synagris* e *Pseudupeneus maculatus* foram as mais frequentes. Maiores valores de abundância foram encontrados na parte central e sul de Pernambuco (PE); no entanto, considerando biomassa, valores mais elevados também foram encontrados no Rio Grande do Norte. Em relação à riqueza, valores elevados foram observados na Paraíba (PB) e no sul de Pernambuco (PE). Em relação à diversidade, valores elevados foram encontrados em toda a área de estudo. Em comparação com outras regiões do Brasil e do mundo, a plataforma do nordeste do Brasil pode ser descrita como uma área de elevada riqueza e diversidade de espécies. Com similaridade de 20%, as análises multivariadas exibiram quatro grupos principais (assembleias), apresentando diferenças significativas entre habitats. A análise DistLM identificou que as variáveis profundidade, latitude e temperatura explicaram 20% da variação encontrada nas assembleias de peixes. Considerando a informação encontrada neste estudo, podemos considerar o sul de Pernambuco (8°30 - 9°S), norte do Rio Grande do Norte (5° S - 5°30'S) e o estado da Paraíba (6° 30'S - 8°S) como áreas prioritárias para o desenvolvimento de planos de manejo e conservação dos ecossistemas marinhos.

Palavras-chave: Ecologia; Habitat demersal; Biodiversidade

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INTRODUÇÃO

Contextualização da pesquisa

Os oceanos fornecem um conjunto único de bens e serviços para a sociedade, incluindo a estabilização do clima, transformação de resíduos tóxicos, fornecimento de alimentos essenciais, medicamentos e milhões de empregos em indústrias como a pesca, aquicultura e turismo (D. LAFFOLEY; BAXTER, 2016; ST. JOHN et al., 2016; WORM et al., 2006). Entretanto, impactos neste ambientes são cada vez mais frequentes, destacando a destruição de habitats, sobrepesca, alterações climáticas, acidificação dos oceanos, poluição e perda de biodiversidade (CARDINALE et al., 2012; HALPERN et al., 2015b; MCCAULEY et al., 2015). Além disso, com mais de 60% da população mundial a menos de 60 km do litoral, os ecossistemas marinhos costeiros demonstram uma capacidade reduzida para suportar a expansão da ocupação e dos usos humanos (ALONGI, 1998; JOHNSON et al., 2013). Dessa forma, o foco nos ecossistemas marinhos, levando em consideração o equilíbrio entre as diversas formas de uso do ambiente e aspectos ecológicos essenciais, vem sendo destaque de vários estudos nas últimas décadas (ALLSOPP et al., 2007; COSTA; PENNINO; MENDES, 2017; FOCK et al., 2002; PIKITCH et al., 2004).

Entre os aspectos essenciais ecológicos do ecossistema marinho, o conhecimento sobre a estrutura populacional da ictiofauna, biodiversidade e sua relação com o habitat tem sido reconhecido mundialmente como fundamental para assegurar a manutenção e preservação do equilíbrio ecológico (ALLSOPP et al., 2007; CARDINALE et al., 2012; EMMETT DUFFY, 2009; LEITE; LIMA, 2008; MCLEAN et al., 2016). Além do valor intrínseco de cada espécie, o conjunto de interações entre espécies e destas com o meio físico-químico, resultam em serviços ecossistêmicos imprescindíveis para manter a vida na Terra. Sendo assim, a ciência da biodiversidade é amplamente reconhecida como área prioritária de investigação científica, tanto nos países desenvolvidos como naqueles em desenvolvimento (JOLY; VERDADE; BERLINCK, 2011). No entanto, para países em desenvolvimento e de grande extensão territorial, estudos em grande escala sobre a biodiversidade são caros, demorados e de difícil implementação, o que leva a uma grande falta de conhecimento e dificulta inferências necessárias para implementação de estratégias eficientes sob o ponto de vista do enfoque ecossistêmico.

O enfoque ecossistêmico é uma estratégia de manejo integrado de recursos que faz uma abordagem holística ao manejo da biodiversidade e de seus componentes (FAO, 2003; GROSS; JOHNSTON; BARBER, 2005). O modelo de gestão envolve o manejo de recursos em uma escala e abrangência que não apenas conservam os componentes da biodiversidade, mas também protegem os processos e funções essenciais do ecossistema do qual fazem parte (por exemplo, ciclo de nutrientes, sequestro de carbono, abastecimento de água doce e alimentos)(GROSS; JOHNSTON; BARBER, 2005). Existe um claro reconhecimento de que a adoção de planos de manejo com enfoque ecossistêmico (PMEE) oferece inúmeras vantagens, como manutenção da biodiversidade e restauração das funções do ecossistema (PIKITCH et al., 2004). No entanto, para implementação de um PMEE, são necessárias informações que possam ser avaliadas de forma integrada (tipo de habitat, biodiversidade, estrutura e distribuição das comunidades, etc.), o que ainda é bastante escasso no Brasil, especialmente na região nordeste.

A costa do Nordeste do Brasil, ocupando mais de 3.000 quilômetros, é a mais extensa do País, abrigando grande biodiversidade, imensa variedade de ecossistemas e a maior extensão de recifes de corais do Atlântico sul (LEÃO et al., 2016; NOAA, 2012). A predominância de águas quentes e a existência de uma termoclina permanente ao longo de toda a região dificulta a circulação vertical de massas d'água, minimizando o aporte de nutrientes de regiões mais profundas, o que determina uma baixa produtividade primária e, consequentemente, baixa abundância em todos os níveis tróficos da cadeia alimentar marinha (NÓBREGA; LESSA; SANTANA, 2009). No entanto, apesar da baixa biomassa específica, a costa nordeste abriga um enorme número de espécies de alto valor comercial e é responsável pelo maior volume de recursos pesqueiros desembarcados no País (MMA, 2010; MPA, 2012). Nesta região, a pesca artesanal domina, contribuindo com aproximadamente 75% dos recursos pesqueiros desembarcados (NÓBREGA; LESSA; SANTANA, 2009). A atividade é caracterizada pelo uso de embarcações de pequeno porte, em sua maioria movidas à vela e com baixa autonomia, gerando recursos para subsistência e comércio em mercados locais (COLONESE et al., 2010). Além disso, a modalidade de pesca envolve mais de 500 comunidades ao longo de toda costa, sendo extremamente importante para alimentação, renda e bem-estar de mais de 200.000 pessoas (NÓBREGA; LESSA; SANTANA, 2009).

O levantamento da ictiofauna no Brasil teve como marco histórico o projeto REVIZEE "Programa de Avaliação do Potencial Sustentável de Recursos Vivos na Zona Econômica Exclusiva", que amostrou intensivamente a região utilizando diferentes artes de pesca (LESSA; BEZERRA; NÓBREGA, 2009; NÓBREGA; LESSA; SANTANA, 2009). A maioria dos levantamentos sobre a ictiofauna brasileira, anteriores ao REVIZEE, por questões de dificuldades logísticas, se restringiu à plataforma interna e áreas costeiras, principalmente na Sudeste (FIGUEIREDO; MENEZES, 1978, 1980, 2000) e sul (MANUEL HAIMOVICIL; KLIPPEL, 1999; SEELIGER; ODEBRECHT; CASTELLO, 1998; VOOREN, 1998). As prospecções do Programa REVIZEE permitiram ampliar de sobremaneira o conhecimento sobre a ictiofauna brasileira tendo sido publicados trabalhos para a região Sudeste-Sul (BERNARDES et al., 2005; FIGUEIREDO, 2002) para a região Central (ROCHA; COSTA, 1999) e para a região Nordeste (DE JESUS MENDES et al., 2011; LESSA; BEZERRA; NÓBREGA, 2009; NÓBREGA; LESSA; SANTANA, 2009). Os teleósteos demersais marinhos e estuarinos no Brasil foram quantificados em 617 espécies, distribuídas em 26 ordens e 118 famílias. Particularmente em relação à região nordeste, não foram realizadas prospecções de arrasto de fundo, onde pesquisas anteriores indicaram que as áreas adequadas para esse tipo de petrecho eram restritas a profundidades inferiores a 50 m, entre as latitudes 10°S e 13°S (ROSSI-WONGSTCHOWSKI; ALMEIDA; ÁVILA-BERNARDES, 2007). No Nordeste a fauna demersal foi prospectada por armadilhas, onde foi observado que, no talude continental, predominaram o pargo (*Lutjanus purpureus*) e cações, entre os peixes, e os caranguejos-aranha e isópodes entre os crustáceos (HAIMOVICI et al., 2006). Estes autores, portanto, ressaltam a falta de conhecimento da fauna demersal do Nordeste do Brasil, principalmente devido à falta de prospecções utilizando arrastos demersais, o que dificulta na elaboração de medidas de manejo que auxiliem na conservação e uso sustentável dos ambientes marinhos.

Devido à importância ecológica, social e econômica da ictiofauna demersal do nordeste do Brasil, somado à necessidade de informações sobre a região, o presente estudo visa descrever a biodiversidade, ecologia e distribuição da ictiofauna demersal da plataforma continental do Nordeste do Brasil (5°-9°S), gerando subsídios para conservação da biodiversidade, habitats críticos e manejo ecossistêmico da pesca. Este é o primeiro estudo no nordeste do Brasil, utilizando a rede de arrasto como arte, baseado em dados independentes da pesca e em larga escala, que analisa detalhadamente a ictiofauna demersal e sua relação com o habitat.

OBJETIVO

Objetivo Geral

Caracterizar a ictiofauna demersal da região costeira do Nordeste do Brasil (5°-9°S) e sua relação com fatores ambientais, gerando subsídios para conservação da biodiversidade, habitats críticos e manejo ecossistêmico da pesca.

Objetivos específicos

- Determinar a biodiversidade da assembléia de peixes demersais da área de estudo.
- Descrever os padrões de variação espacial das principais assembleias de peixes demersais da área de estudo e sua relação com diferentes tipos de habitats e variáveis ambientais.
- Determinar os índices ecológicos das principais assembleias de peixes demersais da área de estudo e sua relação com tipos de habitat.

REFERÊNCIAS

Allsopp, M., Page, R., Johnston, P., Santillo, D., 2007. Oceans in Peril: Protecting marine biodiversity. Worldwatch Pap. 1–56.

Alongi, D.M., 1998. Coastal ecosystem processes, 1st ed. CRC Press, New Jersey.

BERNARDES, R.A., ROSSI-WONGTSCHOWSKI, WAHRLICH, R., VIEIRA, R.C., 2005. Prospecção pesqueira de recursos demersais com armadilhas e pargueiras na Zona Econômica Exclusiva da Região Sudeste-Sul do Brasil. Serie Documentos REVIZEE/Score-Sul, São Paulo.

Cardinale, B.J., Duffy, J.E., Gonzalez, A., Hooper, D.U., Perrings, C., Venail, P., Narwani, A., Mace, G.M., Tilman, D., A.Wardle, D., Kinzig, A.P., Daily, G.C., Loreau, M., Grace, J.B., Larigauderie, A., Srivastava, D.S., Naeem, S., 2012. Biodiversity loss and its impact on humanity. Nature 489, 326–326. doi:10.1038/nature11373

Colonese, A.C., Begossi, A., Brugere, C., Bandeira, A.M., Brandi, R., Wiedemann, M., Azevedo, P., 2010. Bridging ancient and modern artisanal fisheries in Latin America : assessing the role of cultural heritage in poverty alleviation in coastal Brazil 1–4.

Costa, T.L.A., Pennino, M.G., Mendes, L.F., 2017. Identifying ecological barriers in marine environment: The case study of Dasyatis marianae. Mar. Environ. Res. 125, 1–9. doi:10.1016/j.marenvres.2016.12.005

D. Laffoley, Baxter, J.M., 2016. Explaining Ocean Warming: Causes, scale, effects and consequences, Full report. IUCN, Gland, Switzerland. doi:10.2305/IUCN.CH.2016.08.en

De Jesus Mendes, P.A., Thomsen, L., Garcia, R., Gust, G., 2011. Transport of persistent organic pollutants by organo-mineral aggregates (OMAs) in the Lisboa-Setúbal Canyon system. Deep. Res. Part II Top. Stud. Oceanogr. 58, 2345–2353. doi:10.1016/j.dsr2.2011.08.010

Emmett Duffy, J., 2009. Why biodiversity is important to the functioning of real-world ecosystems. Front. Ecol. Environ. 7, 437–444. doi:10.1890/070195

Fao, F.D., 2003. Fisheries management 2. The ecosystem approach to fisheries. FAO Technical Guidelines for Responsible Fisheries, Rome. doi:10.1079/9781845934149.0000

FIGUEIREDO, J.., MENEZES, N.A., 1978. Manual de peixes marinhos do sudeste do Brasil.II. Teleostei (1). Museu de Zoologia da Universidade de São Paulo, São Paulo.

Figueiredo, J.L., 2002. Peixes da zona econômica exclusiva da região sudeste-sul do Brasil : levantamento com rede de meia água. Editora da Universidade de São Paulo, São Paulo.

Figueiredo, J.L., MENEZES, N.A., 2000. Manual de peixes marinhos do sudeste do Brasil. VI. Teleostei (5). Museu de Zoologia da Universidade de São Paulo, São Paulo.

Figueiredo, J.L., MENEZES, N.A., 1980. Manual de peixes marinhos do sudeste do Brasil. III. Teleostei (2). Museu de Zoologia da Universidade de São Paulo, São Paulo.

Fock, H., Uiblein, F., Köster, F., Von Westernhagen, H., 2002. Biodiversity and species-environment relationships of the demersal fish assemblage at the Great Meteor Seamount (subtropical NE Atlantic), sampled by different trawls. Mar. Biol. 141, 185–199. doi:10.1007/s00227-002-0804-y

Gross, T., Johnston, S., Barber, C.V., 2005. A Convenção sobre Diversidade Biológica : Entendendo e Influenciando o Processo Um Guia para Entender e Participar Efetivamente da. Inst. Estud. Avançados da Univ. das Nações Unidas 72.

Halpern, B.S., Frazier, M., Potapenko, J., Casey, K.S., Koenig, K., Longo, C., Lowndes, J.S., Rockwood, R.C., Selig, E.R., Selkoe, K.A., Walbridge, S., 2015. Spatial and temporal changes in cumulative human impacts on the world's ocean. Nat. Commun. 6, 7615.

Johnson, A.F., Jenkins, S.R., Hiddink, J.G., Hinz, H., 2013. Linking temperate demersal fish species to habitat: Scales, patterns and future directions. Fish Fish. 14, 256–280. doi:10.1111/j.1467-2979.2012.00466.x

Joly, C. a, Verdade, M., Berlinck, R.G.S., 2011. Diagnóstico da pesquisa em biodiversidade no Brasil. Rev. Usp 89, 114–133. doi:10.11606/issn.2316-9036.v0i89p114-133

Leão, Z.M.A.N., Kikuchi, R.K.P., Ferreira, B.P., Neves, E.G., Oliveira, M.D.M., Maida, M., Johnsson, R., 2016. Brazilian coral reefs in a period of global change: A synthesis. Brazilian J. Oceanogr. 64, 97–116. doi:10.1590/S1679-875920160916064sp2

Leite, A.P.P., Lima, L.H. de, 2008. Biodiversidade Costeira e Marinha. Macrodiagnostico da ZC.

Lessa, R., Bezerra, J.L., Nóbrega, M.F. de, 2009. Dinamica de Populacoes e Avaliacao dos

Estoques dos Recursos Pesqueirosda regiao Nordeste. Editora Martins & Cordeiro, Fortaleza.

Manuel Haimovicil, S., Klippel, S., 1999. Diagnóstico da Biodiversidade dos Peixes Teleósteos Demersais Marinhos e Estuarinos do Brasil. Rio Grande.

