UNIVERSIDADE FEDERAL DE PERNAMBUCO

CENTRO DE TECNOLOGIA E GEOCIÊNCIAS

DEPARTAMENTO DE OCEANOGRAFIA

PROGRAMA DE PÓS-GRADUAÇÃO EM OCEANOGRAFIA

MARIA JACQUELINE GOMES DE BARROS

ANÁLISES DA ICTIOFAUNA MARINHA E HABITATS ASSOCIADOS ATRAVÉS DE VÍDEOS SUBAQUÁTICOS

Recife

2020

MARIA JACQUELINE GOMES DE BARROS

ANÁLISES DA ICTIOFAUNA MARINHA E HABITATS ASSOCIADOS ATRAVÉS DE VÍDEOS SUBAQUÁTICOS

Dissertação apresentada ao Programa de Pós-Graduação em Oceanografia da Universidade Federal de Pernambuco (PPGO-UFPE), como parte dos requisitos para a obtenção de título de Mestre em Oceanografia.

Área de Concentração: Oceanografia Biológica

Orientadora: Prof. Dra. Beatrice Padovani Ferreira
Coorientadora: Prof. Dra. Mirella Borba Santos Ferreira Costa

Recife
2020

Catalogação na fonte
Bibliotecário Gabriel Luz, CRB-4 / 2222

B277a Barros, Maria Jacqueline Gomes de.

Análises da ictiofauna marinha e habitats associados através de vídeos subaquáticos / Maria Jacqueline Gomes de Barros– Recife, 2020.

76 f.: il.

Orientadora: Profª. Drª. Beatrice Padovani Ferreira.

Coorientadora: Profª. Drª. Mirella Borba Santos Ferreira Costa.

Dissertação (Mestrado) – Universidade Federal de Pernambuco. CTG. Programa de Pós-Graduação em Oceanografia, 2020.

Inclui referências.

1. Oceanografia. 2. Distribuição de peixes. 3. Arrasto de fundo. 4. Capturabilidade. 5. Zonas mesofóticas. I. Ferreira, Beatrice Padovani (Orientadora). II. Costa, Mirella Borba Santos Ferreira (Coorientadora). III. Título.

UFPE

551.46 CDD (22. ed.) BCTG / 2020-148

MARIA JACQUELINE GOMES DE BARROS

ANÁLISES DA ICTIOFAUNA MARINHA E HABITATS ASSOCIADOS ATRAVÉS DE VÍDEOS SUBAQUÁTICOS

Dissertação apresentada ao Programa de Pós-Graduação em Oceanografia da Universidade Federal de Pernambuco (PPGO-UFPE), como parte dos requisitos para a obtenção de título de Mestre em Oceanografia.

Aprovada em: 02 / 03 / 2020

BANCA EXAMINADORA

Profª. Dra. Beatrice Padovani Ferreira (Orientadora)
Departamento De Oceanografia – UFPE

Profª. Dra. Tereza Cristina Medeiros de Araújo (Examinadora Interna)
Departamento De Oceanografia – UFPE

Profª. Dra. Caroline Vieira Feitosa (Examinadora Externa)
Instituto de Ciências do Mar (Labomar) – UFC

Prof. Dr. Marcelo Francisco de Nóbrega (Examinador Externo)
Departamento De Oceanografia – UFPE

A minha mãe Eva (*in memoriam*) e ao meu pai Valdeci

AGRADECIMENTOS

Em primeiro lugar agradeço a Deus, por me permitir chegar até aqui e estar sempre comigo, me guiando e me ajudando a superar as dificuldades da vida. Agradeço ao meu pai Valdeci e a minha mãe Eva, pela educação e por todo amor que me deram. Devo tudo aos meus pais. Além disso, agradeço ao meu pai a sua paciência, compreensão e por todo apoio incondicional. Agradeço ao meu marido Rick por sua parceria, companheirismo, por tentar sempre levantar meu astral nos dias difíceis, por ter bastante paciência e compreensão comigo, por me apoiar em tudo, por todo amor e cuidado que me dá todos os dias. Sou eternamente grata por compartilhar a vida com meu pai e meu marido.

Agradeço a minha professora e orientadora Beatrice, pela oportunidade e confiança de fazer parte do seu time de trabalho. Agradeço por todos os ensinamentos, por me ajudar na identificação de peixes, por me orientar e por me inspirar tanto. Agradeço a minha coorientadora Mirella também pela oportunidade e confiança do trabalho, por sua ajuda e contribuição no campo, no mapa e nas análises de tipo de fundo. Agradeço ao professor Mauro Maida pelas câmeras e apoio nas coletas de dados. Agradeço aos professores Arnaud, Flávia e Thierry pela parceria e oportunidade de fazer parte do projeto Abraços. Agradeço ao Leandro Nolé e aos demais integrantes do Bioimpact/UFRPE todo o apoio e parceria em relação ao trabalho do Abraços. Agradeço ao Daniel Lippi por me ajudar sempre que possível na identificação dos peixes e em várias outras etapas do meu mestrado. Agradeço também a Ana Lídia, Rodrigo, Cabelo e Zé que lá no início tentaram me ajudar tirando dúvidas minhas na identificação de peixes. Agradeço a Camila que tentou me ajudar nos mapas e ao Jonas que também tentou me ajudar nas análises estatísticas. Agradeço a Carol e Deborah por serem tão parceiras comigo durante essa caminhada do mestrado. Agradeço a todos os integrantes do LECOR e do IMAT, pelo companheirismo e apoio ao longo desses últimos anos.

Agradeço aos meus professores do PPGO pelos ensinamentos preciosos, agradeço a todos os meus colegas do DOCEAN pela troca de conhecimento, pela companhia e amizade. Agradeço a chefia do DOCEAN e a coordenação do PPGO pelo seu apoio. Agradeço a CAPES pela bolsa de estudo, agradeço ao projeto ABRAÇOS, ao LMI Tapioca, ao Grupo Fundação o Boticário, ao CNPQ, ao CEPENE e ao PELD-TAMS pela parceria e por todo apoio.

Agradeço a toda a minha família e amigos, em especial a minha Sogra Ana, meu Sogro Marcos, meus cunhados Vitória, Victor e Caco por sua compreensão quando precisei me ausentar, por acreditarem em mim e me apoiarem a ir sempre atrás dos meus sonhos. Agradeço a todo o pessoal do Jiu Jitsu UFPE e da Shokan Jiu Jitsu, em especial ao meu sensei Eloy Bione e a Nathy. Todos vocês foram muito especiais durante essa minha caminhada no mestrado, pois transformaram minha vida através do Jiu Jitsu. Agradeço aos meus dois filhos de 4 patas, Pretinho e Clarinha, por me fazerem companhia e tornarem meus dias mais leves e alegres.

RESUMO

Vídeos vêm sendo utilizados em estudos marinhos por aproximadamente 70 anos e têm sido aplicados como uma alternativa ou complemento a outras técnicas de estudo do ambiente marinho. A aplicação desta tecnologia é prática e produz um registro permanente de dados que podem ser analisados diversas vezes. Neste trabalho foram utilizadas técnicas de vídeos em duas situações: 1) para avaliar a capturabilidade de peixes pela pesca de arrasto de fundo e seu impacto na plataforma continental do Nordeste do Brasil (5ºS - 9ºS) e 2) para estudar a distribuição da ictiofauna ao longo da plataforma insular de Fernando de Noronha, Brasil. No primeiro estudo foram comparadas as assembleias de peixes capturadas em arrastos de fundo científicos, com as que foram amostradas a partir de vídeos (oriundos de uma câmera acoplada a rede) realizados simultaneamente. Não houve diferença significativa entre a estrutura das assembleias de peixes dos arrastos e dos vídeos. Porém, foram observadas tendências de capturabilidade relacionadas ao comportamento, morfologia e capacidade natatória dos peixes. Também foram quantificadas por meio dos vídeos 168 esponjas, as quais majoritariamente eram arrancadas ao entrar em contato com a rede de arrasto. Os vídeos demonstraram ser uma alternativa científica eficiente para o levantamento da abundância e distribuição dos peixes marinhos. Além disso, confirmaram o impacto negativo da pesca de arrasto nos fundos carbonáticos, tornando este tipo de pesca nessas zonas um risco ambiental. No segundo estudo foi utilizado o método “tow video” para avaliar a distribuição por habitat e por profundidade da ictiofauna. Foram registradas longas extensões de rodolitos, agregações de peixes na quebra da plataforma e um novo registro de espécie em Fernando de Noronha: *Prognathodes guyanensis*. Além disso, vimos que a estrutura das assembleias de peixes é diferente entre o Mar de Dentro e Mar de Fora, bem como entre as categorias de profundidade: Rasa (0 – 30 m) e Mesofóticas (abaixo de 30 m); e entre as zonas Mesofótica Superior (30 – 60 m) e Mesofótica Média (60 – 90 m). A técnica utilizada de “tow video” demonstrou ser uma metodologia eficaz e promissora para a observação e monitoramento de assembleias de peixes em ecossistemas de alta diversidade.

Palavras-Chave: Distribuição de peixes. Arrasto de fundo. Capturabilidade. Zonas mesofóticas.

ABSTRACT

Videos have been used in marine studies for approximately 70 years and have been applied as an alternative or complement to other techniques for studying the marine environment. The application of this technology is practical and produces a permanent record of data that can be analyzed several times. In this study, video techniques were used in two situations: 1) to evaluate fish catchability by bottom trawling and its impact on the continental shelf of Northeast Brazil (5ºS - 9ºS) and 2) to study the distribution of ichthyofauna along the insular shelf of Fernando de Noronha, Brazil. In the first study, fish assemblages caught in scientific bottom trawls were compared with those sampled from videos (from a net-mounted camera) performed simultaneously. There was no significant difference between the structure of the fish assemblages from the trawls and from the videos. However, trends of catchability were observed related to the behavior, morphology and swimming capacity of fish. Also, 168 sponges were quantified through the videos and most of them were pulled out when in contact with the trawl net. Videos proved to be an efficient scientific alternative to study the abundance and distribution of marine fish. In addition, they confirmed the negative impact of trawling on the carbonate bottom, presenting this type of fishing in these areas as an environmental risk. In the second study, the "tow video" method was used to evaluate the ichthyofauna distribution by habitat and by depth. Long segments of rhodoliths, fish aggregations at the shelf break and a new record of species in Fernando de Noronha: *Prognathodes guyanensis* were recorded. In addition, we found the structure of fish assemblages is different between the Leeward Side and the Windward Side, as well as between the depth categories: Shallow (0 - 30 m) and Mesophotic (below 30 m); and between the Upper Mesophotic (30 - 60 m) and Middle Mesophotic (60 - 90 m) zones. The "tow video" technique used has proven to be an effective and promising methodology for the observation and monitoring of fish assemblages in high diversity ecosystems.

Keywords: Fish distribution. Bottom trawl. Catchability. Mesophotic zones.

SUMÁRIO

1 INTRODUÇÃO GERAL

Ecossistemas marinhos tropicais são dinâmicos e possuem alta heterogeneidade espacial, apresentando diferentes habitats, como recifes, mangues e áreas de fundo arenoso, os quais estão conectados por diversos processos físicos, químicos, biológicos e geológicos (GROBER-DUNSMORE et al., 2009). A conectividade entre estes diferentes habitats, o tamanho e complexidade destas áreas influenciam na distribuição e composição das assembleias de peixes (JONES; ANDREW 1992; BERKSTRÖM et al., 2013).

Em pesquisas sobre a ecologia da comunidade íctia, uma técnica muito comum é o censo visual subaquático, primeiramente descrito por Brock (1954), sendo considerada a ferramenta mais utilizada nos estudos de ambiente recifal em águas rasas. Porém, tem sido reconhecido que em áreas de maior profundidade, inacessíveis a mergulhadores, também é necessária a pesquisa e conservação ambiental (CAPPO et al., 2003). Nos estudos sobre peixes em áreas mais profundas, os métodos de pesquisa mais utilizados são baseados em técnicas de pesca extrativista, como redes de arrasto, armadilhas e linhas, dependendo da topografia do fundo marinho (CAPPO et al., 2003).