McCauley, D.J., Pinsky, M.L., Palumbi, S.R., Estes, J. a., Joyce, F.H., Warner, R.R., 2015. Marine defaunation: Animal loss in the global ocean. Science (80-.). 347, 247–254. doi:10.1126/science.1255641

McLean, D.L., Langlois, T.J., Newman, S.J., Holmes, T.H., Birt, M.J., Bornt, K.R., Bond, T., Collins, D.L., Evans, S.N., Travers, M.J., Wakefield, C.B., Babcock, R.C., Fisher, R., 2016. Distribution, abundance, diversity and habitat associations of fishes across a bioregion experiencing rapid coastal development. Estuar. Coast. Shelf Sci. 178, 36–47. doi:10.1016/j.ecss.2016.05.026

NOAA, N.C. for C.O.S., 2012. Monaco, M.E S.M. Anderson T.A. Battista M.S. Kendall S.O. Rohmann L.M. Wedding A.M. Clarke. NOAA Technical Memorandum NOS NCCOS 122, Silver Spring.

Nóbrega, M.F. de, Lessa, R., Santana, F.M., 2009. Peixes Marinhos da regiao Nordeste do Brasil. Martins & Cordeiro, Fortaleza.

Pikitch, E.K., Santora, C., Babcock, E. a, Bakun, A., Bonfil, R., Conover, D.O., Dayton, P., Doukakis, P., Fluharty, D., Heneman, B., Houde, E.D., Link, J., Lindenmayer, D.B., Foster, D.R., Franklin, J.F., Hunter, M.L., Noss, R.F., Schmiegelow, F.A., Perry, D., 2004. Ecosystem-Based Fishery Management. Science (80-.). 300, 2003–2003. doi:10.1126/science.1106929

ROCHA, L.O.., COSTA, P.A.., 1999. Manual de Identificação de Peixes Marinhos para a Costa Central, 2nd ed. Programa REVIZEE / SCORE-Central, Rio de Janeiro.

Rossi-Wongstchowski, C., Almeida, E., Ávila-Bernardes, R., 2007. Prospecção pesqueira de espécies pelágicas de pequeno porte com rede de meia-água na Zona Econômica Exclusiva da Região Sudeste-Sul do Brasil, 1st ed. Serie Documentos REVIZEE/Score-Sul, 2.

Seeliger, E., Odebrecht, C., Castello, J., 1998. Os ecossistemas costeiro e Marinho do extremo sul do Brasil, Ecoscientia. Ecoscientia Rio Grande, Rio Grande.

St. John, M.A., Borja, A., Chust, G., Heath, M., Grigorov, I., Mariani, P., Martin, A.P., Santos, R.S., 2016. A Dark Hole in Our Understanding of Marine Ecosystems and Their Services: Perspectives from the Mesopelagic Community. Front. Mar. Sci. 3, 1–6. doi:10.3389/fmars.2016.00031

VOOREN, C.., 1998. Elasmobrânquios demersais, in: Os Ecossistemas Costeiro E Marinho Do Extremo Sul Do Brasil. Ecoscientia Rio Grande, Rio Grande.

Worm, B., Barbier, E.B., Beaumont, N., Duffy, J.E., Folke, C., Halpern, B.S., Jackson, J.B.C., Lotze, H.K., Micheli, F., Palumbi, S.R., Sala, E., Selkoe, K.A., Stachowicz, J.J., Watson, R., 2006. Impacts of Biodiversity Loss on Ocean Ecosystem Services. Science (80-.). 314, 787–790. doi:10.1126/science.1132294

DEMERSAL FISH ASSEMBLAGE OF THE BRAZILIAN NORTHEAST COAST

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INTRODUCTION

Marine biodiversity is largely recognized as essential for ecosystem functioning and the provision of goods and services to humanity (EMMETT DUFFY, 2009; WORM et al., 2006; ZINTZEN et al., 2012). The diversity of organisms influences the capacity of living systems respond to changes in the environment, support ecosystem functions and provide nutrients cycling and food production that ensure human well-being and livelihood of millions of people around the world (EMMETT DUFFY, 2009; HIDDINK et al., 2006). However, resource exploitation, habitat modification, pollution and climatic changes has led to dramatic modification in the composition of marine ecological communities, raising concerns about consequences of those impacts for ecosystems and humanity (CARDINALE et al., 2012; VITOUSEK et al., 1997).

With more than 60% of the world's human population living within 60km of the shoreline, coastal marine ecosystems are under huge pressure given the increasing anthropogenic activities and the reduced capacity to withstand these pressures (ALONGI, 1998; JOHNSON et al., 2013). The Brazilian northeast coast, extending around 3.000km, is one of the most densely populated and largest coastal region of Brazil. This region of low productivity, yet high biodiversity, host several interconnected ecosystems such as mangroves, coral reefs, sandy beaches, seagrass meadows, rocky shores and estuaries. These highly complex hydrological and environmental processes impact the life cycle of marine species, drive their spatiotemporal distribution patterns, and shape the faunal assemblages (EKAU 1999).

Despite environmental impacts and low productivity, fishery in Northeast Brazil is a very important socio-economic activity, as this region is responsible for the highest landed volume of the country (MMA, 2010; MPA, 2012). Artisanal fisheries are dominant in the region, involving more than 500 communities and 200 thousands of people (IBAMA, 2002; NÓBREGA; LESSA;

SANTANA, 2009). These fisheries are adapted to the ecosystem complexity and range from shallow waters, estuary and reefs formations where fishing grounds may be reached by swimming or using rowing or sailing canoes, to outside waters where fishers use sailing or motorized boats to reach the deeper waters of the shelf break (LESSA et al. 2006).

Nevertheless, despite the social, ecologic and economic importance of the northeast coast of Brazil, most part of published studies regarding demersal marine communities and environments have been undertaken in small spatial scales and based on fishery-dependent data (GARCIA JÚNIOR; M, 2010; LESSA; BEZERRA; NÓBREGA, 2009; MARIO TISCHER, 2003; MMA, 2010; NÓBREGA; LESSA; SANTANA, 2009; SHINOZAKI-MENDES et al., 2013; SILVA JÚNIOR et al., 2015), which may difficult necessary inferences for the implementation of efficient strategies from an ecosystem-based approaches perspective.

Ecosystem-based approaches to fisheries management (EAFM) is a new direction for protection of fishery species, essentially reversing the order of management priorities to start with the ecosystem rather than the target species (PIKITCH et al., 2004). There has been clear recognition that the adoption of EAFM provides innumerous advantages, such as health ecosystems, maintenance of biodiversity and restoration of ecosystem functions. However, the implementation of EAFM commonly involves a habitat and community level of information (i.e. biodiversity, assemblage structure and species distribution in relation to habitat and environmental variables, etc), which is barely applied in Brazil, especially, in the northeast region.

In this study, we describe the fish demersal assemblage along the continental shelf of the northeast Brazilian coast (5°-9°S), specifically the ecological descriptors and the distribution and spatial abundance of the fish fauna. The relationship of the fish assemblage and habitat variables is also taken into account. This study was, therefore, designed to fill the current gap of information, also aiming at contributing to the development and implementation of management proposals which address the ecosystem as a whole. This is the first study that integrates large scale analyses of habitat type, biodiversity, abundance and distribution of demersal fishes in the northeast coast of Brazil.

MATERIAL AND METHODS

Study area

The study area comprises part of the northeast Brazilian continental shelf (5°-9°S). The region holds an high biodiversity and many priority areas for conservation and sustainable use (CBD, 2014; SERAFINI; FRANÇA; ANDRIGUETTO-FILHO, 2010). The region is located in the eastern part of the northeastern region of the South American Platform, a few degrees north of the southern branch of the South Equatorial Current nearshore bifurcation (EKAU; KNOPPERS, 1999). The shelf averages 40 km in width and is almost entirely covered by biogenic carbonate sediments, with depth ranging from 40 to 80 m (VITAL et al., 2010). The predominance of hot water and existence of a permanent thermocline throughout all northeast coast difficult vertical circulation of water bodies, hampering enrichment of nutrients from deeper layers. As consequence, the area has low primary production and low abundance of all trophic levels in the marine food chain (HAZIN, 2009).

Sampling and sample processing

This study is based on samples collected during the Acoustics along the BRAzilian COaSt (ABRACOS) surveys, carried out in 30 August - 20 September 2015 and 9 April – 9 May 2017, on board the R/V ANTEA. Sampling was conducted at 37 stations in the northeast Brazilian continental shelf, from Rio Grande do Norte to Alagoas (5°- 9°S, Figure 1). Hauls were performed between 15 and 65 m of depth, for about 5 minutes at 3.2 kt, using a bottom trawl net (body mesh: 40 mm, cod-end mesh: 25mm, entrance dimensions: 28 x10 m). To reduce impacts on benthic habitat, the bottom trawl net was adapted in the second cruise, where bobbins where added to the ground rope. Considering the differential operation of fishing gear in both cruises, we allowed for a better sampling of the fish fauna in terms of habitat (from benthic to demersal-pelagic), and hence biodiversity. For both cruises, sampled area was the same, except for the very north area of Rio Grande do Norte, which was sampled only in the second cruise. Tow duration was considered as the moment of the arrival of the net on the pre-set depth to the lift-off time, recorded by means of a SCANMAR system. The net geometry has also been monitored using SCANMAR sensors, to give headline height, depth, and distance of wings and doors to ensure the net was fishing correctly.

To classify bottom habitat, a stereo-video footage was collected through an underwater camera (GOPRO HERO 3) attached to the net. The habitat types were classified using an adapted methodology proposed by NOAA (2012), categorizing 4 types of habitat in the study region (Figure 2). Temperature, oxygen and salinity, used in further statistical analysis, were collected, for each haul, using a CTD (Figure 3)

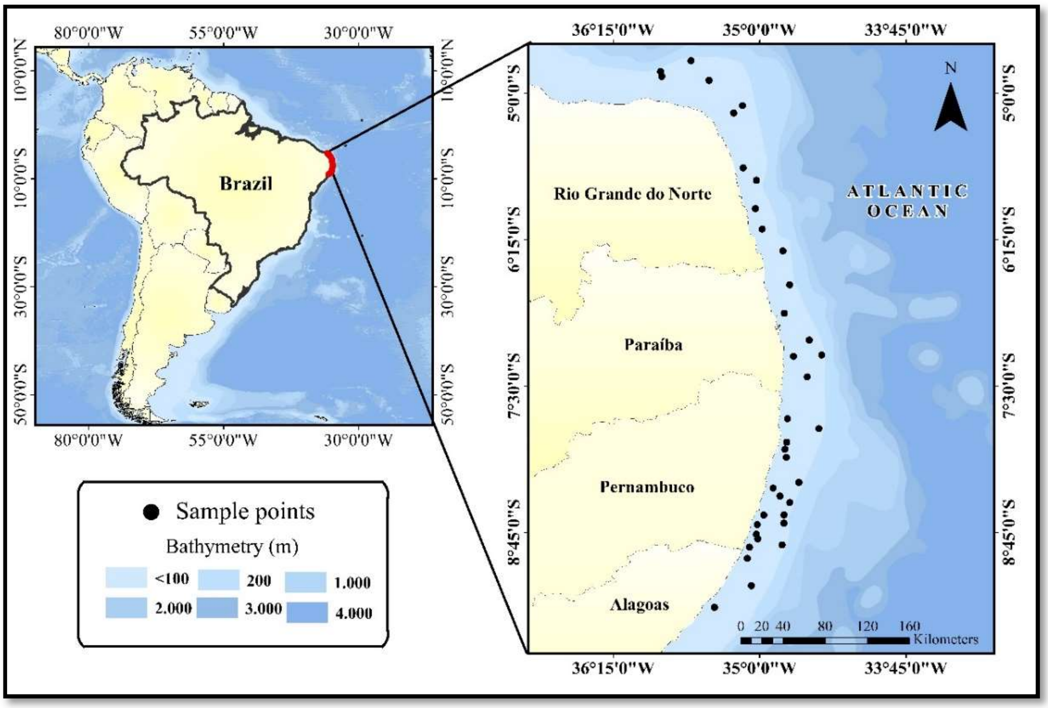

Figure 1 - Study area with trawled sites (black dots) along the northeast Brazilian continental shelf.

For each haul, fishes were identified to the lowest possible taxonomic level, weighed on a motion-compensating scale (to the nearest 0.1 kg), and preserved with a solution of 4% formalin in seawater or by freezing until processing. For very large samples (more than 200 specimens) all identified organisms were counted, weighed, sub-sampled (30 individuals randomly selected for each species) and discarded. In laboratory, total length (TL), and wet weight (WT) were recorded.

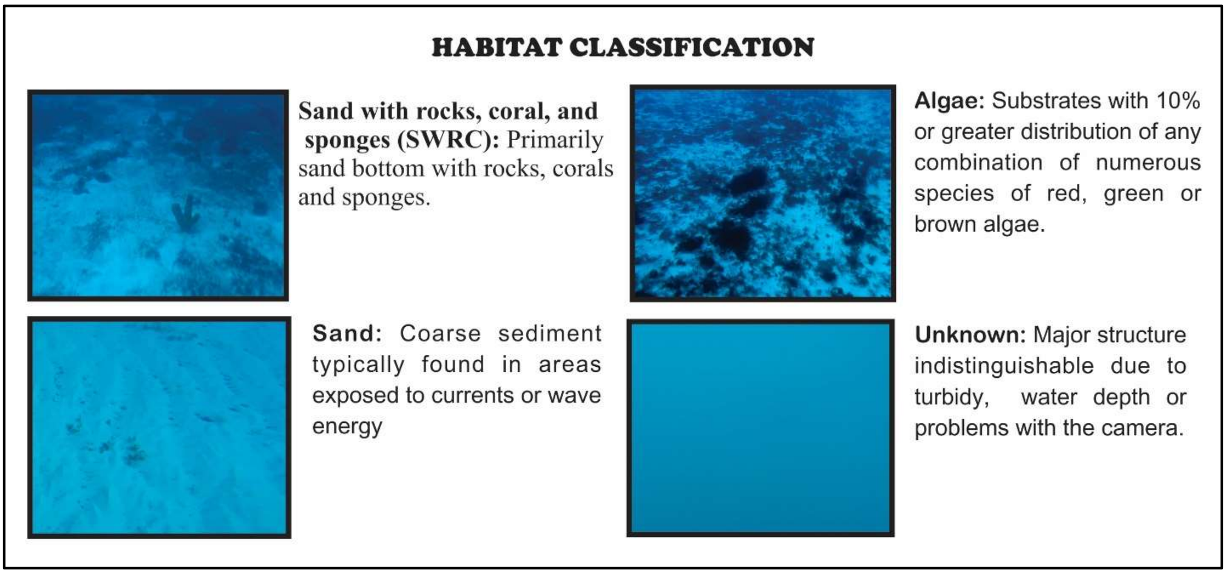

Figure 2 - Types and examples of bottom habitat identified through analysis of stereo-video footage taken along the continental shelf of the northeast Brazilian coast (5°-9°S).

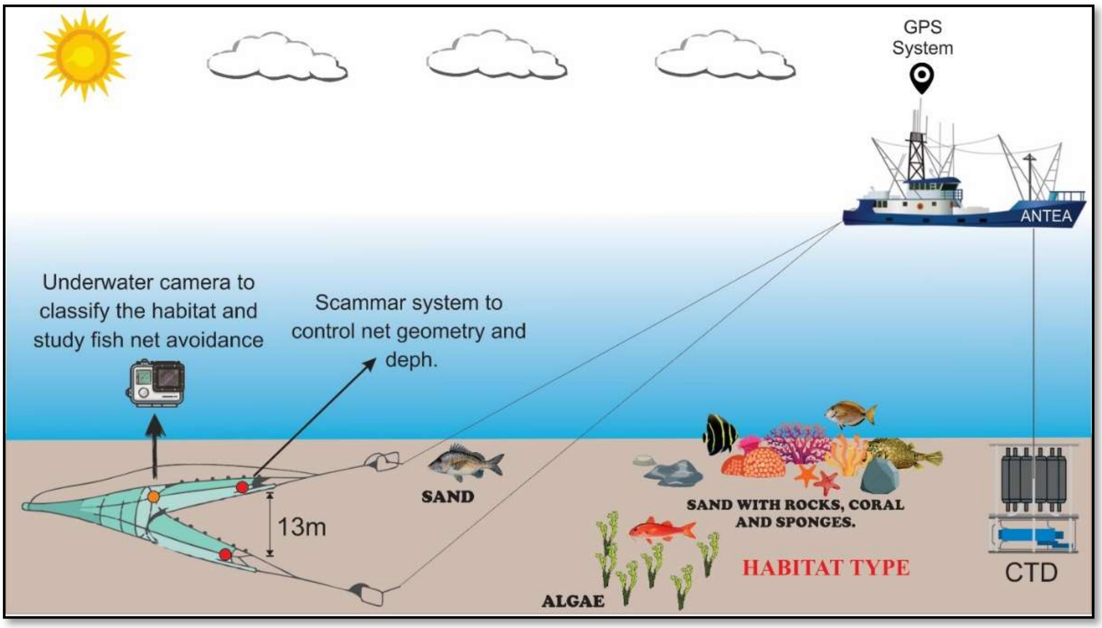

Figure 3 – Schema demonstrating collection of hydrographic and net geometry data, stereo-video footage, and sample collections. The three main habitat types identified in the study are shown.

Data analyses

Fish fauna biodiversity and community descriptors

The relative density and biomass (Cath per unit of effort – CPUE) were calculated considering the number of individuals and weight of fish caught per trawled area (ind/km^2 – kg/km^2). The trawled area was calculated by multiplying the traveled distance of the vessel (in m) with the estimated gear mouth opening (13 m). Results were calculated in square kilometer (km^2).

Species composition and patterns of dominance were analyzed based on Biomass (weight), frequency of occurrence (%F) and relative abundance (catch per unit effort; %CPUE) of each species (GARCIA et al., 2004). Species with %F values equal to or greater than the average value of all species were considered frequent. Species with %F values smaller than the average value were rare. The same procedure was employed for the %CPUE values, resulting in higher abundant (%CPUE ≥ average %CPUE) and lower abundant species (%CPUE < average %CPUE). Finally, based on these criteria, the species were classified in terms of relative importance (relative importance index) in four groups: (1) higher abundant and frequent, (2) higher abundant and rare, (3) lower abundant and frequent and (4) lower abundant and rare (GARCIA et al., 2006). This classification was used to identify the dominant species. Thus, we considered species as dominant when the species was within first, second, and third categories. In addition, species were also classified according to IUCN Red List categories at the regional level (ICMBIO, 2016) which comprises 10 levels of extinction risk: Extinct (EX), Regionally Extinct (RE), Extinct in the Wild (EW), Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC), Data Deficient (DD) and Not Evaluated (NE). The classification criteria, application guidelines, and IUCN Red List methodology on how to apply the Criteria are publically available (IUCN, 2000, 2012)

Community structure was investigated through a Bray-Curtis similarity resemblance matrix, which was used to perform a ANOSIM (Analysis of Similarities), a non- parametric permutation procedure used to teste difference among habitat types (BORCARD; GILLET; LEGENDRE, 2011; CLARKE; SOMERFIELD; WARWICK, 1994; HANCHET et al., 2013). To reduce bias in these analyses, species data were log- transformed (log (x + 1)) before analysis, and rare species (those representing <0.1% of abundance) were not considered. The SIMPER routine was applied to identify the contribution from each species to the similarity (typifying species) and dissimilarity (discriminating species) between habitat types, given that habitat type showed significant differences through ANOSIM analysis (CLARKE; SOMERFIELD; WARWICK, 1994).

To evaluate the influence of abiotic factors on the variability of fish data and to select the best explanatory model, a DISTLM (Distance-Based Linear Model), using Akaike's information criterion (AIC), which considers continuous variables, was applied (ANDERSON; GORLEY; CLARKE, 2008). A stepwise procedure was adopted to test the importance of the independent variables. Redundancy Analysis (dbRDA - Distance-Based redundancy analysis) was used to examine the influence of predictor variables on the spatial distribution of samples (ANDERSON et al., 2008). To avoid strong collinearity among tested variables, Spearman correlation analyses were performed and tested ($p< 0.05$) previously and only variables with non-significant correlation were included. Latitude, temperature, oxygen, salinity and depth were considered for this analysis.

Diversity was expressed as a series of indices calculated by habitat type (shown through box-plots) and latitudinal ranges (shown through maps), using untransformed relative abundance data. To calculate richness, the Margalef index was estimated conform to the equation:

$$DMg = \frac{(S-1)}{\ln N}$$

where S is the total number of species sampled and N is the total number of specimens. This index was chosen for establishing a functional relationship between N and S, minimizing the bias caused by differences in sample sizes. For this index, exceptionally, were used absolute values of abundance, as it is a prerequisite of this analysis. To express equitability, or the distribution of individuals among the species, Pielou's evenness indices (PIELOU, 1977) were calculated according to the equation:

$$J' = {H'}/{H'_{máx}} = H'/\log S$$

where *H'* max is the maximum possible value of Shannon diversity, that value achieved if all species were equally abundant. Shannon diversity and Simpson's index were accessed through the Hill's diversity index N1 and N2 (Hill, 1973; Magurran, 1988), which gradually differ in their indicative value for rare and common species. The general form is

$$Na = (\ P_1^a + \ P_2^a + \cdots + P_n^a)^{\frac{1}{1-a}}$$

with a=0, 1, 2……and *pi* denoting the proportion of abundance for each species i. For a=1, N1 is the exponential Shannon– Wiener index H0, which was employed in its more familiar form,

$$H' = -\sum_{i-l} pi\ ln\, pi$$

While, for a=2, N2 is the reciprocal of Simpson's index:

$$D = \sum P_i^2$$

To test differences among habitats for each calculated index, a two-way ANOVA was performed (SOKAL & ROHLF, 1987) following the necessary assumptions of normality (Kolmogorov-Smirnov test) and homoscedasticity (Levene's test). All procedures described here were performed utilizing the computational package R (R CORE TEAM, 2016), the software primer v7 (CLARKE; SOMERFIELD; WARWICK, 1994) and ArcGIS10.1 (MODELS, 2003) .

RESULTS

Thirty-seven hauls were conducted along the northeast Brazilian continental shelf, resulting in a total effort of 200 minutes and 257.000m^2 of trawled area. Temperature ranged from 25.5°C to 29.6°C ($\bar{x}$ =27.5°C), while salinity and dissolved oxygen varied from 28.5 to 37.5 ($\bar{x}$ =36.6) and 4 mg/l to 4.4 mg/l ($\bar{x}$ =4.2 mg/l), respectively.

Considering all samples together, 7.340 individuals (830 Kg), distributed in 24 orders, 49 families and 120 species, were collected in the study period. Considering the whole studied area, the richest order was Perciformes (24 families, 66 species and 67 % of total individuals caught); followed by Tetraodontiformes (6 families, 21 species and 14% of total individuals caught) (Table

1). The families with the highest catches (the five most abundant in %N) were Haemulidae (3.052 individuals (41%)); Mullidae (527 individuals (7%)); Holocentridae (446 individuals (6%)); Gerreidae (393 individuals (5%)) and Diodontidae (368 individuals (5%)). The five dominant families in % of weight were Haemulidae (226kg (27%)); Diodontidae (80kg (10%)); Ostraciidae (77kg (9%)); Dasyatidae (76kg (9%)) and Pomacanthidae (51kg (6%)) (Table 1). The demersal fish fauna was dominated (%N) by: *Haemulon aurolineatum* (27%); *Haemulon squamipinna* (10%); *Pseudupeneus maculatus* (7%); *Holocentrus adscensionis* (6%) and *Diodon holocanthus* (5%) (Table 1), which together comprised more than half of the total number of individuals. Considering the weight, the fish fauna was dominated (%W) by *Haemulon aurolineatum* (17%); *Diodon holocanthus* (9%); *Hypanus marianae* (9%); *Pseudupeneus maculatus* (6%) and *Pomacanthus paru* (5%) (48% of total weight).

In relation to the relative importance index, 36 (30%) species were considered dominant (those species classified in the category (1) higher abundant and frequent, (2) higher abundant and rare and (3) lower abundant and frequent), while the rest of the species (85; 80%) were classified as lower abundant and rare. According to IUCN Red List, 3 species were considered vulnerable (VU) (*Sparissoma axillare, Sparissoma Frondosum* and *Mycteroperca bonaci*), while 87 species were classified as Least Concern (LC), 25 as Data deficient (DD) and 9 were not evaluated (NE). Considering total length, the overall mean size of the fish demersal fauna was 15.5 cm ± 9.14 (mean±DP). The largest specimen reported belonged to the species *Dasyatis guttata* (108cm ± 6.50 (mean±DP)) and the smallest was a *Caranx latus* (3.9 cm). In relation to total weight, the overall mean was 90g ± 280 (mean±DP) and, the heaviest individual was of the species *Mycteroperca bonaci* (14.600g) and the lightest of *Uraspis helvola* (1.3g) (Table 1).

For all species together, higher values of CPUE (in abundance and biomass) were found in the central and south part of Pernambuco (8 -9°S), including all the coastal shelf, and the south part of Rio Grande do Norte (Figure 4). Considering the CPUE of the most abundant families, those who accounted for 80% of sampled specimens, we observed different patterns along a latitudinal gradient, although all main families were present in most of the studied area (Figure 5). Acanthuridae, Diodontidae, and Mullidae were more frequent and abundant in the south part of Pernambuco, while Haemulidae and Lutjanidae were found in almost all sample sites, with higher values of abundance in the South of Pernambuco and North of Rio Grande do Norte. Gerreidae, Holocentridae and Monocanthidae were more abundant in the south of Rio Grande do Norte and north of Paraiba (6°S - 6° 30'S) and Ostraciidae were more abundant in the north of Paraiba and South of Pernambuco.

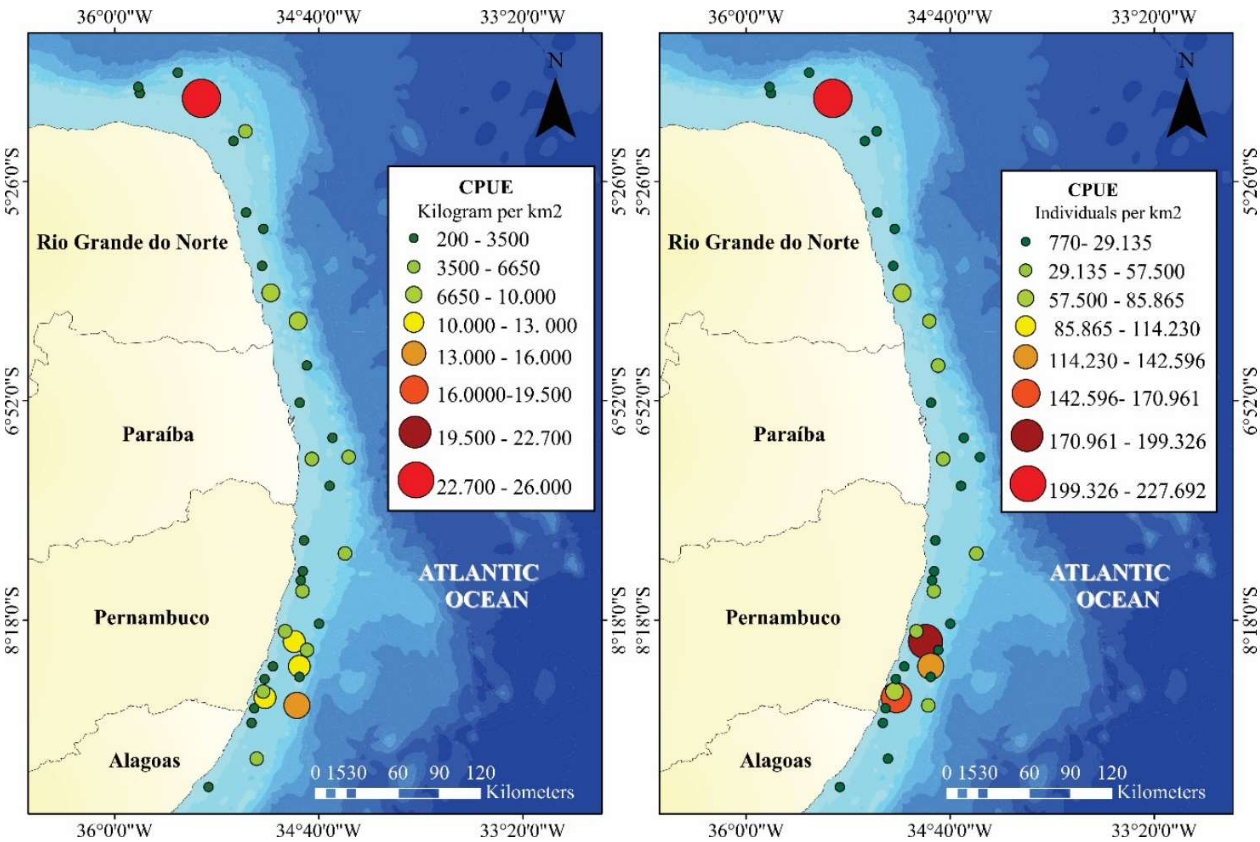

Figure 4- Values of catch per unit of effort (CPUE; ind/km^2; Kg/km^2) along the study area.

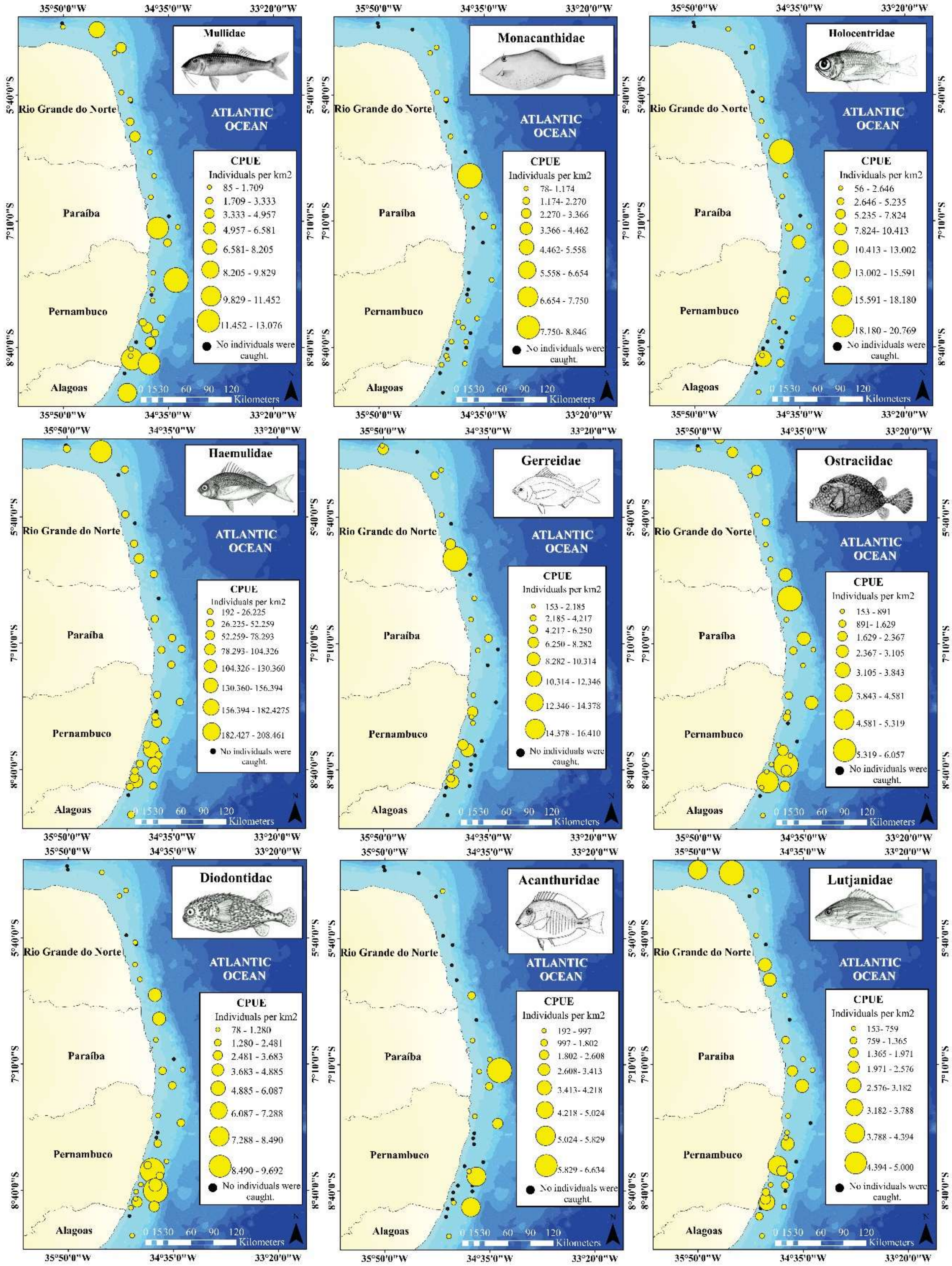

Figure 5 - Spatial distribution and catch per unit of effort (CPUE; Individuals/km2) of the 9 most abundant families caught along the northeast Brazilian continental shelf (5°- 9°S).