Uma alternativa e complemento a esses métodos é o uso de vídeos (WATSON et al., 2005). O primeiro trabalho científico publicado utilizando técnicas de vídeo foi em 1952, onde uma televisão subaquática foi construída para estudar a biologia de organismos marinhos (BARNES, 1952). Desde então, técnicas de vídeo têm sido implementadas a diversos campos de pesquisa relacionados a peixes marinhos, tais como ecologia de peixes e recifes mesofóticos (BLYTH-SKYRME et al., 2013; ANDRADI-BROWN et al, 2016), estrutura de comunidade de peixes demersais (FITZPATRICK et al., 2012), distribuição espacial (PELLETIER et al., 2012), comportamento alimentar (CUMMINGS et al., 1966; VÉRGES et al., 2012), natação dos peixes (KROHN e BOISCLAIR, 1994) e avaliação da funcionalidade e impactos de apetrechos de pesca, como redes de arrasto (SMITH et al., 2000; HUMBORSTAD et al., 2004).

Atualmente, com os avanços tecnológicos, existem inúmeras metodologias de vídeo (MALLET e PELLETIER, 2014), como o vídeo subaquático remoto com isca - BRUV (ELLIS e DeMARTINI, 1995), vídeo operado por mergulhadores - DOV (ALEVIZON e BROOKS, 1975), vídeo operado remotamente - ROV (ADAMS et al, 1995), veículo submarino autônomo - AUV (CLARKE et al., 2010; SINGH et al., 2013), vídeo rebocado – TOW Video (MACHAN e FEDRA, 1975) e submersíveis (LEMBKE et al., 2017). As principais vantagens destas técnicas são a produção de um registro permanente de dados de campo, permitindo várias análises do material e consequentemente identificações mais consistentes dos organismos (CRUZ et al., 2008; PELLETIER et al., 2011). Além disso, os vídeos apresentam um satisfatório custo-benefício e não são destrutivos para o ambiente (SPENCER et al., 2005, MALLET e PELLETIER, 2014).

No Brasil, as técnicas de vídeos foram introduzidas pelo Grupo de Pesquisas em Recifes de Corais e Mudanças Globais (RECOR), da Universidade Federal da Bahia (UFBA), em 2003 (CRUZ et al., 2008). Eles utilizaram o método de vídeo transecto, adaptado de Aronson e Swanson (1997) e Page et al. (2001), para estudar os recifes de corais da Baía de Todos os Santos, Bahia, Brasil (DUTRA et al., 2006). Posteriormente, o método de vídeo transecto foi melhor descrito e testado no trabalho de Cruz et al. (2008), onde foi encontrado que o número de seis vídeos transectos, com 20 m de comprimento, como o menor esforço amostral para avaliar a comunidade de coral dos recifes de Itacolomis, Bahia, Brasil. O número de pesquisas no Brasil utilizando vídeos como principal método de estudo da vida marinha, como organismos bentônicos e mamíferos marinhos (SPIER et al., 2012; ROLIM et al., 2019), tem crescido, porém ainda é pequeno em comparação a outros países (MALLET e PELLETIER, 2014).

No presente trabalho foram utilizadas técnicas de vídeos em duas situações: 1) para avaliação da capturabilidade de peixes pela pesca de arrasto de fundo e seu impacto na plataforma continental do Nordeste do Brasil (5ºS - 9ºS), usando como modelo arrastos científicos e 2) para estudar a distribuição da ictiofauna ao longo da plataforma insular de Fernando de Noronha, utilizando o método TOW Video, com um sistema de câmeras original desenvolvido pelo Prof. Dr. Mauro Maida do Departamento de Oceanografia, UFPE.

Diante disso, este trabalho foi dividido em dois capítulos para melhor apresentação das informações e resultados obtidos. O capítulo um é o primeiro estudo em que são analisadas e comparadas as assembleias de peixes capturadas por redes de arrasto e amostradas a partir de vídeos realizados simultaneamente. O capitulo dois além de analisar a distribuição por profundidade e por habitat de peixes, fornece dados inéditos, uma nova ocorrência de espécie (*Prognathodes guyanensis*) no

Arquipélago de Fernando de Noronha, Brasil. Ambos estudos contribuem para a compreensão das variações espaciais da biodiversidade íctia, permitindo a identificação de áreas prioritárias para conservação, utilizando um método não-letal e não-destrutivo ao ecossistema marinho. Desta forma, podem auxiliar na criação de estratégias de manejo e conservação necessárias para a manutenção da biodiversidade marinha e seu uso sustentável.

2 OBJETIVOS

Este trabalho foi desenvolvido com os seguintes objetivos:

2.1 OBJETIVO GERAL

Apresentar resultados sobre a ecologia da ictiofauna marinha utilizando técnicas de vídeos subaquáticos, como forma de complementar ou substituir metodologias destrutivas e letais aos organismos marinhos.

2.2 OBJETIVOS ESPECÍFICOS

Foram estabelecidos como objetivos específicos:

a) avaliar a capturabilidade das espécies de peixes demersais ao arrasto de fundo, relacionando com seu hábito e comportamento;
b) avaliar o impacto da pesca de arrasto de fundo sobre as espécies de peixes e habitats associados;
c) avaliar a distribuição por profundidade e por habitat da ictiofauna do Arquipélago de Fernando de Noronha;
d) realizar um levantamento das espécies de peixes encontradas em Fernando de Noronha.

3 MANUSCRITO I: Bottom trawling on a carbonate shelf: Can you get what you see?

Manuscrito submetido a revista Continental Shelf Research.

Bottom trawling on a carbonate shelf: Can you get what you see?

ABSTRACT

Bottom trawling is a common fisheries method and also a widespread scientific sampling method for benthic and demersal species. Selectivity and catchability estimates are usually made using different meshes and studies with alternative methods are rare. In this study, to improve the estimation of trawl selectivity, we compare the catches obtained with bottom trawl and the records made by a camera fitted on the top of the net. Scientific trawling was conducted along the Northeast Brazilian Shelf, a typical carbonate shelf with presence of sponges, coralline bottoms and a high water visibility. In total, 23 taxa (19 species and four genera) were identified at the videos and 30 taxa (25 species and five genera) at the trawls. Overall, no significant differences were observed in the assemblage structure identified by trawling and underwater footages. However, divergences were observed in fish catchability between trawls and videos. Net sampling was more selective for fish with low swimming capacity, while species small sized and/or with shelter and fast swimming capacity seemed to be underestimated. Furthermore, underwater footages allowed for an assessment of the trawling impacts on bottom habitats, where the damage on large free-standing sponges could be better observed. Our results confirm negative impact of trawling on carbonate beds due to potential damage to the fragile and slow recovering benthic cover, making this type of fisheries in those areas an environmental hazard. In addition, we demonstrate that videos may act as efficient alternatives to scientific trawling for surveying the abundance and distribution of marine fish.

Keywords: Fish; Underwater footage; Fisheries; Catchability; Fishing gear; Bottom trawl impact.

1. Introduction

Bottom trawl is a fishing method based on pulling a net along the seafloor in order to collect benthic and demersal organisms (Martín et al., 2014). The usage of towed bottom-fishing gears is widespread throughout the world to extract marine resources (Kaiser et al., 2006). Nearly one-quarter of wild marine landings has been swept by trawl nets, which annually captures 19 million tonnes of fish and invertebrates (Amoroso et al., 2018). Previous estimates indicated that the area trawled every year corresponds to almost 50% of the world's continental shelf (Watling and Norse, 1998, Amoroso et al., 2018). However, this fishing technique presents a high destructive power as it deforms the bottom habitat, damaging the benthic ecosystem, and is a non-selective gear destroying a large variety of organisms that it gets in touch. (FAO, 1996; Kumar and Deepthi, 2006; Thomas et al., 2006; Amoroso et al., 2018).

In the last decades, studies have demonstrated that trawling threaten the marine environment. As an example, the doors, wires and sweeps apparels disturb the sediment surface (O'Neill and Summerbell, 2011; Bradshaw et al., 2012; Martín et al., 2014) and lead to an overall decline on benthic production and species richness (Jennings and Kaiser, 1998; Hiddink et al., 2006; Kaiser et al., 2006; Hinz et al., 2009). This directly affects the maintenance of demersal fish production, since the benthic community serves as energy resource for most demersal fish (Smith et al., 2000). Furthermore, trawling can also affect primary productivity due to sediment disturbance and thus stimulate eutrophication (Dounas et al., 2007). It typically leads to substantial reduction in habitat complexity (Kaiser et al., 2002) and may indirectly affects fish growth rate, population size and diet (Hiddink et al., 2011; Eggleton et al., 2018).

Scientific trawling is one of the most used methods to obtain abundance indices for fisheries management (Trenkel et al., 2004b; Hoffman et al., 2009). It provides the identification of a broad diversity of commercial and non-commercial fish and benthic organisms (Brind'Amour et al., 2014). Commercial bottom trawling is much more destructive than scientific trawling since the latter is usually much more limited in time and space. However, possible lost gear material, habitat modification, animal handling and mortality are among the negative effects from this survey method (Trenkel et al., 2019). In any case, a robust estimation of fish presence and biomass from trawling requires quantifying the gear catchability and selectivity.

Catchability is the relation of the relative abundance indices provided by a fishing technique and the actual population density (Trenkel et al., 2004a). In other words, it represents the interaction of the resource abundance and the effectiveness of the fishing gear (Arrenguín-Sanchez, 1996). Many factors can influence bottom trawl catchability, such as depth, season, fish behavior, gear selectivity and vertical distributions of fish (Beentjes et al., 2004; Yule et al., 2008). Selectivity is related to the probability of fish of a specific size to be captured by a fishing gear, providing measures of escapement (Arrenguín-Sanchez, 1996), which can occur both under and above the trawl net, also affecting trawling catchability (Pearcy et al., 1989).

Recording videos have been used as methods to study the marine ecosystem for approximately 70 years (Barnes, 1952). They have demonstrated a satisfactory cost-effectiveness and they are non-destructive to the environment (Spencer et al., 2005, Mallet and Pelletier, 2014). Regarding trawling, videos have been used to compare the sampling effectiveness among fish species using bottom trawl and visual methods (Uzmann et al., 1977; Pearcy et al., 1989; Adams et al., 1995; McIntyre et al., 2015). However, the video footages were not simultaneous to the trawling. Studies that have used video records during trawling were in most cases investigating the behavior and escapement of a specific group of fish, such as flatfishes, elasmobranchs or other target species (Godo et al., 1999; Albert et al., 2003; Chosid et al., 2012; Hannah and Jones, 2012; Bryan et al., 2014; Melli et al., 2019; Noack et al., 2019; Young et al., 2019).

In the present study, we evaluate fish catchability in bottom trawls performed on carbonate bottoms along the Northeast Brazilian continental shelf. We used video footages taken during bottom trawls to compare fish recorded by video with those captured by trawling. We also discuss catchability in relation to fish reactions to the trawl net, as well as the damage it caused to sponges.

2. Material and Methods

2.1 Study Area

The study area (Fig.1) is situated in the Northeast Brazilian continental shelf, from 5ºS to 9ºS. The average of shelf width is 40 km, the shelf break is approximately at 60 m deep and biogenic carbonate sediments predominantly cover the area (Manso et al., 2003; Vital et al., 2010). This region contains high biodiversity and some protected areas, such as APA Costa dos Corais (Ferreira and Maida, 2007), which is in the south part of the study area. Artisanal or commercial bottom trawling in the region is directed to catch shrimp, thus restricted to muddy bottoms, while the present work was conducted in the prevailing carbonate bottoms, typical of the region (Camargo et al., 2015).