Table 1- List of species, number of individuals (n), relative importance index (• lower abundant and rare; •• lower abundant and frequent; ••• higher abundant and rare; •••• higher abundant and frequent), IUCN classification (Vulnerable (VU), Near Threatened (NT), Least Concern (LC), Data Deficient (DD) and Not Evaluated (NE)), total length (mean± standard deviation, minimum and maximum), Total weight (W) (mean ± standard deviation, minimum and maximum).

Order	Family	Species	N	IR	IUCN	Total Length (cm)		Total Weight (g)	
						Mean ± DP	Max-Min	Mean ± DP	Max-Min
Rajiformes	Rhinobatidae	*Pseudobatos percellens (Walbaum, 1792)*	22	••	DD	38.1 ± 13.2	56.5 - 24.4	233.0 ± 214.	605 - 46.9
Myliobatiformes	Dasyatidae	*Dasyatis guttata (Bloch & Schneider, 1801)*	1	•	LC	108. ± 6.50	113 - 103.8	1677. ± 837.	2270 - 1085
		Hypanus marianae Gomes, Rosa & Gadig, 2000	79	••••	DD	51.0 ± 10.8	61.7 - 16.5	1356. ± 1374	5668 - 1
Elopiformes	Elopidae	*Elops saurus Linnaeus, 1766*	1	•	NE	-	-	390	-
Albuliformes	Albulidae	*Albula vulpes (Linnaeus, 1758)*	3	•	DD	39.8	-	622.3	-
Anguilliformes	Muraenidae	*Gymnothorax moringa (Cuvier, 1829)*	1	•	DD	14.4	-	3	-
		Gymnothorax vicinus (Castelnau, 1855)	11	•	DD	27.7 ± 8.67	38.7 - 13.3	34.87 ± 34.4	98.7 - 2.6
Clupeiformes	Pristigasteridae	*Chirocentrodon bleekerianus (Poey, 1867)*	93	•••	LC	6.71 ± 1.57	10.4 - 3.1	1.747 ± 1.49	8.3 - 0.2
	Engraulidae	*Lycengraulis grossidens (Agassiz, 1829)*	3	•	LC	18.2 ± 1.09	19.5 - 17.6	47.5 ± 13.0	62.6 - 39.6
	Clupeidae	*Opisthonema oglinum (Lesueur, 1818)*	165	••••	LC	18.6 ± 3.54	26.8 - 8.2	57.07 ± 30.8	161.9 - 4.6
Siluriformes	Ariidae	*Bagre marinus (Mitchill, 1815)*	9	•	DD	46.8	-	850	-
Aulopiformes	Synodontidae	*Synodus foetens (Linnaeus, 1766)*	29	••	LC	17.9 ± 8.74	35.5 - 7.9	64.59 ± 80.0	278.5 - 2.4
		Synodus intermedius (Spix & Agassiz, 1829)	9	••	LC	14.2 ± 8.48	26.8 - 6.4	48.74 ± 66.0	167 - 1.7
		Synodus synodus (Linnaeus, 1758)	7	•	LC	11.4 ± 2.31	15.5 - 8.9	14.85 ± 9.51	31.2 - 4.8
		Trachinocephalus myops (Forster, 1801)	17	••	LC	11.5 ± 6.06	25.6 - 3.6	28.60 ± 40.8	145.7 - 1.5
Holocentriformes	Holocentridae	*Holocentrus adscensionis (Osbeck, 1765)*	429	••••	LC	11.3 ± 5.67	24.2 - 6.2	26.50 ± 35.2	171.8 - 3.3
		Myripristis jacobus Cuvier, 1829	17	•	NE	7.38 ± 2.58	16 - 5.7	10.71 ± 20.4	89.8 - 3.4
Kurtiformes	Apogonidae	*Astrapogon puncticulatus (Poey, 1867)*	2	•	LC	3.7 ± 0.14	3.8 - 3.6	0.65 ± 0.01	0.66 - 0.64
		Phaeoptyx pigmentaria (Poey, 1860)	4	•	LC	3.75 ± 0.75	4.4 - 2.7	0.595 ± 0.31	0.97 - 0.24
Gobiiformes	Pomacentridae	*Stegastes pictus (Castelnau, 1855)*	1	•	LC	-	-	10	-
		Stegastes fuscus (Cuvier, 1830)	1	•	LC	6.8	-	4.5	-
Carangiformes	Echeneidae	*Echeneis naucrates Linnaeus, 1758*	4	•	LC	21.6	-	24.5	-
	Carangidae	*Caranx crysos (Mitchill, 1815)*	1	•	LC	-	-	1190	-
		Caranx latus Agassiz, 1831	1	•	LC	3.9	-	2.5	-
		Chloroscombrus chrysurus (Linnaeus, 1766)	196	•••	LC	13.5 ± 1.55	18.1 - 10.3	21.19 ± 8.11	48.8 - 9
		Selar crumenophthalmus (Bloch, 1793)	8	•	LC	14.8 ± 5.86	19 - 10.7	111.3 ± 56.1	168 - 7.7
		Selene brownii (Cuvier, 1816)	11	•	LC	13.9 ± 4.04	20.5 - 10.6	49.07 ± 46.9	130.2 - 15.7
		Selene vomer (Linnaeus, 1758)	1	•	LC	-	-	5	-
		Uraspis helvola (Poey, 1860)	1	•	NE	4.4	-	1.3	-
Istiophoridae	Sphyraenidae	*Sphyraena barracuda (Edwards, 1771)*	1	•	LC	-	-	450	-
		Sphyraena guachancho Cuvier, 1829	8	•	LC	43	-	399.3	-

Order	Family	Species	N	IR	IUCN	Total Length (cm)		Total Weight (g)	
						Mean ± DP	Max-Min	Mean ± DP	Max-Min
Pleuronectiformes	Paralichthyidae	*Cyclopsetta fimbriata (Goode & Bean, 1885)*	4	●	LC	18.4 ± 5.38	23.4 - 13.5	84.7 ± 65.1	155 - 23.8
		Syacium micrurum Ranzani, 1842	75	●●	LC	17.8 ± 5.21	25 - 6.5	73.7 ± 51.6	163.2 - 2.4
		Syacium papillosum (Linnaeus, 1758)	7	●	LC	20.5 ± 3.57	24.2 - 15.6	92.17 ± 41.1	142.9 - 38.2
	Bothidae	*Bothus lunatus (Linnaeus, 1758)*	40	●	LC	12.6 ± 0.83	14.3 - 11	23.28 ± 4.78	33.5 - 15
		Bothus ocellatus (Agassiz, 1831)	156	●●●●	LC	11.7 ± 1.67	14.8 - 5.2	20.37 ± 7.95	43.3 - 1.9
		Bothus robinsi Topp & Hoff, 1972	2	●	LC	13.4 ± 0.07	13.5 - 13.4	27 ± 1.27	27.9 - 26.1
	Achiridae	*Achirus achirus (Linnaeus, 1758)*	6	●	LC	11.2 ± 1.96	13.7 - 9.3	26.95 ± 11.2	38.8 - 16
		Achirus lineatus (Linnaeus, 1758)	2	●	LC	12.6 ± 0.07	12.7 - 12.6	38.4 ± 0.56	38.8 - 38
Syngnathiformes	Fistulariidae	*Fistularia tabacaria Linnaeus, 1758*	80	●●●●	LC	43.0 ± 20.7	84.5 - 13.1	60.34 ± 71.5	297.1 - 1.2
	Aulostomidae	*Aulostomus maculatus Valenciennes, 1841*	37	●	NE	26.1 ± 2.77	31.5 - 15.3	29.85 ± 9.07	57 - 3.6
		Aulostomus strigosus Wheeler, 1955	4	●	LC	26.1 ± 8.52	31 - 13.4	34.72 ± 22.3	48 - 1.4
Scombriformes	Scombridae	*Scomberomorus brasiliensis Collette, Russo & Zavala-Camin, 1978*	1	●	LC				
Labriformes	Labridae	*Halichoeres poeyi (Steindachner, 1867)*	3	●	LC	13.2 ± 1.75	14.9 - 11.4	26.43 ± 9.85	36.3 - 16.6
		Halichoeres dimidiatus (Agassiz, 1831)	3	●	LC	19,5	-	218	68 - 150
	Scaridae	*Cryptotomus roseus Cope, 1871*	36	●	LC	8.84 ± 1.35	10.7 - 5.6	9.366 ± 4.06	16.4 - 1.8
		Sparisoma axillare (Steindachner, 1878)	15	●	VU	20,2	-	166,4	-
		Sparisoma frondosum (Agassiz, 1831)	17	●	VU	29,5	-	675	-
		Sparisoma radians (Valenciennes, 1840)	55	●	LC	11.7 ± 4.46	20 - 5.1	40.74 ± 39.9	132.4 - 1.38
	Dactylopteridae	*Dactylopterus volitans (Linnaeus, 1758)*	28	●●	LC	20.5 ± 6.67	29.9 - 5.6	126.2 ± 84.9	315.5 - 2
Perciformes	Gerreidae	*Diapterus auratus Ranzani, 1842*	12	●	LC	16.0 ± 1.23	17.9 - 14.3	60.40 ± 14.9	90.6 - 38.7
		Diapterus rhombeus (Cuvier, 1829)	6	●	LC	13.8 ± 1.57	16.4 - 12.4	40.9 ± 13.7	66.3 - 26.5
		Eucinostomus argenteus (Baird & Girard, 1855)	95	●●●●	LC	14.8 ± 2.53	21 - 9.4	42.74 ± 24.1	105.7 - 10.8
		Eucinostomus gula (Quoy & Gaimard, 1824)	78	●●●●	LC	11.7 ± 1.70	20.7 - 8.5	20.07 ± 7.75	51.4 - 7.8
		Eucinostomus lefroyi (Goode, 1874)	85	●●●	NE	14.9 ± 2.06	19.5 - 9.5	39.11 ± 19.4	87 - 7.8
	Mullidae	*Mulloidichthys martinicus (Cuvier, 1829)*	4	●	LC	5,7	-	1,34	-
		Pseudupeneus maculatus (Bloch, 1793)	521	●●●●	LC	17.0 ± 7.11	27.8 - 5.3	92.20 ± 72.9	294 - 1.04
		Upeneus parvus Poey, 1852	1	●	LC	-	-	18	-
	Serranidae	*Alphestes afer (Bloch, 1793)*	48	●	DD	16.6 ± 1.85	21.4 - 13.5	68.99 ± 21.9	118.2 - 32.5
		Cephalopholis fulva (Linnaeus, 1758)	11	●	DD	11.8 ± 9.05	28.3 - 4.8	73.49 ± 113.	348.65 - 1.14
		Diplectrum formosum (Linnaeus, 1766)	14	●●	LC	16.8 ± 5.99	20.2 - 7.9	52.27 ± 50.5	96.5 - 5.4
		Mycteroperca bonaci (Poey, 1860)	1	●	VU	-	-	14600	-
		Paranthias furcifer (Valenciennes, 1828)	6	●	NE	5.63 ± 0.34	5.9 - 5	1.57 ± 0.21	1.88 - 1.22
		Rypticus bistrispinus (Mitchill, 1818)	3	●	LC	5.43 ± 0.58	6.1 - 5	1.616 ± 0.52	2.22 - 1.3

Order	Family	Species	N	IR	IUCN	Total Length (cm)		Total Weight (g)	
						Mean ± DP	Max-Min	Mean ± DP	Max-Min
Perciformes	Priacanthidae	*Heteropriacanthus cruentatus (Lacepède, 1801)*	1	●	LC	7,4	-	10	-
		Priacanthus arenatus Cuvier, 1829	26	●	LC	20,5	20.5 - 20.5	1320	1320 - 1320
	Chaetodontidae	*Chaetodon ocellatus Linnaeus, 1758*	22	●	DD	11.7 ± 2.67	13.6 - 2.4	50.27 ± 19.1	75.1 - 0.42
		Chaetodon striatus Linnaeus, 1758	53	●●	LC				
	Pomacanthidae	*Holacanthus tricolor (Bloch, 1795)*	8	●	DD	17.2 ± 4.12	22.9 - 13.2	169.3 ± 117.	338.9 - 75.9
		Holacanthus ciliaris (Linnaeus, 1758)	4	●	DD	27	-	558	-
		Pomacanthus paru (Bloch, 1787)	30	●●	DD	37.8 ± 3.48	41 - 33.1	1902. ± 432.	2660 - 1105
	Malacanthidae	*Malacanthus plumieri (Bloch, 1786)*	2	●	LC	43.5 ± 10.9	51.3 - 35.8	403 ± 237.	571 - 235
	Haemulidae	*Anisotremus virginicus (Linnaeus, 1758)*	6	●	LC	20.3 ± 4.31	23.4 - 17.3	227.8 ± 96.0	325 - 95.1
		Conodon nobilis (Linnaeus, 1758)	1	●	LC	14,6	-	41,3	-
		Haemulon aurolineatum Cuvier, 1830	1977	●●●●	LC	15.7 ± 3.02	20.3 - 5.6	55.71 ± 20.5	116.9 - 1.9
		Haemulon parra (Desmarest, 1823)	1	●	LC	27,8	-	312,4	-
		Haemulon plumierii (Lacepède, 1801)	216	●●●●	DD	17.6 ± 4.14	27.5 - 12.6	95.74 ± 79.2	327.9 - 23.1
		Haemulon squamipinna Rocha & Rosa, 1999	704	●●●●	LC	15.8 ± 2.15	19.5 - 11.1	59.07 ± 23.0	110.9 - 18.3
		Haemulon steindachneri (Jordan & Gilbert, 1882)	91	●●●●	LC	17.9 ± 1.76	20 - 14.2	86.93 ± 22.8	123.9 - 41.7
		Haemulon melanurum (Linnaeus, 1758)	5	●	LC	26.7 ± 2.29	30.6 - 25.3	252 ± 66.1	360.7 - 191
		Orthopristis ruber (Cuvier, 1830)	42	●●	LC	17.0 ± 1.66	20.5 - 15.1	70.56 ± 15.3	101 - 54.5
		Haemulopsis corvinaeformis (Steindachner, 1868)	8	●	LC	15.7 ± 1.80	18 - 12.9	55.61 ± 19.2	79.9 - 28.14
	Lutjanidae	*Lutjanus analis (Cuvier, 1828)*	10	●	NT	35.0 ± 5.75	43.5 - 28	674.0 ± 305.	1167.4 - 318.5
		Lutjanus synagris (Linnaeus, 1758)	174	●●●●	NT	21.7 ± 5.30	37.2 - 13.1	172.8 ± 119.	535.5 - 27.3
		Ocyurus chrysurus (Bloch, 1791)	16	●●	NT	22.1 ± 9.75	29 - 15.2	144.1 ± 152.	251.8 - 36.5
	Microdesmidae	*Ptereleotris randalli Gasparini, Rocha & Floeter, 2001*	1	●	LC	-	-	-	-
	Polynemidae	*Polydactylus virginicus (Linnaeus, 1758)*	1	●	LC	17.5 ±	17.5 - 17.5	51,4	51.4 - 51.4
Scorpaeniformes	Scorpaenidae	*Scorpaena melasma Eschmeyer, 1965*	6	●	NE	8.55 ± 2.50	11.3 - 6	13.53 ± 10.3	26 - 4
		Scorpaena inermis Cuvier, 1829	3	●	LC	7.33 ± 0.75	8.1 - 6.6	7.1 ± 2.00	9.2 - 5.2
		Scorpaena isthmensis Meek & Hildebrand, 1923	6	●	LC	13.5 ± 4.90	18.2 - 6.2	55.66 ± 40.8	112 - 5
		Scorpaena plumieri (Bloch, 1789)	2	●	LC	19.5 ± 5.58	23.5 - 15.6	207.1 ± 167.	325.6 - 88.6
		Scorpaena bergii Evermann & Marsh, 1900	11	●	LC	6.56 ± 0.72	7.5 - 5	5.445 ± 1.72	8.2 - 2
	Triglidae	*Prionotus punctatus (Bloch, 1793)*	9	●	LC	16.2 ± 4.65	23.7 - 8	63.24 ± 48.9	163.8 - 4.29
Moroniformes	Ephippidae	*Chaetodipterus faber (Broussonet, 1782)*	9	●	LC	14.0 ± 6.54	23 - 8.1	129.5 ± 143.	352.3 - 6.3
Acanthuriformes	Sciaenidae	*Odontoscion dentex (Cuvier, 1830)*	5	●	NE	16.3 ± 1.32	18.5 - 15	54.72 ± 11.6	74.3 - 46.1
		Pareques acuminatus (Bloch & Schneider, 1801)	9	●	LC	12.0 ± 1.41	15.1 - 10.5	25.81 ± 11.5	52.7 - 16.3
	Acanthuridae	*Acanthurus bahianus (Castelnau, 1855)*	46	●●	LC	17.9 ± 5.55	23.5 - 4.8	113.1 ± 54.1	185.4 - 1.8
		Acanthurus chirurgus (Bloch, 1787)	90	●●●●	LC	20.9 ± 8.77	27.6 - 3.4	271.4 ± 177.	518.1 - 0.68
		Acanthurus coeruleus Bloch & Schneider, 1801	18	●	LC	26.3 ± 1.93	29.3 - 24.3	367.6 ± 61.7	438.8 - 294.2