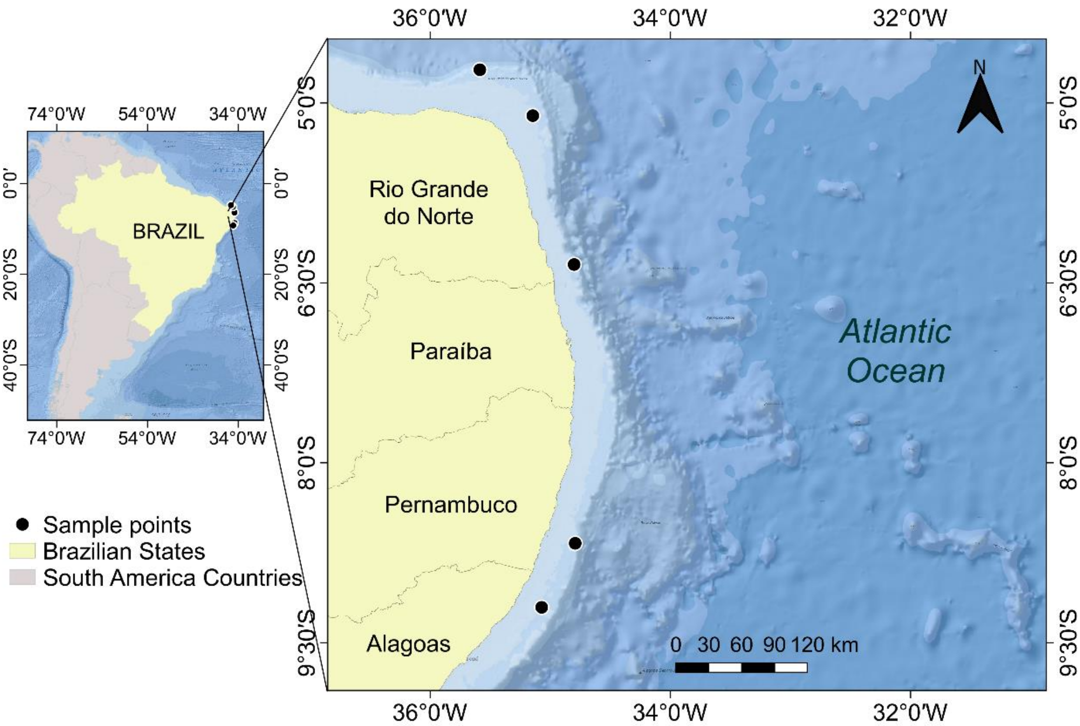


Fig.1. Study area with the five sample points where we could compare video and trawling. Cartographic Base: IBGE, 2017. GCS_SIRGAS2000.

2.2 Sampling

Samples were collected on board the French R/V ANTEA, during the 'Acoustics along the BRAzilian COaSt 2' (ABRACOS 2; Bertrand, 2017) survey performed from 9 April until 9 May 2017. Sampling was conducted using a bottom trawl (body mesh: 40 mm, cod-end mesh: 25 mm, entrance dimensions horizontal x vertical: 28 ×10 m) and video footages by an underwater camera (GoPro Hero 3+) attached in the upper part of the mouth of the net. Videos were recorded from 14 trawls, however, only five trawls presenting videos with adequate field of view (e.g. recording the entire net mouth) were considered here. In these sampling points, trawling was performed between 35 and 65 m deep, during approximately 6 min at 3.0 knots. Tow duration was based on video observations, from the moment of the arrival of the net on the ocean floor to the lift-off time. To ensure the net was fishing correctly we utilized SCANMAR sensors to monitor the net geometry, to give headline height, depth, and distance of wings and doors. In addition, bobbins were added to the ground rope (rockhopper) to reduce net damage and impacts on benthic habitat.

For each haul, fish were identified based on fish identification guides (Carpenter, 2002a; 2002b; Garcia Júnior et al., 2010; 2015), counted and preserved with a solution of 4% formalin in seawater or by freezing until processing. For videos identification and counting, trained people performed visual census based on fish identification guides (Lessa and Nóbrega, 2000; Humann and Deloach, 2002). Fish that could not be identified to species level were grouped to genus level. Fish species and families were classified according to Craig and Hastings (2007) and Nelson (2016).

2.3 Data analyses

Data consisted of fish counts (relative abundance - %N) identified at the lowest taxonomic possible level obtained from videos observations and trawling catches. The relative index of density (catch per unit of area – CPUA) was calculated considering the number of individuals per trawled area (ind.km^{-2}). To estimate the trawled area, we multiplied the distance covered by the net through the bottom (in meters) with the average mouth opening (13 m).

To describe species dominance patterns we used the frequency of occurrence (FO) and the relative numerical abundance in percentage (NP) (Garcia et al., 2006). Species that presented NP greater/lower than the average NP were considered Abundant/Scarce. Similarly, species that presented FO greater/lower than the average FO were considered Frequent/Rare. Based on these criteria, the degree of species dominance was classified in four categories of relative importance (relative importance index): (1) Abundant and Frequent, (2) Abundant and Rare, (3) Scarce and Frequent and (4) Scarce and Rare (Garcia et al., 2006).

We investigated patterns of catchability based on the differences between the number of individuals sampled by videos and by trawls (net change). To better describe fish assemblages, we calculated the number of species (S), the Shannon-wiener diversity index (H') and the Pielou's evenness index (J'). To test for differences between the CPUA, S, H’ and J’ of fish sampled by the video and trawling method, we used the non-parametric Wilcoxon signed rank test.

Furthermore, we used the CPUA to investigate the structure of fish assemblages from videos and trawls. To reduce the effect of shoals in the analyses, the CPUA data was log-transformed (Log(x+1)). We built a resemblance matrix, based on Bray-Curtis similarity index, and performed a non-parametric permutation procedure ANOSIM (Analysis of Similarity) to test for differences in the structure of fish assemblages between videos and trawls (Clarke, 1993).

Finally, during video analyses, we also counted all free-standing sponges that appeared in the videos. All statistical analyses were performed on the software PAST (Hammer et al., 2001) with a significance level of 0.05.

3. Results

The five hauls analyzed in this study corresponded to a total effort of 30 min and 36,416 m^2 of trawled area. From bottom trawls, 490 fishes distributed in 23 families and identified in 30 taxa, at the level of 25 species and 5 genera were captured. Whereas 370 fishes distributed in 19 families were identified through the videos, classified in 23 taxa at the level of 19 species and 4 genera (Table 1).

The relative abundance of fish in both video and trawl methods were similar. Approximately 70% of fish assemblages were represented by *Holocentrus adscensionis* (26% in videos and 29% in bottom trawls), *Pseudupeneus maculatus* (20% in videos and 15% in bottom trawls), *Diodon holocanthus* (0% in videos, 15% in bottom trawls), *Fistularia tabacaria* (13% in videos and 4% in bottom trawls) and *Acanthurus sp.* (9% in videos and 4% in bottom trawls) (Fig. 2).

Four species were only observed in videos: *Caranx crysos, Halichoeres dimidiatus, Malacanthus plumieri* and *Calamus pennatula,* while 11 were only observed in trawl catches, the most abundant being *Diodon holocanthus* (Table 1).

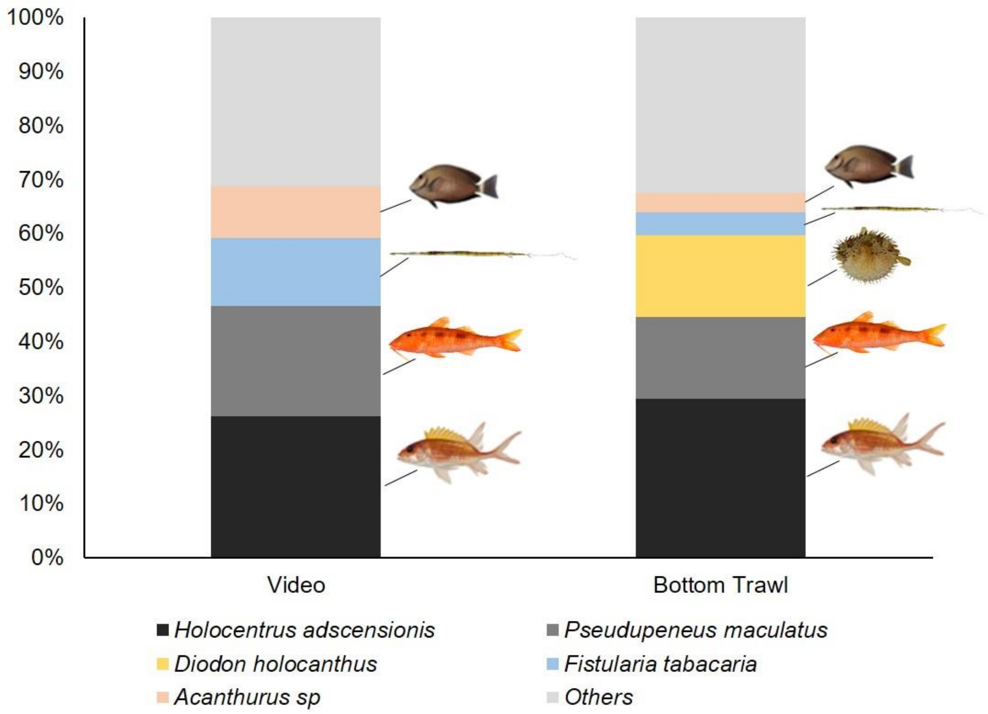


Fig. 2. Relative abundance of fishes (%) sampled by two different methods along the Northeast Brazilian continental shelf (4°–9°S): video and bottom trawl.

Table 1
List of species, number of individuals (N), relative importance index (1: Abundant and frequent; 2: Abundant and rare; 3: Scarce and frequent; 4: Scarce and rare) for fishes sampled in all five stations by videos and bottom trawls along the Northeast Brazilian continental shelf (4°–9°S).

Family	Genera / Species	N		Relative Importance Index	
		Video	Bottom Trawl	Video	Bottom Trawl
Acanthuridae	*Acanthurus sp.*	35	18	1	1
Aulostomidae	*Aulostomus strigosus*	0	5		4
Balistidae	*Balistes sp.*	1	2	4	3
Carangidae	*Caranx crysos*	1	0	4	
Chaetodontidae	*Chaetodon ocellatus*	9	19	3	1
	Chaetodon striatus	2	3	3	3
Dactylopteridae	*Dactylopterus volitans*	1	1	4	4
Dasyatidae	*Hypanus guttatus*	0	1		4
	Hypanus marianae	7	7	3	3
Diodontidae	*Diodon holocanthus*	0	74		1
Fistulariidae	*Fistularia tabacaria*	47	21	1	1
Gerreidae	*Eucinostomus sp.*	0	3		4
Haemulidae	*Anisotremus virginicus*	2	2	4	4
	Haemulon aurolineatum	9	13	4	4

	Haemulon plumierii	10	15	3	1
Holocentridae	*Holocentrus adscensionis*	97	144	1	1
Labridae	*Halichoeres dimidiatus*	1	0	4	
Lutjanidae	*Lutjanus synagris*	0	4		3
	Ocyurus chrysurus	1	2	4	4
Malacanthidae	*Malacanthus plumieri*	6	0	3	
Microdesmidae	*Ptereleotris randalli*	0	1		4
Monacanthidae	*Aluterus monoceros*	0	1		4
Mullidae	*Pseudupeneus maculatus*	75	74	1	1
Ostraciidae	*Acanthostracion sp.*	6	34	3	1
	Lactophrys trigonus	16	13	1	3
Pomacanthidae	*Holacanthus ciliaris*	6	6	3	3
	Pomacanthus paru	9	8	3	3
Pomacentridae	*Stegastes pictus*	0	1		4
Rhinobatidae	*Pseudobatos percellens*	0	1		4
Scaridae	*Sparisoma sp.*	9	13	3	3
Sciaenidae	*Pareques acuminatus*	0	1		4
Serranidae	*Alphestes afer*	0	2		4
	Cephalopholis fulva	15	1	1	4
Sparidae	*Calamus pennatula*	5	0	3	

The average abundance of fish from videos was 303.9 ind/km^2 and from trawls was 403.9 ind/km^2. Additionally, the average frequency of occurrence of fish species was 30% on videos and 36.5% on trawls. Species that were only registered either in videos or in trawls samples were mostly considered scarce and rare. Four species were considered abundant and frequent in both sampling methods (*Acanthurus sp*, *Fistularia tabacaria*, *Holocentrus adscensionis* and *Pseudupeneus maculatus*) and five were scarce and frequent (*Chaetodon striatus, Hypanus marianae, Holacanthus ciliaris, Pomacanthus paru* and *Sparisoma sp*). We did not find any abundant and rare species (Table 1).

Considering the net change between fish sampled by the two different methods, the species that prevailed in the videos were *Malacanthus plumieri* (which was identified only by videos), *Acanthurus sp*, *Fistularia tabacaria* and *Cephalopholis fulva,* while in the bottom trawls *Diodon holocanthus* (which was identified only from trawls), *Acanthostracion sp* and *Holocentrus adscensionis* were predominant (Fig. 3). The latter prevailed in the trawls due to an aggregation of squirrelfish in one of the stations, since removing the shoal from the analysis *Holocentrus adscensionis* is more abundant in the videos (10 individuals) than in the bottom trawls (nine individuals).

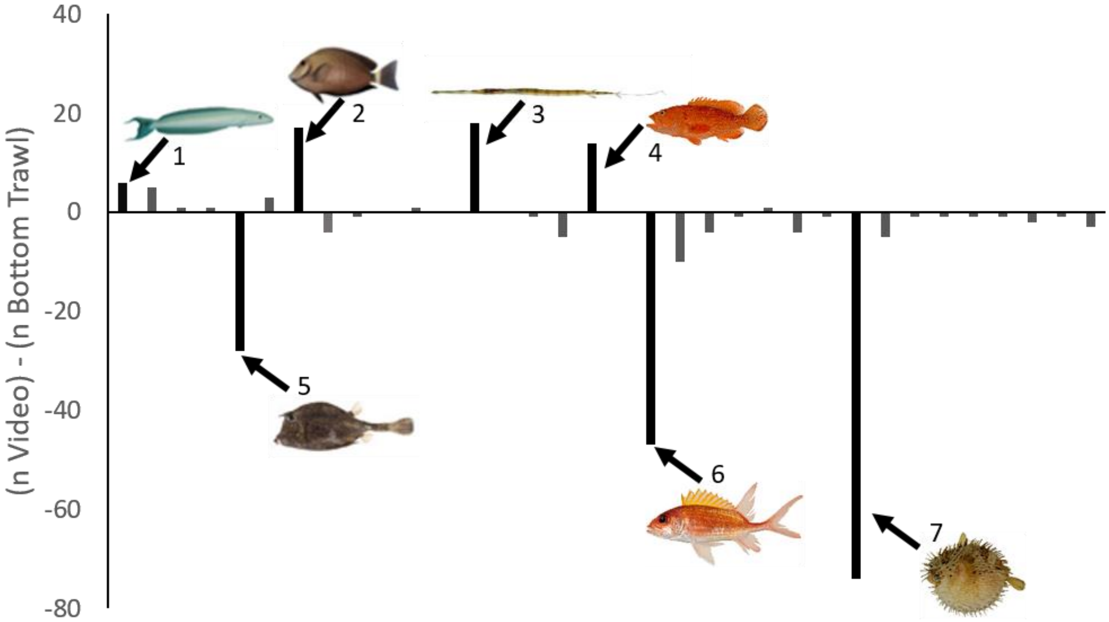


Fig. 3. Net change between fish sampled by videos and by bottom trawls along the Northeast Brazilian continental shelf (4°–9°S). The main differences are highlighted (1. *Malacanthus plumieri*; 2. *Acanthurus sp*; 3. *Fistularia tabacaria*; 4. *Cephalopholis fulva*; 5. *Acanthostracion sp*; 6. *Holocentrus adscensionis*; 7. *Diodon holocanthus*).

The CPUA and number of species was slightly higher but not significantly different in trawl than video (Fig. 4; Table 2). Shannon-Wiener diversity and Pielou's evenness were also not significantly different between the two methods (Fig. 4; Table 2).

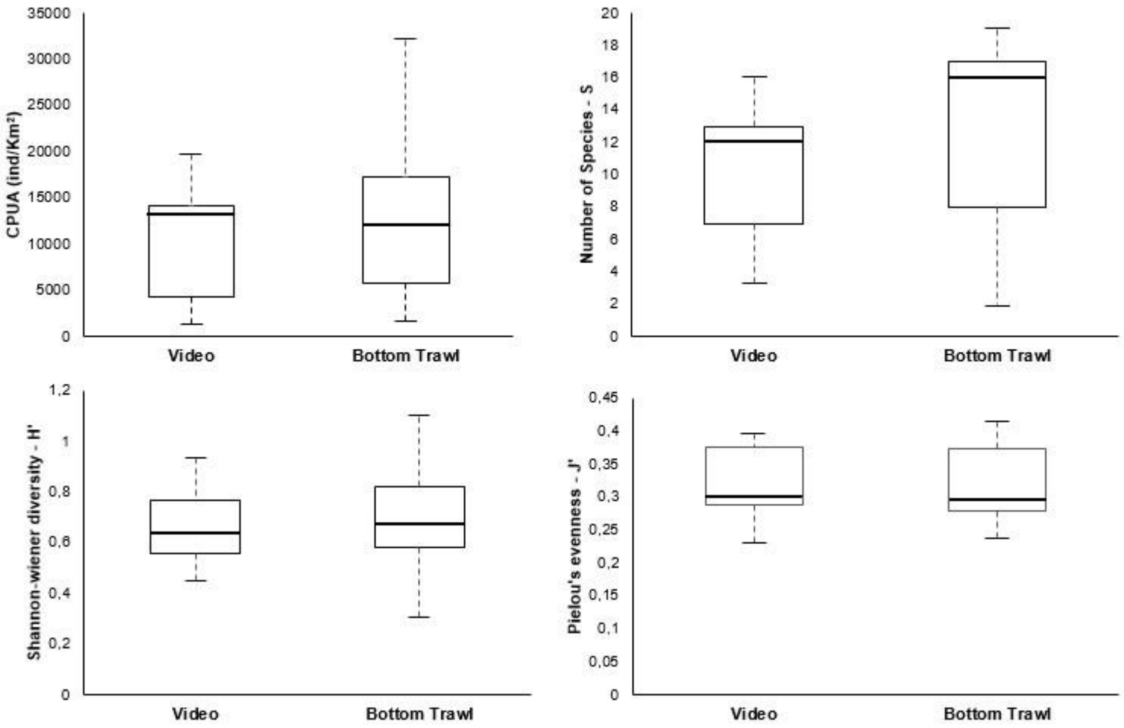


Fig.4. Box plot of Catch Per Unit of Area – CPUA (ind.km^{-2}), Number of Species (S), Shannon-Wiener Diversity Index (H') and Pielou's Evenness Index (J') of fish sampled by videos and bottom trawls along the Northeast Brazilian continental shelf (4°–9°S).

Table 2
Wilcoxon signed rank test results between video and trawl samples along the Northeast Brazilian continental shelf (4°–9°S).

	Wilcoxon signed rank test (*z*)	*p*
CPUA (ind.km^{-2})	12.136	0.22
S - Number of Species	1.511	0.13
H' - Shannon-Wiener Diversity Index	0.944	0.35
J' - Pielou's Evenness Index	0.404	0.69

Similarly, the ANOSIM analysis, based on the log-transformed CPUA dataset, did not revealed significant difference in the structure of fish assemblages from videos and from bottom trawls (R = - 0.092; p = 0.72).

In total, 168 individual sponges were observed in videos. All sponges hit by the trawl net were damaged (Fig. 5).

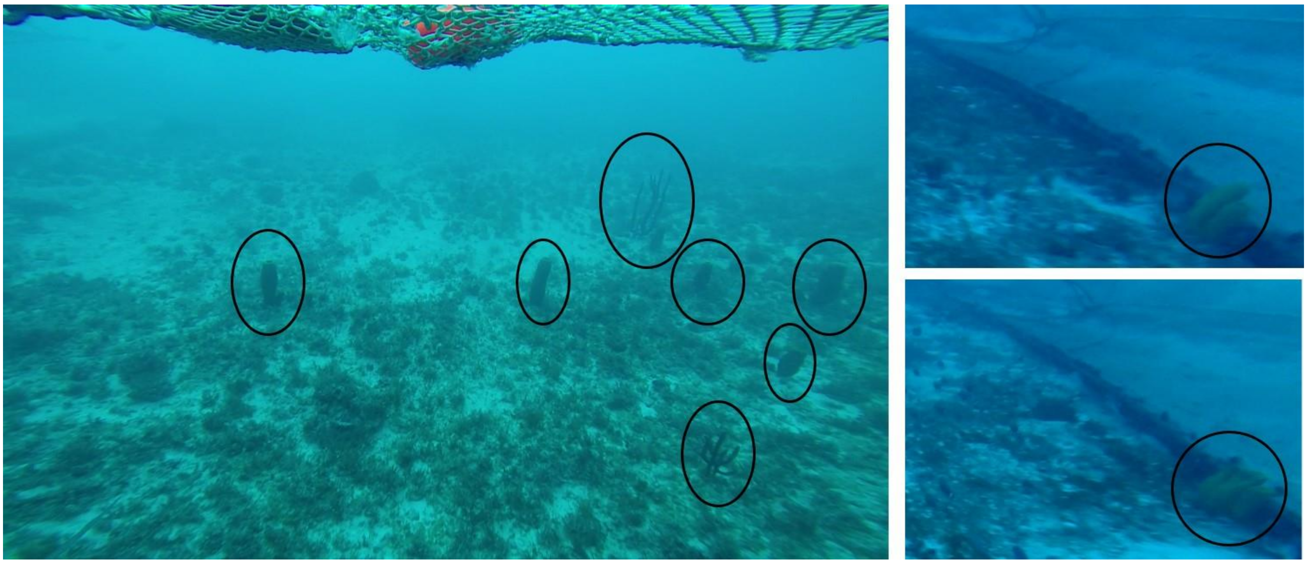


Fig. 5. Images examples of the sponges dragged by the trawl net along the Northeast Brazilian continental shelf (4°–9°S).

4. Discussion

This is the first study comparing the entire fish community obtained from videos and trawls carried out simultaneously. The structure of fish assemblages was similar between the bottom trawl and video methods as already observed by McIntyre et al. (2015) in the northeast Atlantic. Although the mean CPUA and S estimates were slightly greater in the bottom trawl than in the video, there was no significant difference in fish community structure from the two sampling methods. These results suggest that video is an appropriate alternative for studies aiming at analyzing the distribution of fish assemblages and community structure (Milkov et al., 1999; Lauth et al., 2004; Morrison and Carbines, 2006; Shucksmith et al., 2006; Assis et al., 2007; Stoner et al., 2007; Schaner et al., 2009; Warnock et al., 2016; Lembke et al., 2017; Mérillet et al., 2018).

Previous studies have demonstrated differences among species when comparing visual surveys and bottom trawl sampling efficiency (Uzmann et al., 1977; Adams et al.,1995; Trenkel et al., 2004b; McIntyre et al., 2015). In this study, despite the non-significant difference between the fish assemblages sampled by the two different methods, distinct species specific patterns were observed. For instance, *Cephalopholis fulva, Malacanthus plumieri, Calamus pennatula* and *Halichoeres dimidiatus* were common in videos, always escaping the trawl net passage (except the *Cephalopholis fulva*), due to their ability to hide in caves, to take refuge underneath coral rubble or to dive into the sand (Clark et al., 1988; Fiorentini et al., 1999; Claydon and Kroetz, 2007; Guidetti et al., 2008). Noteworthy, the rockhopper prevented the net of digging into the bottom. Surgeonfishes *Acanthurus sp* were also able to evade capture possibly not only because of their shelter attempts (Benevides et al., 2016), but also because they were most abundant in small size classes (around 5 cm in length). Small bodied fish can be detected in video analyses but may be inefficiently capture by trawls (Fiorentini et al., 1999, Trenkel et al., 2004a).

Although squirrelfish *Holocentrus adscensionis* frequently hide in coral crevices during daytime (Greenfield, 1981), and thus potentially had the ability to escape, they did not escape and were more abundant in the trawl catches than in video. This is related to the occurrence of a large aggregation event in one of the stations, probably a spawning aggregation since most individuals were ready to spawn (BPF, pers. obs.), which leaves them more vulnerable (Chollett et al., 2020). In a shoal, the behavior of an individual fish can be influenced by the movement of the surrounding fishes, resulting in different reactions of the fish in front of trawl and consequently enabling a tendency to have high catchability at high densities and low catchability at low densities (Godo et al., 1999).