Order	Family	Species	N	IR	IUCN	Total Length (cm)		Total Weight (g)	
						Mean ± DP	Max-Min	Mean ± DP	Max-Min
Spariformes	Sparidae	*Calamus calamus (Valenciennes, 1830)*	14	●	DD	22.5 ± 4.86	26.1 - 6.5	188.9 ± 88.3	321.4 - 5.3
		Calamus pennatula Guichenot, 1868	23	●	LC	19.0 ± 6.04	27.7 - 11	146.7 ± 120.	342.5 - 19.3
Lophiiformes	Antennariidae	*Antennarius multiocellatus (Valenciennes, 1837)*	1	●	DD	5,6	-	7	-
	Ogcocephalidae	*Ogcocephalus vespertilio (Linnaeus, 1758)*	3	●	LC	17.7 ± 10.2	25 - 10.5	444.5 ± 601.	870 - 19
Tetraodontiformes	Ostraciidae	*Acanthostracion polygonius Poey, 1876*	204	●●●●	LC	15.5 ± 3.21	25 - 4.8	100.3 ± 52.1	293.1 - 5.9
		Acanthostracion quadricornis (Linnaeus, 1758)	81	●●●●	LC	21.2 ± 3.80	30 - 10.2	168.4 ± 80.7	449.5 - 23.3
		Lactophrys trigonus (Linnaeus, 1758)	49	●●	LC	21.3 ± 8.30	35.2 - 12.8	609.3 ± 195.	1093.6 - 264.7
	Balistidae	*Balistes vetula Linnaeus, 1758*	3	●	NT	48	-	1221	-
		Balistes capriscus Gmelin, 1789	2	●	NT	-	-	500	-
		Xanthichthys ringens (Linnaeus, 1758)	1	●	LC	18	-	167	-
	Monacanthidae	*Aluterus heudelotii Hollard, 1855*	3	●	LC	24.4 ± 0.56	24.8 - 24	114.8 ± 8.27	120.7 - 109
		Aluterus monoceros (Linnaeus, 1758)	4	●	NT	-	-	567	-
		Aluterus scriptus (Osbeck, 1765)	3	●	LC	-	-	439	-
		Cantherhines macrocerus (Hollard, 1853)	13	●●	LC	20.4 ± 8.48	29.2 - 6	242.9 ± 191.	579.1 - 2.7
		Cantherhines pullus (Ranzani, 1842)	3	●	LC	14.7 ± 1.47	16.4 - 13.7	66.06 ± 22.5	92 - 51
		Monacanthus ciliatus (Mitchill, 1818)	66	●	LC	9.15 ± 0.81	11.6 - 7.6	13.19 ± 4.58	31.3 - 6.6
		Stephanolepis hispidus (Linnaeus, 1766)	59	●●	LC	11.3 ± 5.83	36.9 - 7.1	36.46 ± 60.9	364.2 - 5.6
	Tetraodontidae	*Canthigaster figueiredoi Moura & Castro, 2002*	2	●	DD	7.65 ± 0.49	8 - 7.3	10.3 ± 3.25	12.6 - 8
		Sphoeroides spengleri (Bloch, 1785)	141	●●●●	LC	9.91 ± 1.32	14.1 - 5.6	19.09 ± 8.64	53.2 - 3
		Sphoeroides testudineus (Linnaeus, 1758)	1	●	DD	9,5	-	18,1	-
	Diodontidae	*Chilomycterus spinosus spinosus (Linnaeus, 1758)*	5	●	LC	15.8 ± 1.85	17.6 - 13.9	229.6 ± 62.4	283 - 161
		Diodon holocanthus Linnaeus, 1758	349	●●●●	LC	14.7 ± 3.67	21.6 - 7.6	213.3 ± 115.	562.7 - 33.2

The ANOSIM analyses showed a significant difference in the species composition among habitats (R= 0.31, P = 0.019), while the Simper analysis revealed the most important species contributing to the similarity and dissimilarity among habitat types (Table 2 and 3). The results showed a low within-habitat similarity, ranging in all assemblages between 35.6 and 37.4%. In the habitat SWCR, the species *P. maculatus*, *D. holocanthus*, *L. synagris* and *H. marianae* contributed to the highest percentage (35%) of typifying species (those cumulatively contributing with 70 % to the similarity), whilst other eight species cumulatively contributed to another 35%. The Sand habitat had the lowest number of consolidating species (6) and *H. marianae*, *D. formosum* and *H. steindachneri* contributed mostly (45%). In relation to the habitat Algae, there were eight consolidating species, *L. trigonus, A. polygonius* and *Eucinostomus sp* which showed the highest contribution (58%).

Unlike within-group similarity, the dissimilarity levels between the three types of habitat were high, ranging from 67 to 71%, with discriminating species (those cumulatively contributing >70 % of the dissimilarity) between habitats being more numerous than the consolidating species within assemblages, ranging from 21 to 31. Discrimination between the habitats Algae and SWCR was primarily a result of species that were absent in the algae habitat (e.g. *H. adscensionis, H. aurolineatum* and *H. plumierii*) and species that had high differences in the mean abundances (*P. maculatus* and *L. synagris* were more abundant in SWCR habitat). Differences among the habitats SWCR-Sand and Sand-Algae were achieved mainly through differences in the mean abundances. For example, *H. plumierii* and *D. holocanthus* were more abundant in SWCR habitat when compared to Sand Habitat, while *L. trigonus* and *D. holocanthus* were more abundant in algae habitat than sand habitat (Table 3).

Table 2 - SIMPER results of demersal fish species contributing > 70 % of similarity for each habitat type.

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Habitat SWCR: Average similarity = 37.4					
Pseudupeneus maculatus	6,89	4,11	**1,77**	10,99	10,99
Diodon holocanthus	6,18	3,46	**1,54**	9,25	20,23
Lutjanus synagris	5,51	3,05	**1,23**	8,16	28,40
Hypanus marianae	4,55	2,60	**1,24**	6,95	35,35
Acanthostracion polygonius	4,89	2,31	0,94	6,17	41,52
Holocentrus adscensionis	4,89	2,22	0,91	5,94	47,47
Haemulon plumierii	4,76	2,01	0,81	5,37	52,83
Acanthostracion quadricornis	3,97	1,88	0,82	5,03	57,86
Haemulon aurolineatum	5,10	1,67	0,62	4,47	62,33
Fistularia tabacaria	3,95	1,49	0,70	3,98	66,30
Chaetodon ocellatus	3,15	0,98	0,54	2,61	68,91
Bothus ocellatus	3,16	0,95	0,55	2,54	71,46
Habitat Sand: Average similarity = 35.6					
Hypanus marianae	6,22	7,72	**3,58**	21,67	21,67
Diplectrum formosum	4,38	4,29	**0,89**	12,05	33,72
Haemulon steindachneri	5,42	4,04	**0,89**	11,33	45,05
Acanthostracion quadricornis	4,26	3,92	0,86	11,01	56,06
Pseudupeneus maculatus	5,59	3,77	0,91	10,59	66,65
Acanthostracion polygonius	4,48	2,96	0,91	8,32	74,97
Habitat Algae: Average similarity = 36.9					
Lactophrys trigonus	6,30	9,74	4,42	26,40	26,40
Acanthostracion polygonius	6,06	8,60	6,97	23,31	49,70
Eucinostomus sp	4,29	2,89	0,58	7,84	57,54
Acanthostracion quadricornis	4,20	2,89	0,58	7,83	65,37
Dactylopterus volitans	3,31	2,84	0,58	7,69	73,06
Fistularia tabacaria	3,77	2,84	0,58	7,69	80,75
Diodon holocanthus	5,03	2,76	0,58	7,47	88,21
Hypanus marianae	3,88	2,22	0,58	6,03	94,24

Table 3 - SIMPER results of demersal fish species contributing > 70 % of dissimilarity between the main habitat types in the northeast Brazilian continental shelf (5°- 9°S) identified using cluster analysis.

Species	Av.Abund (Habitat SWCR)	Av.Abund (Habitat: Sand)	Av.Diss	Diss/SD	Contrib%	Cum%
Haemulon plumierii	5,10	4,77	2,48	1,09	3,69	3,69
Diodon holocanthus	6,18	1,73	2,47	1,50	3,67	7,36
Haemulon steindachneri	2,07	5,42	2,19	1,34	3,26	10,62
Diplectrum formosum	0,76	4,38	2,08	1,43	3,09	13,71
Lutjanus synagris	5,51	3,90	2,03	1,11	3,02	16,73
Haemulon plumierii	4,76	3,73	2,01	1,11	2,98	19,71
Eucinostomus sp	0,62	4,52	1,95	1,02	2,90	22,62
Holocentrus adscensionis	4,89	2,95	1,94	1,14	2,88	25,49
Pseudupeneus maculatus	6,89	5,59	1,71	0,95	2,54	28,03
Fistularia tabacaria	3,95	2,48	1,68	1,29	2,50	30,54
Eucinostomus argenteus	2,71	1,93	1,66	0,89	2,46	33,00
Acanthostracion polygonius	4,89	4,48	1,61	1,06	2,39	35,39
Syacium micrurum	3,17	3,12	1,57	1,08	2,34	37,72
Chloroscombrus chrysurus	1,55	2,06	1,55	0,73	2,30	40,02
Chaetodon ocellatus	3,15	0,00	1,51	0,91	2,24	42,27
Bothus ocellatus	3,16	0,00	1,47	0,94	2,18	44,45
Trachinocephalus myops	1,69	2,65	1,38	1,05	2,05	46,50
Acanthostracion quadricornis	3,97	4,26	1,35	1,07	2,01	48,51
Haemulon squamipinna	3,09	0,00	1,33	0,71	1,98	50,49
Average dissimilarity = 67						

Species	Av.Abund (Habitat SWCR)	Av.Abund (Habitat: Algae)	Av.Diss	Diss/SD	Contrib%	Cum%
Pseudupeneus maculatus	6,89	2,45	2,83	1,44	3,96	3,96
Holocentrus adscensionis	4,89	0,00	2,53	1,38	3,53	7,49
Haemulon aurolineatum	5,10	0,00	2,52	1,01	3,52	11,01
Haemulon plumierii	4,76	0,00	2,42	1,27	3,38	14,39
Lutjanus synagris	5,51	1,75	2,40	1,36	3,35	17,74
Eucinostomus sp	0,62	4,29	2,14	1,22	2,99	20,74
Lactophrys trigonus	2,29	6,30	2,11	1,40	2,95	23,68
Diodon holocanthus	6,18	5,03	2,04	1,13	2,85	26,54
Haemulon squamipinna	3,09	2,38	1,83	0,93	2,56	29,09
Fistularia tabacaria	3,95	3,77	1,83	1,24	2,55	31,64
Chaetodon ocellatus	3,15	1,89	1,67	1,00	2,33	33,97
Dactylopterus volitans	2,28	3,31	1,64	1,18	2,30	36,27
Acanthostracion quadricornis	3,97	4,20	1,62	1,02	2,26	38,53
Bothus ocellatus	3,16	1,53	1,60	1,06	2,23	40,76
Dasyatis marianae	4,55	3,88	1,59	1,15	2,22	42,98
Chilomycterus spinosus spinosus	0,79	2,98	1,49	1,27	2,08	45,06
Syacium micrurum	3,17	0,00	1,47	0,97	2,05	47,12
Eucinostomus argenteus	2,71	0,00	1,46	0,76	2,03	49,15
Stephanolepis hispidus	2,69	1,46	1,43	1,09	1,99	51,15
Average dissimilarity = 71						

Species	Av.Abund (Habitat Sand)	Av.Abund (Habitat: Algae)	Av.Diss	Diss/SD	Contrib%	Cum%
Lactophrys trigonus	1,26	6,30	3,65	1,83	5,32	5,32
Diodon holocanthus	1,73	5,03	3,39	1,07	4,94	10,27
Haemulon steindachneri	5,42	1,75	3,34	1,28	4,87	15,14
Eucinostomus sp	4,52	4,29	3,27	1,25	4,77	19,90
Pseudupeneus maculatus	5,59	2,45	3,18	1,21	4,64	24,54
Diplectrum formosum	4,38	1,53	2,91	1,23	4,24	28,78
Haemulon aurolineatum	4,77	0,00	2,81	0,95	4,10	32,88
Dactylopterus volitans	1,73	3,31	2,63	1,27	3,83	36,71
Lutjanus synagris	3,90	1,75	2,48	1,11	3,62	40,33
Haemulon plumierii	3,73	0,00	2,19	0,95	3,20	43,53
Fistularia tabacaria	2,48	3,77	2,19	1,32	3,19	46,72
Dasyatis marianae	6,22	3,88	2,18	1,05	3,17	49,89
Chilomycterus spinosus spinosus	0,00	2,98	2,13	1,24	3,11	53,00
Average dissimilarity = 68						

A Distance based Linear Model (DistLM) identified that depth explained the largest proportion of the variation in the fish assemblage (8%), followed by temperature (7%) and latitude (5%). Considering all significant variables, 20% of the total variation was explained by the model, (Table 4). The graphical response of DISTLM provided by dbRDA, which pointed the direction and magnitude of the relationship between tested variables and fish assemblage, indicated a relationship between Depth and SWCR habitat, and temperature with sand and Algae habitat (Figure 6).