In most cases, *Holocentrus adscensionis* appeared in videos trying to hide into the corals and sponge's structures, however, aggregating individuals behaved swimming away from the net with other fish. The aggregation may also have induced a bias in fish counting, causing underestimated abundance in the video census (Tessier et al., 2005; Lowry et al., 2012). Removing the shoal from the analysis, the squirrelfish were more abundant in the videos than in the trawls, similarly to the other fish with the ability to hide that managed to escape the net. The behavioral change and possible underestimation in fish counting on video analyses, due to the large aggregation, resulted in a greater abundance in the trawls than in the videos.

The blue runner *Caranx crysos* (Mitchill, 1815) was not captured in the trawls. Probably, its fast swimming capacity allowed the fish to keep its position ahead of the net, eventually escaping the net during or at the end of the haul (Beentjes et al., 2004). Similarly, the cornetfishes *Fistularia tabacaria* has high swimming endurance and their elongated body possibly contributed to their escapement from the trawl net (Fritzsche, 1976; Beentjes et al., 2004).

On the other hand, the porcupine puffer fish *Diodon holocanthus* was not recorded in videos but was the most abundant fish in the bottom trawls catches. This species was likely not detected in videos since the upper vision of the camera make difficult identifying the fish due to its camouflage with the substrate and immobility. Also, they react to threats inflating or expanding their body with air or water (Shipp, 2003). Thus, we believe that when the porcupine puffer fish felt threatened by the trawl net they were not in the camera's field of view anymore, and as a consequence of their immobility and behavior they were immediately dragged to the end of the net. The boxfishes *Acanthostracion spp* are also slow swimming benthic-dwelling (Matsuura, 2003) and present a good camouflage with the substrate, which similarly contribute to their high catchability and complicate their identification in video census (Beentjes et al., 2004).

Catchability differences were noted as discussed above and were associated to fish behavior, swimming ability, morphological features, density and distribution (He, 1993; Godo et al., 1999; Beentjes et al., 2004; Trenkel et al., 2004a; Yule et al., 2008; McIntyre et al., 2015). Furthermore, videos illustrated a strong bottom-trawl impact with the destruction of sponges. It is noteworthy that this damage could be higher if the net was not adapted with rockhopper. Trawl nets indeed remove rocks and corals and smooth out natural topography, consequently reducing the structural heterogeneity, which is an important factor to the recruitment and survival of countless fish (Auster et al., 1996; Pilskaln et al., 1998; Kumar and Deepthi, 2006). The direct damage to the benthic organisms may affect a variety of demersal fishes because of the depletion of food supply and shelters, which exposes the fishes to predation (Kumar and Deepthi, 2006).

We recognize the limits of our study including the small number of videos in our study due to camera stability and water transparency. Towed cameras have difficulties to keep their stability, which affects the field of view of the camera (Barker et al.,1999; Jones et al., 2009). The stability and visibility of our towed videos were sometimes compromised due to the effects of dragging disturbance. Nevertheless, the videos analyzed in this study provided comparable results of fish assemblages composition and diversity, in relation to bottom trawls catches. In addition, important observations on fish behavioral reactions and also on sponge depletion have been done.

Certainly, trawl surveys are useful to collect biological samples for diet, reproductive and ageing studies, allowing the estimation of population age structures, the calculation of growth and mortality rates, which are essential for the management and monitoring of fish populations (McIntyre et al., 2015). However, the implementation of less destructive methods is necessary, especially in conservation areas. This study demonstrated that videos can be an efficient alternative for surveying the abundance and distribution of marine fish.

5. Conclusion

In general, the image of fish abundances and structure of fish assemblages obtained from videos and bottom-trawls were not significantly different. However, fish catchability varied according to the behavior of each species, its swimming capacity and morphology. Bottom trawl was more selective for fish with low swimming capacity, while species small sized and/or with shelter and fast swimming capacity could escape the net.

Furthermore, underwater footages allowed for an assessment of the trawling impacts on bottom habitats, where the damage on large free-standing sponges could be better observed. Our results substantiate the negative impacts of bottom trawling on carbonate beds due to potential damage to the fragile and slow recovering benthic cover, making commercial fisheries in those areas an environmental hazard. Finally, we conclude that video may act as an efficient alternative to scientific trawling in studies on fish and benthic fauna. Scientific trawling could be replaced by Tow Video method, which also uses a towed camera, however, it does not use a net, performing a non-invasive methodology.

Acknowledgements

We acknowledge the French oceanographic fleet for funding the research expedition ABRACOS 2 and the crew of the R/V ANTEA for their assistance and guidance in the field operations. We also acknowledge the cooperation of all participants from the LECOR and BIOIMPACT Laboratories. This study was partially financed by the project PELD-TAMS (Long Duration Ecological Program – Sustainable Tamandaré), by CAPES (Coordination for the Improvement of Higher Education Personnel) through a student grant to Maria Jacqueline Gomes de Barros, Leandro Nolé Eduardo and Alex Souza Lira, and by CNPQ (National Council for Scientific and Technological Development) through a productivity research grant to Beatrice Padovani Ferreira and Flávia Lucena Frédou. This work is a contribution to the LMI TAPIOCA and to the PELD-TAMS.

Declarations of interest

None.

Funding

This work was supported by the French oceanographic fleet, through the project ABRACOS 2 (http://dx.doi.org/10.17600/17004100), and partially financed by the project PELD-TAMS (Long Duration Ecological Program – Sustainable Tamandaré), by CAPES (Coordination for the Improvement of Higher Education Personnel) and by CNPQ (National Council for Scientific and Technological Development).

6. References

Adams, P.B., Butler, J.L., Laiding, T.E., Dahlin, K.A., and Wakefield, W.W., 1995. Population estimates of Pacific coast groundfishes from video transects and swept-area trawls. Fishery Bulletin. 93, 446-455.

Albert, O.T., Harbitz, A., Høines, A.S., 2003. Greenland halibut observed by video in front of survey trawl: behaviour, escapement, and spatial pattern. Journal of Sea Research. 50, 117– 127. https://doi.org/10.1016/S1385-1101(03)00063-7

Amoroso, R.O., Pitcher, C.R., Rijnsdorp, A.D., McConnaughey, R.A., Parma, A.M., Suuronen, P., et al., 2018. Bottom trawl fishing footprints on the world's continental shelves. Proceedings of the National Academy of Sciences, USA. 115 (43) E10275-E10282. https://doi.org/10.1073/pnas.1802379115

Arrenguín-Sanchez, F., 1996. Catchability: a key parameter for fish stock assessment. Reviews in Fish Biology and Fisheries. 6, 221-242.

Assis, J., Narváez, K., Haroun, R., 2007. Underwater towed video: a useful tool to rapidly assess elasmobranch populations in large marine protected areas. Journal of Coastal Conservation. 11, 153-157. https://doi.org/10.1007/s11852-008-0015-x

Auster, P.J., Malatesta, R.J., Langton, R.W., Watling, W., Valentine, P.C., Donaldson, C.L.S., Langton, E.W., Shepard, A.N., Babb, I.G., 1996. The impacts of mobile fishing gear on seafloor habitats in the Gulf of Maine (northwest Atlantic): Implications for conservation of fish populations. Reviews in Fisheries Science. 4 (2), 185–202.

Barker, B.A.J., Helmond, I., Bax, N.J. Williams, A., Davenport, S., Wadley, V.A., 1999. A vessel-towed camera platform for surveying seafloor habitats of the continental shelf. Continental Shelf Research. 19, 1161-1170.

Barnes, H., 1952. Under-water television and marine biology. Nature, 169, 477-479.

Beentjes, M.P., Smith, M., Phillips, N.L., 2004. Analysis of catchability for east coast South Island trawl surveys and recommendations on future survey design. New Zealand Fisheries Assessment Report. 68 pages. ISSN 1175-1584.

Benevides, L.J., Nunes, J.A.C.C., Costa, T.L.A., Sampaio, C.L.S., 2016. Flight response of the barber surgeonfish, *Acanthurus bahianus* Castelnau, 1855 (Teleostei: Acanthuridae), to spearfisher presence. Neotropical Ichthyology. 14(1), e150010. https://doi.org/10.1590/1982-0224-20150010

Bertrand, A., 2017. ABRACOS 2 cruise, RV Antea. https://doi.org/10.17600/17004100

Bradshaw, C., Tjensvoll, I., Sköld, M., Allan, I.J., Molvaer, J., Magnusson, J., Naes, K., Nilsson, H.C., 2012. Bottom trawling resuspends sediment and releases bioavailable contaminants in a polluted fjord. Environmental Pollution. 170, 232-241. http://doi.org/10.1016/j.envpol.2012.06.019

Brind'Amour, A., Laffargue, P., Morin, J., Vaz, S., Foveau, A., Bris, H.L., 2014. Morphospecies and taxonomic sufficiency of benthic megafauna in scientific bottom trawl surveys. Continental Shelf Research. 72, 1-9. http://dx.doi.org/10.1016/j.csr.2013.10.015

Bryan, D.R., Bosley, K.L., Hicks, A.C., Haltuch, M.A., Wakefield, W.W., 2014. Quantitative video analysis of flatfish herding behavior and impact on effective area swept of a survey trawl. Fisheries Research. 154,120–126. http://dx.doi.org/10.1016/j.fishres.2014.02.007

Camargo, J.M.R., Araújo, T.C.M., Ferreira, B.P., Maida, M., 2015. Topographic features related to recent sea level history in a sediment-starved tropical shelf: Linking the past, present and future. Regional Studies in Marine Science. 2, 203–211. http://dx.doi.org/10.1016/j.rsma.2015.10.009

Carpenter, K.E. (ed). 2002a. The living marine resources of the Western Central Atlantic. Volume 2: Bony fishes part 1 (Acipenseridae to Grammatidae). FAO Species Identification Guide for Fishery Purposes and American Society of

Ichthyologists and Herpetologists Special Publication No. 5. Rome, FAO. pp. 601-1374.

Carpenter, K.E. (ed). 2002b. The living marine resources of the Western Central Atlantic. Volume 3: Bony fishes part 2 (Opistognathidae to Molidae), sea turtles and marine mammals. FAO Species Identification Guide for Fishery Purposes and American Society of Ichthyologists and Herpetologists Special Publication No. 5. Rome, FAO. pp. 1375-2127.

Chollett, I., Priest, M., Fulton, S., Heyman, W.D., 2020. Should we protect extirpated fish spawning aggregation sites?. Biological Conservation. 241, 108395. https://doi.org/10.1016/j.biocon.2019.108395

Chosid, D.M., Pol, M., Szymanski, M., Mirarchi, F., Mirarchi, A., 2012. Development and observations of a spiny dogfish Squalus acanthias reduction device in a raised footrope silver hake Merluccius bilinearis trawl. Fisheries Research. 114, 66–75. http://dx.doi.org/10.1016/j.fishres.2011.03.007

Clark, E., Rabin, J.S., Holderman, S., 1988. Reproductive behavior and social organization in the sand tilefish, *Malacanthus plumieri.* Environmental Biology of Fishes. 22 (4), 273-286.

Clarke, K.R., 1993. Non-parametric multivariate analyses of changes in community structure. Australian Journal of Ecology. 18, 117–143.

Claydon, J.A.B., Kroetz, A.M., 2007. The Distribution of Early Juvenile Groupers Around South Caicos, Turks and Caicos Islands. In: Proceedings of the 60th Gulf and Caribbean Fisheries Institute. 60, 345-350.

Craig, M.T., Hastings, P.A., 2007. A molecular phylogeny of the groupers of the subfamily Epinephelidae (Serranidae) with a revised classification of the Epinephelini. Ichthyological Research. 54, 1-17.

Dounas, C., Davies, I., Triantafyllou, G., Koulouri, P., Petihakis, G., Arvanitidis, C., Sourlatzis, G., Eleftheriou, A., 2007. Large-scale impacts of bottom trawling on shelf primary productivity. Continental Shelf Research. 27, 2198–2210. http://doi.org/10.1016/j.csr.2007.05.006

Eggleton, J.D., Depestele, J., Kenny, A.J., Bolam, S.G., Garcia, C., 2018. How benthic habitats and bottom trawling affect trait composition in the diet of seven demersal and benthivorous fish species in the North Sea. Journal of Sea Research. 142, 132–146. https://doi.org/10.1016/j.seares.2018.09.013

FAO. 1996. Report of the technical consultation on reduction of wastage in fisheries. FAO Fish. Rep., 547: 27 p.

Ferreira, B.P., Maida, M., 2007. Características e Perspectivas para o Manejo da Pesca na Área de Proteção Ambiental Marinha da Costa dos Corais. In: Áreas Aquáticas Protegidas Como Instrumento de Gestão Pesqueira. Serie Areas Protegidas, Brasília. 39–51.

Fiorentini, L., Dremière, P.Y., Leonori, I., Sala, A., Palumbo., V., 1999. Efficiency of the bottom trawl used for the Mediterranean international trawl survey (MEDITS). Aquatic Living Resources. 12 (3), 187−205.

Fritzsche, R.A., 1976. A Review of the Cornetfishes, Genus Fistularia (Fistulariidae), with a Discussion of Intrageneric Relationships and Zoogeography. Bulletin of Marine Science. 26 (2), 196-204.

Garcia, A.M., Bemvenuti, M.A., Vieira, J.P., Motta Marques, D.M.L., Burns, M.D.M., Moresco, A., Vinicius, M., Condini, L., 2006. Checklist comparison and dominance patterns of the fish fauna at Taim Wetland, South Brazil. Neotrop. Ichthyol. 4, 261–268.

Garcia Júnior, J., Mendes, L.F., Sampaio, C.L.S., Lins, J.E. 2010. Biodiversidade marinha da Bacia Potiguar: Ictiofauna. Série Livros, 38. Rio de Janeiro, Museu Nacional. 195p.

Garcia Júnior, J., Mendes, L.F., Sampaio, C.L.S., Nóbrega, M.F., Oliveira, J.E.L. 2015. Biodiversidade marinha da Bacia Potiguar/RN: Peixes da Plataforma Continental. Série Livros, 54. Rio de Janeiro, Museu Nacional. 217p.

Godo, O.R., Walsh, S.J., Engas, A., 1999. Investigating density-dependent catchability in bottom-trawl surveys. ICES Journal of Marine Science. 56, 292–298.

Greenfield, D.W., 1981. Holocentridae. In: W. Fischer, G. Bianchi and W.B. Scott (eds.) FAO species identification sheets for fishery purposes. Eastern Central Atlantic; fishing areas. 2 (34), 47 (in part). Department of Fisheries and Oceans Canada and FAO.

Guidetti, P., Vierucci, E., Bussotti, S., 2008. Differences in escape response of fish in protected and fished Mediterranean rocky reefs. Journal of the Marine Biological Association of the United Kingdom. 88(3), 625–627. https://doi.org/10.1017/S0025315408000933

Hammer, Ø., Harper, D.A.T., Ryan, P.D., 2001. PAST: Paleontological statistics software package for education and data analysis. Palaeontologia Electronica. 4 (1), 9 p. http://palaeo-electronica.org/2001_1/past/issue1_01.htm

Hannah, R.W., Jones, S.A., 2012. Evaluating the behavioral impairment of escaping fish can help measure the effectiveness of bycatch reduction devices. Fisheries Research. 131, 39–44. http://doi.org/10.1016/j.fishres.2012.07.010

He, P., 1993. Swimming speeds of marine fish in relation to fishing gears. ICES Marine Science Symposia. 196, 183-189.

Hiddink, J.G., Jennings, S., Kaiser, M.J., 2006. Indicators of the Ecological Impact of Bottom-Trawl Disturbance on Seabed Communities. Ecosystems. 9, 1190–1199. http://doi.org/10.1007/s10021-005-0164-9

Hiddink, J.G., Johnson, A.F., Kingham R., Hinz, H., 2011. Could our fisheries be more productive? Indirect negative effects of bottom trawl fisheries on fish condition. Journal of Applied Ecology. 48, 1441–1449. http://doi.org/10.1111/j.1365-2664.2011.02036.x

Hinz, H., Prieto, V., Kaiser, M.J., 2009. Trawl disturbance on benthic communities: chronic effects and experimental predictions. Ecological Applications. 19 (3), 761–773.

Hoffman, J.C., Bonzek, C.F., Latour, R.J., 2009. Estimation of Bottom Trawl Catch Efficiency for Two Demersal Fishes, the Atlantic Croaker and White Perch, in Chesapeake Bay. Marine and Coastal Fisheries. 1 (1), 255-269. https://doi.org/10.1577/C08-048.1

Humann, P., Deloach, N., 2002. Reef Fish Identification: Florida, Caribbean and Bahamas. New World Publications, Inc. 3rd Edition, Jacksonville, Florida. 481 p.

Jennings, S., Kaiser, M.J., 1998. The Effects of Fishing on Marine Ecosystems. Advances in Marine Biology. 34, 153 p. ISBN 0-12-0261344.

Jones, D.O.B., Bett, B.J., Wynn, R.B., Masson, D.G., 2009. The use of towed camera platforms in deep-water science. Underwater Technology. 28, 41–50. https://doi.org/10.3723/ut.28.041

Kaiser, M.J., Collie, J.S., Hall, S.J., Jennings, S., Poiner, I.R., 2002. Modification of marine habitats by trawling activities: prognosis and solutions. Fish and Fisheries. 3, 114-136.

Kaiser, M.J., Clarke, K.R., Hinz, H., Austen, M.C.V., Somerfield, P.J., Karakassis, I., 2006. Global analysis of response and recovery of benthic biota to fishing. Marine Ecology Progress Series. 311, 1-14. https://doi.org/10.3354/meps311001

Kumar, A.B., Deepthi, G.R., 2006. Trawling and by-catch: Implications on marine ecosystem. Current Science. 90 (7), 922-931.

Lauth, R.R., Wakefield, W.W., Smith, K., 2004. Estimating the density of thornyheads, *Sebastolobus* spp., using a towed video camera sled. Fisheries Research. 70, 39-48. https://doi.org/10.1016/j.fishres.2004.06.009

Lembke, C., Grasty, S., Silverman, A., Broadbent, H., Butcher, S., Murawski, S., 2017. The camera-based assessment survey system (C-BASS): A towed camera platform for reef fish abundance surveys and benthic habitat characterization in the Gulf of Mexico. Continental Shelf Research. 151, 62-71. https://doi.org/10.1016/j.csr.2017.10.010

Lessa, R., Nóbrega, M.F., 2000. Programa REVIZEE/SCORE-NE - Guia de identificação de peixes marinhos da região Nordeste. Recife, UFRPE-DIMAR, 128p.

Lowry, M., Folpp, H., Gregson, M., Suthers, I., 2012. Comparison of baited remote underwater video (BRUV) and underwater visual census (UVC) for assessment of artificial reefs in estuaries. Journal of Experimental Marine Biology and Ecology. 416-417, 243–253. https://doi.org/10.1016/j.jembe.2012.01.013

Mallet, D., Pelletier, D., 2014. Underwater video techniques for observing coastal marine biodiversity: A review of sixty years of publications (1952–2012). Fisheries Research. 154, 44–62. http://doi.org/10.1016/j.fishres.2014.01.019

Manso, V., Correa, I., Guerra, N., 2003. Morfologia e sedimentologia da Plataforma Continental Interna entre as praias Porto de Galinhas e Campos-Litoral Sul de Pernambuco, Brasil. Pesquisas em Geociências. 30 (2), 17–25. https://doi.org/10.22456/1807-9806.19587

Martín, J., Puig, P., Palanques, A., Ribó, M., 2014. Trawling-induced daily sediment resuspension in the flank of a Mediterranean submarine canyon. Deep-Sea Research II. 104, 174-183. https://doi.org/10.1016/j.dsr2.2013.05.036

Matsuura, K., 2003. Ostraciidae. Boxfishes (trunkfishes, cowfishes). In K.E. Carpenter (ed.) FAO species identification guide for fishery purposes. The living marine resources of the Western Central Atlantic. 3, 1980-1987. Bony fishes part 2 (Opistognathidae to Molidae), sea turtles and marine mammals.

McIntyre, F.D., Neat, F., Collie, N., Stewart, M., Fernandes, P.G., 2015. Visual surveys can reveal rather different 'pictures' of fish densities: Comparison of trawl and video camera surveys in the Rockall Bank, NE Atlantic Ocean. Deep-Sea Research I. 95, 67-74. http://doi.org/10.1016/j.dsr.2014.09.005

Melli, V., Krag, L.A., B. Herrmann, B., Karlsen, J.D., 2019. Can active behaviour stimulators improve fish separation from Nephrops (Nephrops norvegicus) in a horizontally divided trawl codend?. Fisheries Research. 211, 282–290. https://doi.org/10.1016/j.fishres.2018.11.027

Mérillet, L., Robert, M., Salaün, M., Schuck, L., Mouchet, M., Kopp, D., 2018. Underwater video offers new insights into community structure in the Grande Vasière (Bay of Biscay). Journal of Sea Research. 139, 1–9. https://doi.org/10.1016/j.seares.2018.05.010

Milkov, A., Vogt, P., Cherkashev, G., Ginsburg, G., Chernova, N., Andriashev, A., 1999. Sea-floor terrains of Haskon Mosby Mud Volcano as surveyed by deep-tow video and still photography. Geo-Marine Letters. 19, 38-47. https://doi.org/10.1007/s003670050091

Mitchill, S.L., 1815. The fishes of New York, described and arranged. Trans. Lit. Philos. Soc. New York. 1, 355-492.

Morrison, M., Carbines, G., 2006. Estimating the abundance and size structure of an estuarine population of the sparid *Pagrus auratus*, using a towed camera during nocturnal periods of inactivity, and comparisons with conventional sampling techniques. Fisheries Research. 82, 150-161. https://doi.org/10.1016/j.fishres.2006.06.024

Nelson, J.S., Grande, T., Wilson, M.V.H., 2016. Fishes of the world. 5th Edition, John Wiley & Sons, Inc, Hoboken, New Jersey.

Noack, T., Stepputtis, D., Madsen, N., Wieland, K., Haase, S., Krag, L.A., 2019. Gear performance and catch process of a commercial Danish anchor seine. Fisheries Research. 211, 204–211. https://doi.org/10.1016/j.fishres.2018.11.012

O'Neill, F.G., Summerbell, K., 2011. The mobilisation of sediment by demersal otter trawls. Marine Pollution Bulletin. 62, 1088–1097. https://doi.org/10.1016/j.marpolbul.2011.01.038

Pearcy, W.G., Stein, D.L., Hixon, M.A., Pikitch, E.K., Barss, W.H., Starr, R.M., 1989. Submersible Observations of Deep-Reef Fishes of Heceta Bank, Oregon. Fishery Bulletin, U.S. 87, 955-965.

Pilskaln, C.H., Churchill, J.H., Mayer, L.M., 1998. Resuspension of sediments by bottom trawling in the Gulf of Maine and potential geochemical consequences. Conservation Biology. 12 (6), 1223–1229.

Schaner, T., Fox, M.G., Taraborelli, A.C., 2009. An inexpensive system for underwater video surveys of demersal fishes. Journal of Great Lakes Research. 35, 317–319. https://doi.org/10.1016/j.jglr.2008.12.003

Shipp, R.L., 2003. Tetraodontidae. In Carpenter K.E. (ed) FAO species identification guide for fishery purposes. The living marine resources of the Western Central Atlantic. 3, 1988–2006. Rome, Italy: FAO of the United Nations.