Table 4 - Result of the DISTLM analysis with p-value of the permutation and the percentage of explanation of variables for the selected model. In bold the selected variables.

Variable	P(perm)	Proportion
Depth	**0.001**	**8%**
Temperature	**0.004**	**7%**
Latitude	**0.043**	**5%**
O2(mg/l)	0.256	4%
Salinity	0.871	2%

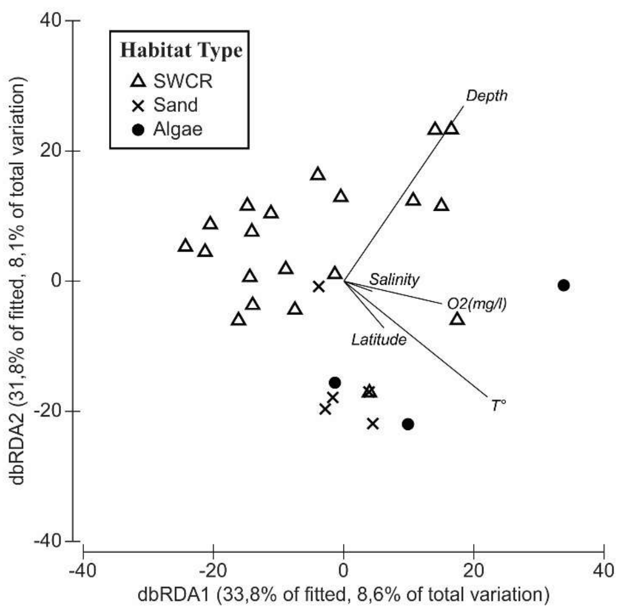

Figure 6 - Result of the redundancy analysis based on the linear model (dbRDA) with predictor variables showing the greatest importance for the linear model.

Margalef richness index ranged from 1.80 to 5.93, presenting pick of values in Pernambuco (PE) (6°S - 9°S). Lower number of species were observed in the North of Rio Grande do Norte (RN) (5°S) and Alagoas (AL) (9°S) (Figure 7)). The N1 diversity index varied between 1.785 and 15.070 effective species, while the N2 index oscillated between 1.268 and 11.711 effective species. Considering the indexes N1 and N2, the highest values of diversity were found in the South of PE, in the state of PB, with other isolated points of comparatively high and of moderate diversity in RN. As observed for the richness index, the lowest values of diversity were reported in the north of RN (5°S) and Alagoas (9°S). Species evenness observed values ranged from 0.226 to 0.911, indicating a higher equability of species distribution all over the coast of RN and PB (enclosed area between 5°S - 8°S), decreasing to relatively moderate values in PE. Though, lowest values were also found in isolated points distributed in RN and PE (Figure 8).

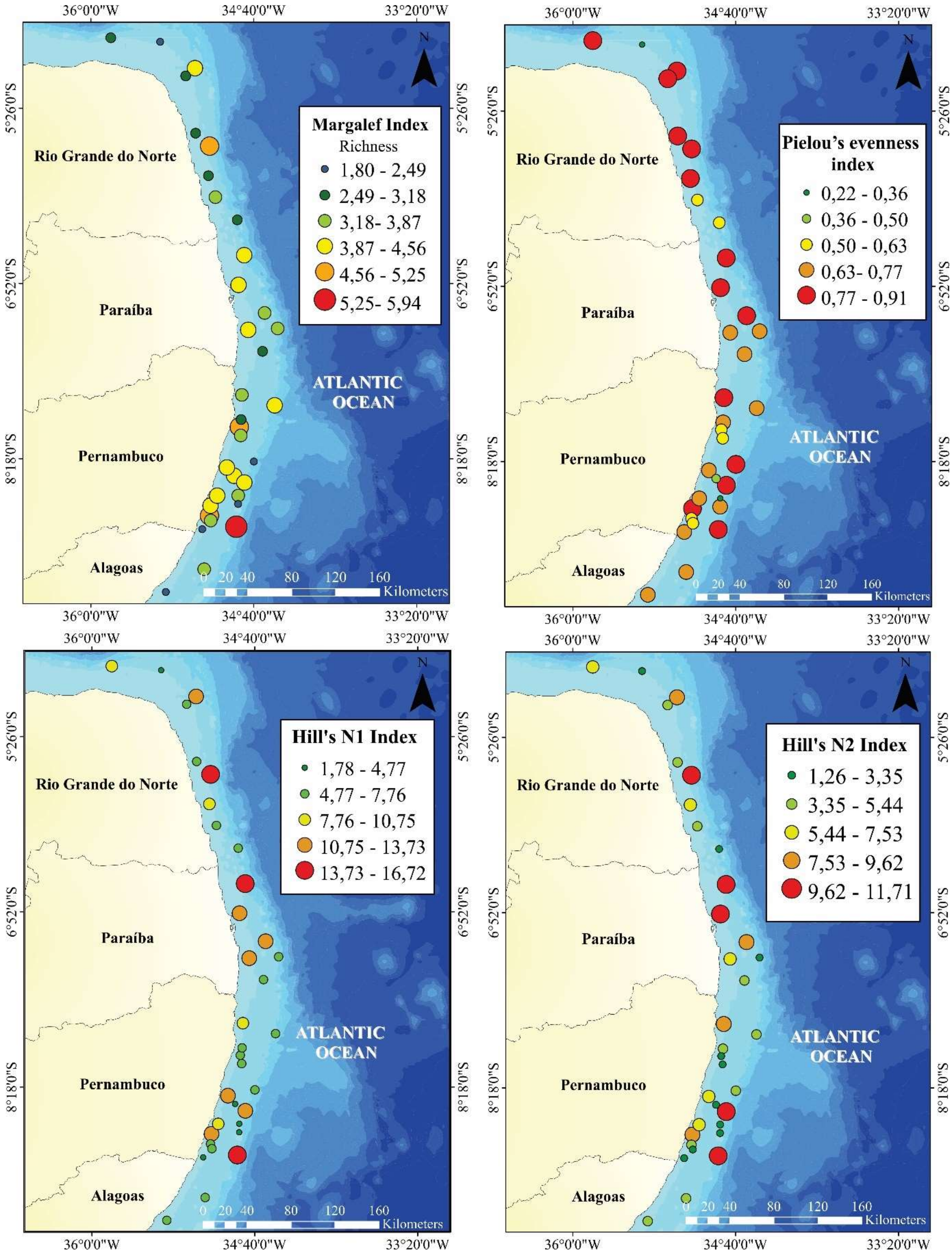

Figure 7 - Spatial representation of estimations of Margalef index, Pielou's evenness, Hill's Shannon index (N1) and Hill's Simpson's index (N2) of demersal fishes caught along the northeast Brazilian continental shelf (5°- 9°S).

For a better visualization of biodiversity indexes variation, box-plots were calculated considering habitat type (Figure 8). The habitat SWCR presented higher values of richness (P <0.05) and diversity, followed, in a decreasing order, by algae and sand. However, diversity indexes (N1 and N2 indexes) did not show statistical differences among habitats. In relation to evenness, higher values were found for sand, followed, in a decreasing order, by algae and SWCR (p <0.05).

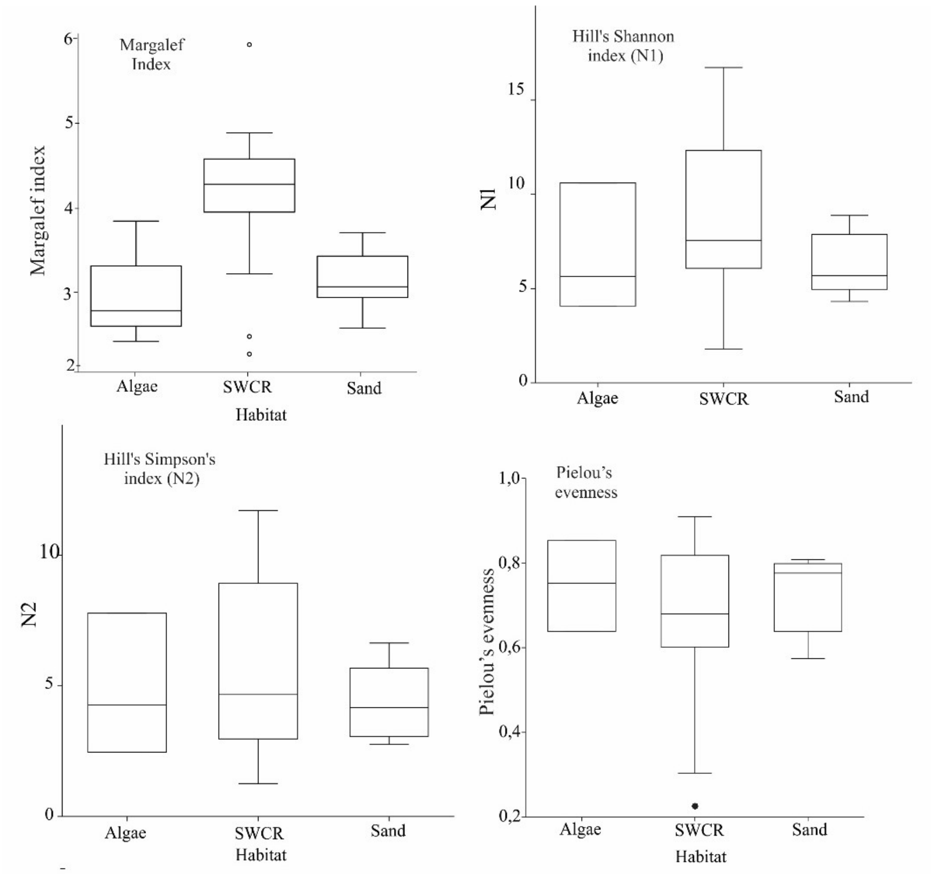

Figure 8 – Box plot of Margalef richness index, Pielou's evenness, Shannon diversity, Hill's Shannon index (N1) and Hill's Simpson's index per habitat type (SWCR – Sand with coral and rock.

DISCUSSION

In comparison with others regions in Brazil and around the world, the Brazilian northeast continental shelf, with 120 demersal fish species of 49 families, can be described as an area of high fish diversity (CAUSSE et al., 2011; DEMESTRE; SANCHEZ; ABELLO, 2000; FARIÑA; FREIRE; GONZÁLEZ-GURRIARÁN, 1997; JAUREGUIZAR et al., 2006; JOHANNESEN et al., 2012; MILOSLAVICH et al., 2011; NÓBREGA; LESSA; SANTANA, 2009; PRISTA et al., 2003; SOUSA; AZEVEDO; GOMES, 2005). Many important processes are related with the patterns of high diversity of species, as environmental heterogeneity, competition, predation, recruitment and abiotic characteristics, which, in some combination, vary according to latitude strata and interact in producing the observed structure of a local assemblage (MITTELBACH et al., 2007; MORA, 2015a). The importance of the northeast coast of Brazil is acknowledged internationally. This area is classified as an Ecologically or Biologically Significant Marine Area (EBSA), regarded as "a special area in the ocean that serve important purposes, in one way or another, to support the healthy functioning of oceans and the many services that it provide''(CBD, 2014). Northeast Brazil contains unique and rare species, and a relatively high proportion of sensitive and endangered reef fishes, with slow recovery and highly susceptible to habitat degradation and depletion by human activity, as the species *Sparissoma axillare, Sparissoma Frondosum* and *Mycteroperca bonaci,* reported in this study (BENSON et al., 2005; FERREIRA et al., 2012; FLOETER et al., 2016).

Many authors consider dominant species those which together contribute > 90% of the total number of individuals, while others also consider frequency of occurrence and abundance to be important indicators (DAHLBERG; ODUM, 1970; GARCIA et al., 2004; MAHON; BALON, 1977; YANEZ-ARANCIBIA, 1986). According to Yanéz-Arancini (1986), in tropical regions, the definition of a species as dominant must consider at least three ecological factors: abundance, biomass and occurrence. Therefore, considering these factors, the demersal assemblage of the Brazilian northeast continental shelf (5°-9°S) is dominated by the families Haemulidae, Mullidae, Holocentridae, Diodontidae, Dasyatidae, Ostraciidae and Lutjanidae. Such patterns are probably related to habitat type, once most of these families are classified as distinctive reef-associated, and swimming capacity, as species less able to produce fast burst-type swimming to evade capture are more likely to end up in trawlers' nets (e.g. Diodontidae, Ostraciidae) (KILLEN; NATI; SUSKI, 2015; RANGEL; CHAVES; MONTEIRO-NETO, 2007). The dominance of the demersal assemblage by few families (7 of the total of 52) has also been registered in other studies in Brazil (AZEVEDO et al., 2007; MUTO; SOARES; ROSSI-WONGTSCHOWSKI, 2000; ROCHA; ROSSI-WONGTSCHOWSKI, 1998) and around the world (JAUREGUIZAR et al., 2006; JOHANNESEN et al., 2012; PRISTA et al., 2003), seeming to be an ecological pattern of demersal assemblages or an effect of the selectivity of the fishing gear.

Higher values of biomass (given as CPUE) were found in Pernambuco (PE) and part of Rio Grande do Norte (RN), however, in relation to abundance (N° of individuals), PE tended to present a higher number of specimens than any other sampled place, given mainly by the presence of Haemulidae schools in PE. Nevertheless, despite differences among areas, the north of RN and south of PE presented points of high values of CPUE, which is probably related to the great extension of coral reefs found in these regions (COSTA; OLAVO; MARTINS, 2007; LEÃO et al., 2016). Moreover, a Marine Protected Area (named Costa do Corais), located in the south of Pernambuco, play a fundamental role in the conservation of the ecosystem and maintenance of a high level of species richness and abundance (FLOETER; FERREIRA; GASPARINI, 2007; STEINER et al., 2015). According to FLOETER (2007), the protection of this area has increased the abundance and size of target species of fisheries, including top predators and large herbivores belonging to important functional groups. Many studies have shown that fishing activity impacts marine ecosystems by depleting fish population, altering community structure, modifying ecosystem functions and, thus, affecting the abundance of individuals (CARDINALE et al., 2012; HALPERN et al., 2015a; VITOUSEK et al., 1997). Hence, a protected area may improve the conservation of biodiversity and ecosystems, and possibly reverse the global and local decline in fish populations by protecting critical breeding, nursery and feeding habits (CHUENPAGDEE; FRAGA; EUAN, 2000).

In regard to richness (expressed through Margalef index), higher values were found in Paraiba (PB) and again, in south of Pernambuco (PE). A wide range of variables determine species richness of a location (e.g. human activity, physical factors, prey availability), but, in our study area, we believe that same factors that driven the “hotspot” of CPUE (presence, complexity and conservation of coral reefs) are responsible for the highest values of richness. As this measurement directly express biodiversity, areas that support high species richness should be priority in management strategies of ecosystem conservation (PITTMAN et al., 2007).

Besides richness, which is the number of species, additional information of dominance, the extent to which one or a few species dominate the community, may also be helpful to define and discriminate ecological communities (MAGURRAN, 2004). In this study, through diversity indexes, we described how evenly the individuals in the community are distributed over the different species. High values of diversity were found along the entire study area, which the state of Paraiba and south of Pernambuco presenting a widely range of high values. Thus, we may assume that these areas have one of the most favorable environment for the fish community in our study area. As fishes are mobile organisms that actively select the optimum between a pool of habitats, it could be expected, therefore, that the abundance of each species should be larger near its optimum suite of environmental conditions (ROSSO; QUIRÓS, 2010). These results also reflect particular characteristics of each location, as fishery pressure, pollution, oceanographic conditions, food availability, river inflow and evolutionary process. In relation to differences among habitats types, higher values were found for SWCR (Sand with coral and Rocks), reflecting the greater environmental benefits (food availability, shelter , nursery) provided by this habitat (MORA, 2015a).

Knowledge of the distribution areas of species has fundamental implications for the understanding of biodiversity and improvement of conservation policies (MOTA-VARGAS; ROJAS-SOTO, 2012). In this study, most part of the abundant fish families (those who accounted for 80% of sampled specimens) were found along the entire latitudinal range of the study area, showing that, besides the environmental heterogeneity and latitude variation among sampled sites, there is no physical barriers that prevent fish distribution occupation along the study area. Most part of abundant families in this study are known as reef-associated (living and feeding on or near coral reefs) and were found in higher values in the south of Pernambuco (e.g. Acanthuridae, Mullidae, Diodontidae), as already attested before. In addition, the fish distribution pattern found in this study also reinforce the hypotheses of a faunal corridor for reef fish species associated with deep outer-shelf reefs formations (30-70m) along the shelf-edge zone in the South American continental margin, connecting the south-western Atlantic and the Caribbean (FEITOZA; ROSA; ROCHA, 2005).

The importance of habitat types for the structure of demersal fish community is widely recognized (KRAISER et al., 2002; NOAA, 2012; ROSS; RHODE; QUATTRINI, 2015). As pointed by DEMESTRE (2000), the different types of bottom habitats are an important delimiting factor for the association of fish species in different communities. As an example, the distribution, abundance and diversity of fishes in coastal ecosystems are modified by variations in habitat (e.g. type, quality, area), seascape composition (e.g. habitat context, diversity, connectivity) and the level of physical exposure to both natural and anthropogenic disturbances (BORLAND et al., 2017; MORA, 2015b; NAGELKERKEN et al., 2015). Thus, the conservation of habitats is intimately linked with the preservation of demersal fish communities and maintenance of health ecosystems. To implement a sustainable management, the creation of a Marine Spatial Planning (MSP) "a practical way to create and establish a more rational organization of the use of marine space and the interactions between its uses, to balance demands for development with the need to protect marine ecosystems, and to achieve social and economic objectives in an open and planned way" Has been highly recommended (DAHL; EHLER; DOUVERE, 2009). The idea, besides stimulating interest in the development of Marine Protected Areas, is also related to the management of the multiple uses of the spaces (FOLEY et al., 2010), aiming to obtain the best benefit of the oceans. Oceans managed in a sustainable way may stimulate economic and employment growth and allow the international community to reach its global targets, by recognizing that small-scale fisheries are making a significant contribution to poverty alleviation and food security.

The similarity percentage procedure (SIMPER), which was applied to identify those species that contribute most to the observed differences among habitat types, showed that differences are primarily due to abundance of species, followed, as secondary factor, by the specie composition. It means that usually species are present in more than one habitat type, however, some habitats are more favorable for specific assemblages. As example, we found that the species *H. marianae* were present in all habitat types, however, were more abundant in the sand habitats. Moreover, this analyze pointed out the main species of each habitat type, being this information, therefore, an important subsidy for development of management plans (COCHRANE; GARCIA, 2009). This analyze reinforce the hypothesis that coral reefs in the northeast of Brazil may be a last refuge for some rare or endemic reef fishes distributed across the continental margin, including threatened (IUCN) commercial species currently depleted within the Brazilian EEZ (e.g. *Sparissoma axillare, Sparissoma Frondosum* and *Mycteroperca* *bonaci*) (FEITOZA; ROSA; ROCHA, 2005; FERREIRA et al., 2012; MMA; BIOL, 2000). Finally, the consistency of the main species of each habitat found in this study with available information on species habitat preference (FROESE; PAULY, 2017), confirms that the employed methodology on habitat identification was adequate.

In this study, it was observed that 20% of the variance in species abundance was explained by environmental variables, using the method DistLM. Depth was the primary variable associated with species abundance, followed by variation in temperature and latitude. Depth is an important structurer environmental factor on demersal fish communities as already reported (JOHANNESEN et al., 2012; MASSUTÍ et al., 2004; PAJUELO et al., 2016). Differential mortality or growth with depth, migration to deeper water with increasing size and ecological differences among shallow and deep waters, may be the main factor responsible for those patterns (FRÉDOU; FERREIRA, 2005; ROBERTS, 1996). In addition, as depth tended to increase with the distance from the shore, which is directly related to anthropic impacts, samples sites near to the coast, consequently in shallower waters and more impacted, might be different from sites far from the coast (CARDINALE et al., 2012; CLARK et al., 2010; VITOUSEK et al., 1997)

Latitude was also a significant factor affecting fish abundance, reflecting differences among long-term process associated with particular characteristics of each location , as costal shelf width, river inflow, anthropic impacts and generation of ocean currents and thermal gradients (WILLIG; KAUFMAN; STEVENS, 2003). In addition, these results were consistent with the descriptive analysis of species CPUE distribution, which presented different values of abundance and biomass among latitudes, although the main species were distributed throughout the area. Finally, the temperature was other significant factor on the redundancy analyses. Although we did not find a significant correlation of temperature with depth and latitude, we recognize that these variables might have some sort of relation, thus, conclusion in regard to temperature should be taken with caution. Many studies have shown temperature as an important abiotic factor, controlling key physiological, biochemical and life-history processes of the demersal fishes (SELLESLAGH; AMARA, 2008). Moreover, all fish species have a thermal preference that optimizes physiological process, being expected variation of fish species followed by temperature changes (BEITINGER; FITZPATRICK, 1979).

Over the years, the vast extent of the coastline and the variety of coastal marine ecosystems in Brazil caused a wrong impression of inexhaustible sea resources. This perception, added to population growth, led to policies that encouraged unsustainable use of resources (MILOSLAVICH et al., 2011). As a result, many regions in the northeast of Brazil are facing adverse impacts on the structure and function of marine ecosystems, as severe mangrove loss, coastal erosion, pollution and high fishing exploitation levels (CARDINALE et al., 2012; COSTA; OLAVO; MARTINS, 2007; ELFES et al., 2014). In addition, even though Brazil has implemented conservation practices in coastal and maritime zones (Marine Protected Areas, Marine Reserves, and Marine National Parks), these efforts represent less than 0.4% of the total area within the territorial sea and economic exclusive zone (MILOSLAVICH et al., 2011). As consequence, only a small portion of the enormous Brazilian coastline is under some form of ecosystem based management, while there are large areas under anthropogenic pressure. Considering the social, economic, and biological importance of Brazilian marine organisms, and the likelihood that the growing population will exert even higher anthropogenic pressures such as fishing, large-scale conservation and management plans are urgently needed.

To mitigate these impacts and implement a most widely accepted ecosystem based management, such as marine protected areas, an initial step is the determination of seascapes and biological communities that are “representative” or “distinctive” (e.g., biodiversity anomalies) or function as “surrogates” for biodiversity (MORA, 2015b). In this study, which is focused on part of the northeast Brazilian cost (5°-9°S), we describe the biodiversity, ecology, distribution and abundance of demersal fishes along the continental shelf, characterizing its relationship with habitat types. Therefore, taken into account these information, we consider the south of Pernambuco (8°30’S - 9°S), north of Rio Grande do North (5°S - 5°30’S) and the state of Paraiba (6°30’S - 8°S) as significant areas for the development of management plans and conservation of marine ecosystems. Yet, we are aware that this study may be limited due to gear selectivity and spatial extent covered by this survey. Consequently, whilst this study represents the most extensive fisheries-independent sampling of the demersal fish assemblage in the study area, it does not provide a complete inventory of all demersal fish species of the Brazilian northeast continental shelf.

It is now widely recognized that anthropogenic pressures and climatic changes has dramatic effects on biodiversity, threating the inherent right of the species to exist and a wide range of ecosystems services crucial for human survival. Consequently, increasing our knowledge about biodiversity is essential to minimize these impacts. The knowledge of biodiversity generates in this study, added with other works around the world, is a step forward towards the conservation and sustainable use of the oceans, seas and marine resources.

CONSIDERAÇÕES FINAIS

Atualmente é amplamente reconhecido que pressões antropogênicas e mudanças climáticas têm efeitos dramáticos sobre a biodiversidade, ameaçando o direito inerente de sobrevivência das espécies e uma ampla gama de ecossistemas essenciais para sobrevivência humana. Dessa forma, aumentar o conhecimento sobre a biodiversidade e ecossistemas marinhos é imprescindível para urgente mitigação de impactos ambientais. Este trabalho, foi o primeiro estudo, com dados não provenientes da pesca, que caracterizou a ictiofauna demersal da região costeira do Nordeste do Brasil (5°-9°S) e sua relação com fatores ambientais, gerando subsídios para conservação da biodiversidade, habitats críticos e manejo ecossistêmico da pesca. Levando em consideração as informações geradas neste estudo, pudemos evidenciar áreas com elevados valores de biodiversidade e, por consequência, prioritárias para conservação e manejo. Além disso, os resultados demostram forte associação de espécies ameaçadas e de importância comercial com ambientes de recifes de corais, evidenciando a importância da manutenção destes ecossistemas. Apesar dos resultados gerados neste trabalho, estudos complementares, sobretudo aqueles que consideram os múltiplos usos dos oceanos, ainda são necessários, afim de equilibrar as demandas do desenvolvimento com a necessidade de proteger os ecossistemas marinhos, alcançando objetivos sociais, econômicos e ambientais.

REFERENCES

ALLSOPP, M. et al. Oceans in Peril: Protecting marine biodiversity. **Worldwatch Paper**, n. 174, p. 1–56, 2007.

ALONGI, D. M. **Coastal ecosystem processes**. 1. ed. New Jersey: CRC Press, 1998.

ANDERSON, M. J.; GORLEY, R. N.; CLARKE, K. R. **PERMANOVA+ for PRIMER: Guide to Software and Statistical Methods**. Plymouth: PRIMER-E, 2008.

AZEVEDO, M. C. C. D et al. Demersal fishes in a tropical bay in southeastern Brazil: Partitioning the spatial, temporal and environmental components of ecological variation. **Estuarine, Coastal and Shelf Science**, v. 75, n. 4, p. 468–480, 2007.

BEITINGER, T. L.; FITZPATRICK, L. C. Physiological and ecological correlates of preferred temperature in fish. **Integrative and Comparative Biology**, v. 19, n. 1, p. 319–329, 1979.

BENSON, L. et al. New data for Late Pleistocene Pinedale alpine glaciation from southwestern Colorado. **Quaternary Science Reviews**, v. 24, n. 1–2, p. 49–65, 2005.

BERNARDES, R. A. et al. **Prospecção pesqueira de recursos demersais com armadilhas e pargueiras na Zona Econômica Exclusiva da Região Sudeste-Sul do Brasil**. São Paulo: Serie Documentos REVIZEE/Score-Sul, 2005.

BORCARD, D.; GILLET, F.; LEGENDRE, P. **Numerical Ecology with R**. 1. ed. Québec: Springer New York Dordrecht London Heidelberg, 2011.

BORLAND, H. P. et al. Habitat type and beach exposure shape fish assemblages in the surf zones of ocean beaches. **Marine Ecology Progress Series**, v. 570, p. 203–211, 2017.

CARDINALE, B. J. et al. Biodiversity loss and its impact on humanity. **Nature**, v. 489, n. 7415, p. 326–326, 2012.

CAUSSE, R. et al. Demersal ichthyofaunal shelf communities from the Dumont d'Urville Sea (East Antarctica). **Polar Science**, v. 5, n. 2, p. 272–285, 2011.

CBD. **Ecologically or Biologically Significant Marine Areas (EBSAs). Special places in the world's oceans.** 2. ed. Recife: Secretariat of the Convention on Biological Diversity, 2014.

CHUENPAGDEE, R.; FRAGA, J.; EUAN, J. **Importance of Marine Protected Areas and Their Benefits: The Local Community's Perspectives**. [s.l: s.n.]. v. 9(8)

CLARK, M. R. et al. The ecology of seamounts: Structure, function, and human impacts. **Annual Review of Marine Science**, v. 2, n. 1, p. 253–278, 2010.

CLARKE, K.; SOMERFIELD, P. J.; WARWICK, R. **Change in marine communities: an approach to statistical analysis and interpretation**. 1. ed. Plymouth: PRIMER-E Ltd, 1994.

COCHRANE, K. L.; GARCIA, S. **A Fishery manager's Guidebook**. 2. ed. [s.l.] Food and Agriculture Organization of the United Nations and Blackwell Publishing, 2009.

COLONESE, A. C. et al. Bridging ancient and modern artisanal fisheries in Latin America : assessing the role of cultural heritage in poverty alleviation in coastal Brazil. n. 45, p. 1–4, 2010.

COSTA, P. A. .; OLAVO, G.; MARTINS, A. S. **Biodiversidade na costa central brasileira**. Rio de Janeiro: Museu Nacional, 2007.

COSTA, T. L. A.; PENNINO, M. G.; MENDES, L. F. Identifying ecological barriers in marine environment: The case study of Dasyatis marianae. **Marine Environmental Research**, v. 125, p. 1–9, 2017.

D. LAFFOLEY; BAXTER, J. M. **Explaining Ocean Warming: Causes, scale, effects and consequences**. Gland, Switzerland: IUCN, 2016.

DAHLBERG, M. D.; ODUM, E. P. Annual Cycles of Species Occurrence, Abundance, and Diversity in Georgia Estuarine Fish Populations. **American Midland Naturalist**, 1970.

DE JESUS MENDES, P. A. et al. Transport of persistent organic pollutants by organo-mineral aggregates (OMAs) in the Lisboa-Setúbal Canyon system. **Deep-Sea Research Part II: Topical Studies in Oceanography**, v. 58, n. 23–24, p. 2345–2353, 2011.

DEMESTRE, M.; SANCHEZ, P.; ABELLO, P. Demersal fish assemblages and habitat characteristics on the continental shelf and upper slope of the north-western Mediterranean. **Journal of the Marine Biological Association of the UK**, v. 80, n. 6, p. 981–988, 2000.

EKAU, W.; KNOPPERS, B. An introduction to the pelagic system of the north-east and east Brazilian shelf. **Archive of Fishery and Marine Research**, v. 47, n. 2/3, p. 113–132, 1999.

ELFES, C. T. et al. A regional-scale ocean health index for Brazil. **PLoS ONE**, v. 9, n. 4, 2014.

EMMETT DUFFY, J. Why biodiversity is important to the functioning of real-world ecosystems. **Frontiers in Ecology and the Environment**, v. 7, n. 8, p. 437–444, 2009.

FAO, F. D. **Fisheries management 2. The ecosystem approach to fisheries**. Rome: FAO Technical Guidelines for Responsible Fisheries, 2003.

FARIÑA, A C.; FREIRE, J.; GONZÁLEZ-GURRIARÁN, E. Demersal Fish Assemblages in the Galician Continental Shelf and Upper Slope (NW Spain): Spatial Structure and Long-term Changes. **Estuarine, Coastal and Shelf Science**, v. 44, p. 435–454, 1997.

FEITOZA, B. M.; ROSA, R. S.; ROCHA, L. A. Ecology and Zoogeography of Deep- Reef Fishes in Northeastern Brazil. **Bulletin of Marine Science**, v. 76, n. 3, p. 725–742, 2005.

FERREIRA, B. et al. Reef fish spawning aggregations on the Northeastern Brazilian coast: status of knowlege and management. **12th International Coral Reef Symposium**, n. July, p. 1–570, 2012.

FIGUEIREDO, J. .; MENEZES, N. A. **Manual de peixes marinhos do sudeste do Brasil.II. Teleostei (1)**. São Paulo: Museu de Zoologia da Universidade de São Paulo, 1978.

FIGUEIREDO, J. L. **Peixes da zona econômica exclusiva da região sudeste-sul do Brasil : levantamento com rede de meia água**. São Paulo: Editora da Universidade de São Paulo, 2002.