Shucksmith, R., Hinz, H., Bergmann, M., Kaiser, M.J., 2006. Evaluation of habitat use by adult plaice (Pleuronectes platessa L.) using underwater video survey techniques. Journal of Sea Research. 56, 317–328. https://doi.org/10.1016/j.seares.2006.06.001

Smith, C.J., Papadopoulou, K.N., Diliberto, S., 2000. Impact of otter trawling on an eastern Mediterranean commercial trawl fishing ground. ICES Journal of Marine Science. 57, 1340–1351. https://doi.org/10.1006/jmsc.2000.0927

Spencer, M.L., Stoner, A.W., Ryer, C.H., Munk, J.E., 2005. A towed camera sled for estimating abundance of juvenile flatfishes and habitat characteristics: Comparison with beam trawls and divers. Estuarine, Coastal and Shelf Science. 64, 497-503. https://doi.org/10.1016/j.ecss.2005.03.012

Stoner, A.W., Spencer, M.L., Ryer, C.H., 2007. Flatfish-habitat associations in Alaska nursery grounds: Use of continuous video records for multi-scale spatial analysis. Journal of Sea Research. 57, 137–150. http://doi.org/10.1016/j.seares.2006.08.005

Tessier, E., Chabanet, P., Pothin, K., Soria, M., Lasserre, G., 2005. Visual censuses of tropical fish aggregations on artificial reefs: slate versus video recording techniques. Journal of Experimental Marine Biology and Ecology. 315, 17– 30. https://doi.org/10.1016/j.jembe.2004.08.027

Thomas, J.V., Sreedevi, C., Kurup, B.M., 2006. Variations of the infaunal polychaetes due to bottom trawling along the inshore waters of Kerala (south-west coast of India). Indian Journal of Marine Sciences. 35 (3), 249-256.

Trenkel, V.M., Francis, R.I.C.C., Lorance, P., Mahévas, S., Rochet, M., Tracey, D.M., 2004a. Availability of deep-water fish to trawling and visual observation from a remotely operated vehicle (ROV). Marine Ecology Progress Series. 284, 293-303.

Trenkel, V.M., Lorance, P., Mahévas, S., 2004b. Do visual transects provide true population density estimates for deepwater fish?. ICES Journal of Marine Science. 61 (7), 1050-1056. https://doi.org/10.1016/j.icesjms.2004.06.002

Trenkel, V.M., Vaz, S., Albouy, C., Brind'Amour, A., Duhamel, E., Laffargue, P., Romagnan, J.B., Simon, J., Lorance, P., 2019. We can reduce the impact of scientific trawling on marine ecosystems. Marine Ecology Progress Series. 609, 277–282. https://doi.org/10.3354/meps12834

Uzmann, J.R., Cooper, R.A., Theroux, R.B., Wigley, R.L., 1977. Synoptic Comparison of Three Sampling Techniques for Estimating Abundance and Distribution of Selected Megafauna: Submersible VS Camera Sled VS Otter Trawl. Marine Fisheries Review. 39 (12), 11-19.

Vital, H., Gomes, M.P., Tabosa, W.F., Frazão, E.P., Santos, C.L.A., Placido Junior, J.S., 2010. Characterization of the Brazilian continental shelf adjacent to Rio Grande do Norte State, NE Brazil. Brazilian Journal of Oceanography. 58, 43–54. http://doi.org/10.1590/S1679-87592010000500005

Warnock, W., Harvey, E.S., Newman, S.J., 2016. Remote drifted and diver operated stereo–video systems: A comparison from tropical and temperate reef fish assemblages. Journal of Experimental Marine Biology and Ecology. 478, 45–53. http://doi.org/10.1016/j.jembe.2016.02.002

Watling, L., Norse, E.A., 1998. Disturbance of the Seabed by Mobile Fishing Gear: A Comparison to Forest Clearcutting. Conservation Biology. 12 (6), 1180-1197.

Young, H.J., Raoult, V., Platell, M.E., Williamson, J.E., Gaston, T.F., 2019. Within-genus differences in catchability of elasmobranchs during trawling. Fisheries Research. 211, 141–147. https://doi.org/10.1016/j.fishres.2018.11.015

Yule, D.L., Adams, J.V., Stockwell, J.D., Gorman, O.T., 2008. Factors Affecting Bottom Trawl Catches: Implications for Monitoring the Fishes of Lake Superior. North American Journal of Fisheries Management. 28,109–122.

4 MANUSCRITO II: Fish distribution over the seascape of a tropical insular shelf using towed video

Manuscrito em preparação para ser submetido a revista Continental Shelf Research.

Fish distribution over the seascape of a tropical insular shelf using towed video

ABSTRACT

Seascape can be defined as a mosaic of spatially defined habitat patches, such as rhodolith beds, sand beds, seaweed banks, shallow-water reefs and mesophotic reefs, characterized by biotic and abiotic processes. Earlier studies in mesophotic zones were scarce and relied on extractive methods, such as trawls and dredges. In this study we used towed video method along the insular shelf of Fernando de Noronha Archipelago (FNA, Brazil) to evaluate the habitat and depth distribution of fish along the tropical insular shelf. In total, 49171 fishes distributed in 30 families were identified through video analyses, classified in 80 taxa at the level of 61 species, 13 genera and 6 families. Significant differences in the structure of fish assemblages were found between the Leeward and Windward Sides of FNA and between depth gradients, more specifically between Shallow (0 – 30 m) and other mesophotic zones (over 30 m) and between Upper (30 – 60 m) and Middle (60 – 90 m) mesophotic zones. Also, we identify shelf break points in the Windward Side as important fish aggregation sites, presenting unique species, among them commercially important fish and vulnerable species. Habitat types influenced on 24% of the total variation in fish assemblage structure. Further investigations in cross-shelf changes in currents and oceanographic conditions, especially at the shelf break, may better explain these variations. Furthermore, we found a new species record for the FNA: *Prognathodes guyanensis*, which occurred in the shelf break of the Windward Side, at the depth of approximately 80 m and nearby black corals. This finding not only shows a range extension record for the species, but also represents the incipient knowledge about the mesophotic ecosystems of FNA. Additionally, extensive rhodolith beds were found along the insular shelf of FNA, mainly on the Windward Side. Considering the presence of species categorized by IUCN as Vulnerable (4) or Data Deficient (7) and the well-known importance of rhodolith beds and mesophotic ecosystems, conservation measures for these regions should be considered in the management plan of the Marine Protected Areas of Fernando de Noronha.

Keywords: Fish assemblage structure; Video analyses; Rhodolith beds; Mesophotic ecosystems.

1. Introduction

Seascape can be defined as a mosaic of spatially defined habitat patches characterized by biotic and abiotic processes (Jones and Andrew, 1992). The application of ecology in seascape is relatively new and addresses the physical features of the ocean, including geomorphology and chemical properties, related to the ecology and biodiversity of species (Fuller, 2013). The physical and biological structure of habitats influence the distribution of fish, as well as the interactions of fish (habitat formers organisms) with the marine environment may characterize the habitat (Jones and Andrew, 1992).

The majority of fish species lives in tropical or subtropical waters (Eschmeyer et al., 2010) and approximately 40% of them dwelling associated to shallow continental shelves (Lowe-McConnell, 1999; Nelson, 2016). The cross-shelf distribution of reef fish is highly associated with the habitat types (Christensen et al., 2003). Fish community structure may vary according to the types of habitat, the distance between them and their area (Berkström et al., 2013). Furthermore, it can also present differences along shallow and mesophotic depth gradients (from 30 m to over 150 m deep), where species richness, abundance and biomass tend to decrease with increasing depths (Andradi-Brown et al., 2016).

Until recently, it was difficult to obtain devices and methods for conducting research in depths greater than 30 m (Menza et al., 2007). Earlier studies in mesophotic zones were scarce and relied on extractive methods, such as trawls and dredges (Kahng and Maragos, 2006; Bare et al., 2010). With the technological advancements and increased development of equipment, such as drop cameras, mesophotic areas have been better explored (Menza et al., 2007; Bare et al., 2010; Soares et al., 2019). Usually, the sample methods used for spatial monitoring of fish and associated habitats are underwater visual census (UVC), experimental fishing, acoustics, satellite images and underwater video (Murphy and Jenkins, 2010). Like UVC (Brock, 1954), underwater video records habitat features and produces data on species composition, lengths and taxonomy (Murphy and Jenkins, 2010). Furthermore, underwater videos can census habitats at depths and times that are risky for divers, reduce the impact of divers on fish behavior when deployed remotely, provide a permanent record of the census and are non-extractive (Cappo et al., 2003).

Tow video technique was first used by Machan and Fedra (1975), initially in shallow waters, where the camera was towed by a slow speed boat (0.1 - 1 $m.s^{-1}$) along pre-established transects (30 meters long) on a 30 km trajectory. The main advantage of this method is the ability to sample large areas in a short period of time, besides being considered efficient to analyze the benthic cover, perform habitat mapping and identify rare species (Morrison and Carbines, 2006; Mallet and Pelletier, 2014). Tow videos have been most used in studies focused on benthic macrofauna and macroflora, though some have examined demersal fish species (Mallet and Pelletier, 2014).

In Brazil, the usage of video is relatively recent (Dutra et al., 2006). It was first used to perform video transects for studying coral reefs in “Todos os Santos Bay” (Bahia, Brazil), with an adaptation of the methodology from Aronson and Swanson (1997) and Page et al. (2001) (Dutra et al., 2006). Thereafter, the video transect method was better described and tested in the work of Cruz et al. (2008), where the number of six video transects (20 m long each) was found as the lowest sampling effort to evaluate the coral community of the Itacolomis reefs, Bahia, Brazil. Previous studies have compared video transects with other methods (e.g. visual census) to verify their accuracy in data acquisition and they have found that: this technique is valid for observation and monitoring fish assemblages in high diversity ecosystems such as coral reefs (Pelletier et al, 2011); it is a very promising method for the management of marine protected areas (Tessier et al., 2013); the use of videos to measure fish size presents accurate data (Harvey et al., 2002) and it is better than the measurements made by divers (Cappo et al., 2003).

In the present work, we used an original system of cameras towed along the insular shelf of Fernando de Noronha Archipelago (FNA), Brazil, from depths of 2.5 m up to 115.7 m. The aim of this study is to determine and evaluate the habitat and depth distribution of fish along the tropical insular shelf of FNA. This study contributes to the understanding of the spatial variations of fish biodiversity through a non-invasive and non-destructive method to the environment. It may also assist in creating conservation strategies for the maintenance of marine biodiversity and its sustainable use.

2. Material and Methods

2.1. Study area

The study area is the insular shelf of the Fernando de Noronha Archipelago (FNA), which is composed by 21 islands and islets and it is located in the South Equatorial Atlantic Ocean (Assunção et al., 2016). The archipelago is situated 345 km away from the northeast coast of Brazil and it possess a total area of approximately 26 km^2 (Maida and Ferreira, 1997). However, 91% of the total area is constituted by the main island, which possess the same name of the archipelago (Assunção et al., 2016) (Fig.1).

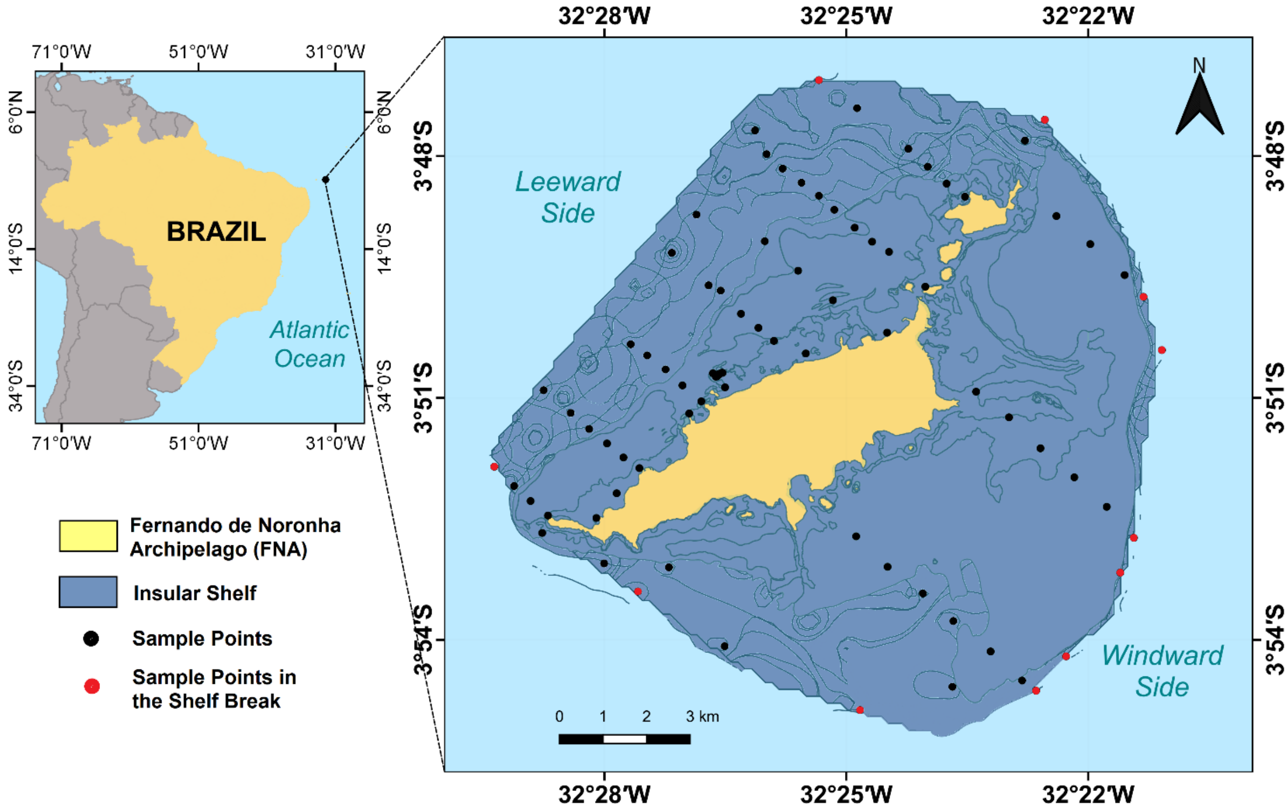


Fig.1. Study area with the video transects (sample points represent the start point of each video transect) along the insular shelf of Fernando de Noronha Archipelago, Brazil. Video transects performed in the shelf break are highlighted (red dots). Cartographic Base: In situ data combined with CPRM (2019) database. GCS_SIRGAS2000**.**