FIGUEIREDO, J. L.; MENEZES, N. A. **Manual de peixes marinhos do sudeste do Brasil. III. Teleostei (2)**. São Paulo: Museu de Zoologia da Universidade de São Paulo, 1980.

FIGUEIREDO, J. L.; MENEZES, N. A. **Manual de peixes marinhos do sudeste do Brasil. VI. Teleostei (5)**. São Paulo: Museu de Zoologia da Universidade de São Paulo, 2000.

FLOETER, S.; FERREIRA, C.; GASPARINI, J. **Os efeitos da pesca e da proteção através de UC's marinhas: três estudos de caso e implicações para os grupos funcionais de peixes recifais no Brasil**. Brasília: Ministério do Meio Ambiente, 2007. v. 4

FLOETER, S. R. et al. Geographic Variation in Reef-Fish Assemblages along the Brazilian Coast. **Global Ecology and Biogeography**, v. 10, n. 4, p. 423–431, 2016.

FOCK, H. et al. Biodiversity and species-environment relationships of the demersal fish assemblage at the Great Meteor Seamount (subtropical NE Atlantic), sampled by different trawls. **Marine Biology**, v. 141, n. 1, p. 185–199, 2002.

FRÉDOU, T.; FERREIRA, B. P. Bathymetric trends of northeastern Brazilian snappers (pisces, lutjanidae): Implications for the reef fishery dynamic. **Brazilian Archives of Biology and Technology**, v. 48, n. 5, p. 787–800, 2005.

FROESE, R.; PAULY, D. **Fishbase**.

GARCIA, A. M. et al. Comparison of 1982-1983 and 1997 . 1998 E Nino Effects on the. **Estuaries**, v. 27, n. 6, p. 0–6, 2004.

GARCIA, A. M. et al. Checklist comparison and dominance patterns of the fish fauna at Taim Wetland, South Brazil. **Neotrop. Ichthyol**, v. 4, n. 2, p. 261–268, 2006.

GARCIA JÚNIOR, J.; M. **Biodiversidade marinha da Bacia Potiguar : ictiofauna**. Rio de Janeiro: Museu Nacional, 2010.

GROSS, T.; JOHNSTON, S.; BARBER, C. V. A Convenção sobre Diversidade Biológica : Entendendo e Influenciando o Processo Um Guia para Entender e Participar Efetivamente da. **Instituto de Estudos Avançados da Universidade das Nações Unidas**, p. 72, 2005.

HALPERN, B. S. et al. Spatial and temporal changes in cumulative human impacts on the world's ocean. **Nature Communications**, v. 6, n. May, p. 7615, 2015a.

HALPERN, B. S. et al. Spatial and temporal changes in cumulative human impacts on the world's ocean. **Nature Communications**, v. 6, p. 7615, 14 jul. 2015b.

HANCHET, S. M. et al. Diversity, relative abundance, new locality records, and updated fish fauna of the Ross Sea region. **Antarctic Science**, v. 25, n. 5, p. 619–636, 2013.

HAZIN, F. **Metereologia e Sensoriamento Remoto, Oceanogra Física, Oceanografia Química e Oceanografia Geologica**. Fortaleza: Martins & Cordeiro, 2009.

HIDDINK, J. G. et al. Importance of fish biodiversity for the management of fisheries and. **MarBef Marine Biodiversity and Ecosystem Functioning - EU Network of Excellence**, p. 1–3, 2006.

IBAMA. **GEO BRASIL 2002: Perspectivas do Meio Ambiente no Brasil**. Edições IB ed. Brasília: IBAMA, 2002.

ICMBIO. **Executive Summary Brazil Red Book of Threatened Species of Fauna sumario**. Brasília, DF: Instituto Chico Mendes de Conservaçã o da Biodiversidade, Ministério de Meio Ambiente, 2016.

IUCN. **IUCN Red List Categories and Criteria**. [s.l: s.n.].

IUCN. **Guidelines for Application of IUCN Red List Criteria at Regional and National Levels: Version 4.0**. [s.l: s.n.].

JAUREGUIZAR, A. J. et al. Fish assemblages of the northern Argentine coastal system: Spatial patterns and their temporal variations. **Fisheries Oceanography**, v. 15, n. 4, p. 326–344, 2006.

JOHANNESEN, E. et al. Demersal fish assemblages and spatial diversity patterns in the arctic-atlantic transition zone in the barents sea. **PLoS ONE**, v. 7, n. 4, 2012.

JOHNSON, A. F. et al. Linking temperate demersal fish species to habitat: Scales, patterns and future directions. **Fish and Fisheries**, v. 14, n. 3, p. 256–280, 2013.

JOLY, C. A; VERDADE, M.; BERLINCK, R. G. S. Diagnóstico da pesquisa em biodiversidade no Brasil. **Revista Usp**, v. 89, p. 114–133, 2011.

KILLEN, S. S.; NATI, J. J. H.; SUSKI, C. D. Vulnerability of individual fish to capture by trawling is influenced by capacity for anaerobic metabolism. **Proceedings Royal Society Biological**, v. 282, n. 1813, p. 20150603, 2015.

KRAISER, M. J. et al. Modification of marine habitats by trawling activities:\rprognosis and solutions. **Fish and Fisheries**, v. 3, p. 114–136, 2002.

LEÃO, Z. M. A. N. et al. Brazilian coral reefs in a period of global change: A synthesis. **Brazilian Journal of Oceanography**, v. 64, n. Special Issue 2, p. 97–116, 2016.

LEITE, A. P. P.; LIMA, L. H. DE. Biodiversidade Costeira e Marinha. **Macrodiagnostico da ZC**, 2008.

LESSA, R.; BEZERRA, J. L.; NÓBREGA, M. F. DE. **Dinamica de Populacoes e Avaliacao dos Estoques dos Recursos Pesqueirosda regiao Nordeste.** Fortaleza: Editora Martins & Cordeiro, 2009.

MAGURRAN, A. E. **Measuring biological diversity**. Malden: Blackwell Pub, 2004.

MAHON, R.; BALON, E. K. Ecological fish production in Long Pond, a lakeshore lagoon on Long Point, Lake Erie. **Environmental Biology of Fishes**, v. 2, n. 3, p. 261–284, 1977.

MANUEL HAIMOVICIL, S.; KLIPPEL, S. **Diagnóstico da Biodiversidade dos Peixes Teleósteos Demersais Marinhos e Estuarinos do Brasil**. Rio Grande: [s.n.].

MARIO TISCHER. Aspectos socioeconômicos do aproveitamento da ictiofauna acompanhante das pescarias de camaroes peneídeos, em Sirinhaém, Pernambuco- Brasil. **Boletim Técnico do CEPENE**, v. 11, n. 1, p. 271–276, 2003.

MASSUTÍ, E. et al. Mediterranean and Atlantic deep-sea fish assemblages: differences in biomass composition and size-related structure. **Scientia Marina**, v. 68, n. S3, p. 101–115, 30 dez. 2004.

MCCAULEY, D. J. et al. Marine defaunation: Animal loss in the global ocean. **Science**, v. 347, n. 6219, p. 247–254, 2015.

MCLEAN, D. L. et al. Distribution, abundance, diversity and habitat associations of fishes across a bioregion experiencing rapid coastal development. **Estuarine, Coastal and Shelf Science**, v. 178, p. 36–47, 2016.

MILOSLAVICH, P. et al. **Marine biodiversity in the Atlantic and Pacific coasts of South America: Knowledge and gapsPLoS ONE**, 2011.

MITTELBACH, G. G. et al. Evolution and the latitudinal diversity gradient: Speciation, extinction and biogeography. **Ecology Letters**, v. 10, n. 4, p. 315–331, 2007.

MMA. **Panorama da Conservação dos Ecossistemas Costeiros e Marinhos no Brasil**. Brasília: MMA/SBF/GBA, 2010.

MMA; BIOL, D. Convenção da Diversidade Biológica. **Serie Biodiversidade**, p. 30, 2000.

MODELS, A. D. ArcGIS Marine Data Model. **ArcGIS Marine Data Model Reference**, n. June, p. 35, 2003.

MORA, C. **Ecology of Fishes on Coral Reefs**. Cambridge: Cambridge University Press, 2015a.

MORA, C. **Ecology of Fishes on Reefs**. Ontario: Academic Press, 2015b.

MPA. **BOLETIM ESTATÍSTICO DA PESCA E AQUICULTURA 2011**. Brasília: Ministério da Pesca e Aquicultura, 2012.

MUTO, E. Y.; SOARES, L. S. H.; ROSSI-WONGTSCHOWSKI, C. L. D. B. Demersal fish assemblages off São Sebastião, southeatern Brazil: structure and environmental conditioning factors (summer 1994). **Revista Brasileira de Oceanografia**, v. 48, n. 1, p. 9–27, 2000.

NAGELKERKEN, I. et al. The seascape nursery: A novel spatial approach to identify and manage nurseries for coastal marine fauna. **Fish and Fisheries**, v. 16, n. 2, p. 362–371, 2015.

NOAA, N. C. FOR C. O. S. **Monaco, M.E S.M. Anderson T.A. Battista M.S. Kendall S.O. Rohmann L.M. Wedding A.M. Clarke**. Silver Spring: NOAA Technical Memorandum NOS NCCOS 122, 2012.

NÓBREGA, M. F. DE; LESSA, R.; SANTANA, F. M. **Peixes Marinhos da regiao Nordeste do Brasil.** Fortaleza: Martins & Cordeiro, 2009.

PAJUELO, J. G. et al. Assemblages of deep-sea fishes on the middle slope off Northwest Africa (26°–33° N, eastern Atlantic). **Deep Sea Research Part I: Oceanographic Research Papers**, v. 118, n. September, p. 66–83, 2016.

PIELOU, E. C. Ecological diversity. **Limnology and Oceanography**, v. 22, n. 1, p. 174–174, jan. 1977.

PIKITCH, E. K. et al. Ecosystem-Based Fishery Management. **Science**, v. 300, n. February, p. 2003–2003, 2004.

PITTMAN, S. J. et al. Predictive mapping of fish species richness across shallow-water seascapes in the Caribbean. **Ecological Modelling**, v. 204, n. 1–2, p. 9–21, 2007.

PRISTA, N. et al. The demersal fish assemblage of the coastal area adjacent to the Tagus estuary (Portugal): Relationships with environmental conditions. **Oceanologica Acta**, v. 26, n. 5–6, p. 525–536, 2003.

R CORE TEAM. **R: A language and environment for statistical computing**Vienna, AustriaR Foundation for Statistical Computing, , 2016. Disponível em: <https://www.r-

project.org>

RANGEL, C. A.; CHAVES, L. C. T.; MONTEIRO-NETO, C. Baseline Assessment of the Reef Fish Assemblage From Cagarras Archipelago, Rio De Janeiro, Southeastern Brazil. **Brazilian Journal of Oceanography**, v. 55, n. 1, p. 7–17, 2007.

ROBERTS, C. Settlement and beyond: population regulation and community structure of reef fishes. In: **Reef Fisheries**. Dordrecht: Springer Netherlands, 1996. v. 20p. 85–112.

ROCHA, G.; ROSSI-WONGTSCHOWSKI, C. Demersal fish community on the inner shelf of Ubatuba, southeastern Brazil. **Rev. bras. oceanogr**, v. 46, n. 2, p. 93–109, 1998.

ROCHA, L. O. .; COSTA, P. A. . **Manual de Identificação de Peixes Marinhos para a Costa Central**. 2. ed. Rio de Janeiro: Programa REVIZEE / SCORE-Central, 1999.

ROSS, S. W.; RHODE, M.; QUATTRINI, A. M. Demersal fish distribution and habitat use within and near Baltimore and Norfolk Canyons, U.S. middle Atlantic slope. **Deep-Sea Research Part I: Oceanographic Research Papers**, v. 103, n. August, p. 137–154, 2015.

ROSSI-WONGSTCHOWSKI, C.; ALMEIDA, E.; ÁVILA-BERNARDES, R. **Prospecção pesqueira de espécies pelágicas de pequeno porte com rede de meia-água na Zona Econômica Exclusiva da Região Sudeste-Sul do Brasil**. 1. ed. 2: Serie Documentos REVIZEE/Score-Sul, 2007.

ROSSO, J. J.; QUIRÓS, R. Patterns in fish species composition and assemblage structure in the upper Salado river lakes, Pampa Plain, Argentina. **Neotropical Ichthyology**, v. 8, n. 1, p. 135–144, 2010.

SEELIGER, E.; ODEBRECHT, C.; CASTELLO, J. **Os ecossistemas costeiro e Marinho do extremo sul do Brasil**. Rio Grande: Ecoscientia Rio Grande, 1998.

SELLESLAGH, J.; AMARA, R. Environmental factors structuring fish composition and assemblages in a small macrotidal estuary (eastern English Channel). **Estuarine, Coastal and Shelf Science**, v. 79, n. 3, p. 507–517, 2008.

SERAFINI, T. Z.; FRANÇA, G. B. DE; ANDRIGUETTO-FILHO, J. M. Ilhas oceânicas brasileiras: biodiversidade conhecida e sua relação com o histórico de uso e ocupação humana. **Revista da Gestão Costeira Integrada**, v. 10, n. 3, p. 281–301, 2010.

SHINOZAKI-MENDES, R. et al. Reproductive biology of Haemulon plumieri (Teleostei: Haemulidae) in Ceará state, Northeastern Brazil. **Brazilian Journal of Biology**, v. 73, n. 2, p. 391–396, maio 2013.

SILVA JÚNIOR, C. A. B. DA et al. Aspects of the reproductive biology and characterization of Sciaenidae captured as bycatch in the prawn trawling in the northeastern Brazil. **Acta Scientiarum. Biological Sciences**, v. 37, n. 1, p. 1, 10 mar. 2015.

SOUSA, P.; AZEVEDO, M.; GOMES, M. C. Demersal assemblages off Portugal: Mapping, seasonal, and temporal patterns. **Fisheries Research**, v. 75, n. 1–3, p. 120–137, 2005.

ST. JOHN, M. A. et al. A Dark Hole in Our Understanding of Marine Ecosystems and Their Services: Perspectives from the Mesopelagic Community. **Frontiers in Marine Science**, v. 3, n. March, p. 1–6, 2016.

STEINER, A. Q. et al. Zonação de recifes emersos da Área de Proteção Ambiental Costa dos

Corais, Nordeste do Brasil. **Iheringia. Série Zoologia**, v. 105, n. 2, p. 184–192, 2015.

VITAL, H. et al. Characterization of the Brazilian continental shelf adjacent to Rio Grande do Norte State, Ne Brazil. **Brazilian Journal of Oceanography**, v. 58, n. SPEC. ISSUE 1, p. 43–54, 2010.

VITOUSEK, P. M. et al. Human Domination of Earth' s Ecosystems. **Science**, v. 277, n. 5325, p. 494–499, 1997.

VOOREN, C. . Elasmobrânquios demersais. In: **Os ecossistemas costeiro e marinho do extremo sul do Brasil.** Rio Grande: Ecoscientia Rio Grande, 1998.

WILLIG, M.; KAUFMAN, D.; STEVENS, R. Latitudinal gradients of biodiversity: pattern, process, scale, and synthesis. **Annual Review of Ecology, Evolution, and Systematics**, v. 34, p. 273–309, 2003.

WORM, B. et al. Impacts of Biodiversity Loss on Ocean Ecosystem Services. **Science**, v. 314, n. 5800, p. 787–790, 2006.

YANEZ-ARANCIBIA, A. **Ecologia de la zona costera: analisis de siete topicos**. [s.l.] A.G.T. Editor, 1986.

ZINTZEN, V. et al. Diversity and Composition of Demersal Fishes along a Depth Gradient Assessed by Baited Remote Underwater Stereo-Video. **PLoS ONE**, v. 7, n. 10, 2012.