The climate of the FNA is tropical, the average air and sea water temperatures are 25.4ºC and 26-27ºC respectively and the average salinity is 36 (Maida and Ferreira, 1997). There are two well-marked seasons, the rainy from March to July and the dry from August to January (Almeida, 2006; Mohr et al., 2009). The morphological layout of the main island creates two different sides, the Leeward Side (LS), which faces the continent and where the sea is more protected from the action of winds and ocean currents, and the Windward Side (WS), facing the "open ocean" and where the sea is more exposed to these natural conditions (Ivar do Sul et al., 2009; Assunção et al., 2016).

In general, the insular shelf of the archipelago presents a diameter of 10 km and a break around the depth of 100 meters (Barcellos et al., 2011). The reefs are composed mainly of volcanic rocks, the reef cover is dominated by *Montastraea cavernosa* species (Krajewski and Floeter, 2011) and the substrate is covered predominantly by algae clumps and brown macroalgae (Wilson et. al., 2003). Fernando de Noronha is a marine national park protected legally by the Institute of Environmental Preservation of the Brazilian government, Chico Mendes Institute for the Conservation of the Biodiversity – ICMBio. Since 1988 fishing has been prohibited up to 50 meters deep and 70% of the coastal area has become a Marine Protected Area (Maida and Ferreira, 1997). The non-park area is designated for sustainable use, while in the park area it is not allowed the exploitation of any type of natural resources, although scientific, educational and recreational use is permitted (Maida and Ferreira, 1997).

2.2. Sampling and sample processing

Towed videos were performed along the insular shelf of Fernando de Noronha Archipelago in the Leeward Side in July 2016 and in the Windward Side in May 2017, both campaigns representing the rainy season (Fig.1). Experiments were carried out during the research expeditions from the project "Deep reefs of the Fernando de Noronha Archipelago: Mapping, connectivity and protection". Sampling was conducted using a system of three cameras (frontal, left side and right side) developed by M. Maida. The cameras were connected to a cable and towed from a vessel at an average speed of 1.16 knots for approximately 10 min. The side cameras were used to identify fishes only in case the frontal camera images were not enough to the identification.

The cable transmitted video signals in real-time to a laptop computer that displayed and recorded images. The real-time transmission assisted us in towing the camera system close to the substrate, at a constant height from the seafloor (about 1 m above the seabed), and quickly responding to depth changes. The transects were on average 400 m long and presented a distance of approximately 100 m between each other. The vessel's side scan sonar and a GPS were used to collect the water depths and the geographic coordinates of each video transect (Fig. 2).

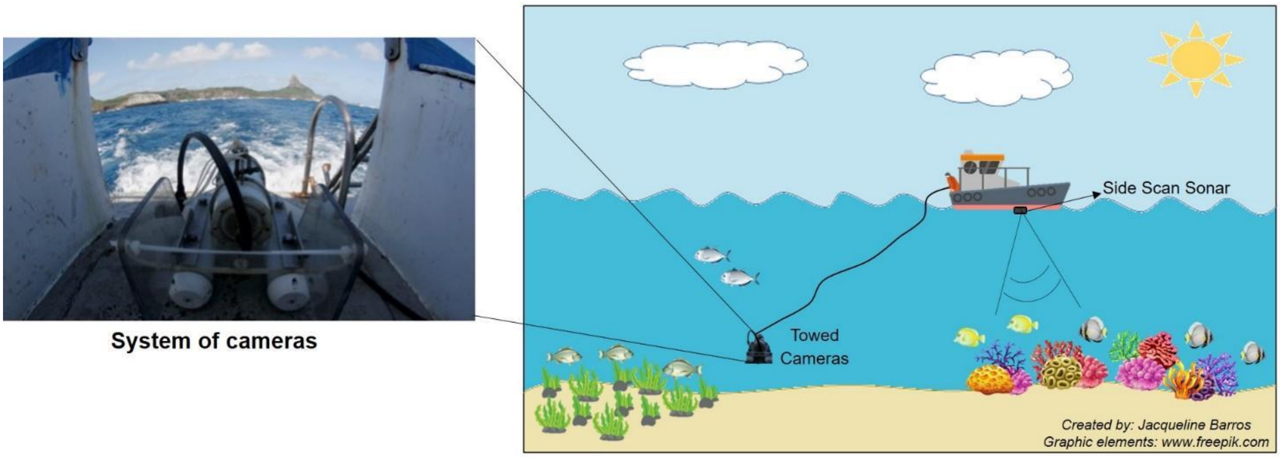


Fig. 2. Towed video methodology used along the insular shelf of the Fernando de Noronha Archipelago, Brazil.

A detailed video analysis was undertaken in order to characterize the sea bottom of each video transect. Each transect was divided into segments that corresponded to a dominant bottom feature (type of sediment and substrate coverage). Afterward, based on Eduardo et al. (2018), these analyses were combined with an adaptation of the methodology of Monaco et al. (2012) and we were able to identify five habitat types: (1) Reefs – Consolidated sediment covered mostly by colonies of corals , with the presence of sponges and algae; (2) Algae – Primarily seaweed banks dominated by green algae; (3) Sand - coarse sediment with few fine gravels and without any substrate coverage; (4) Sand with rocks, coralline formations and sponges (SWCS) - Mainly sand bottom with 20% or greater distribution of biogenic rocks, calcareous algae or green algae, corals and sponges; (5) Rhodoliths with coralline formation and sponges (RWCS) – Seabed covered predominantly by rhodoliths with 20% or greater distribution of calcareous algae or green algae, corals and sponges (Fig.3).

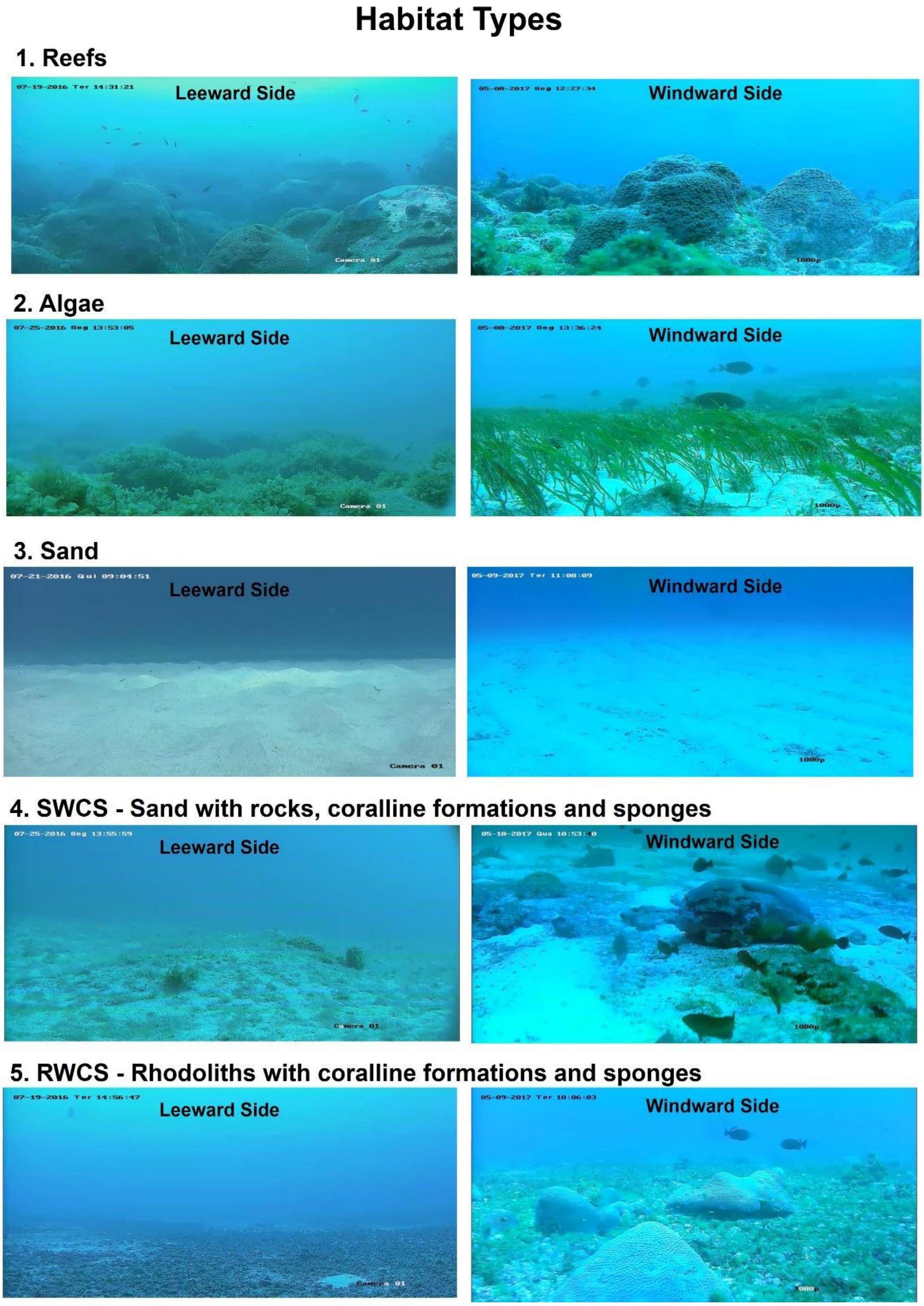


Fig.3. Images examples of habitat types that were identified in the video transects along the insular shelf of Fernando de Noronha Archipelago, Brazil.

According to the habitat types, all video transects were divided into sections. Using the length of each section we calculated the percentage of the five habitat types present in every video transects. In addition, we used depth classes based on Rocha et al. (2018) study and classified the video transects in: Shallow (depths up to 30 m), Upper Mesophotic (from 30 m to 60 m deep), Middle Mesophotic (from 60 m to 90 m deep) and Lower Mesophotic (depths over 90 m). Nine transects presented depths that converged two classes, such as Upper and Middle Mesophotic or Middle and Lower Mesophotic. Thus, we classified them at the class that represented most of the transect length.

Fishes were identified to the lowest possible taxonomic level and quantified to get the abundance of each species at each transect. When the image quality from the video footage was low, making it difficult to identify the species, higher levels of taxonomic identification were used, such as genus or family. Trained people performed visual census on videos based on fishes' identification guides (Lessa and Nóbrega, 2000; Humann and Deloach, 2002). Fish species and families were classified according to Craig and Hastings (2007), Nelson (2016) and Parenti and Randall (2018). Abundances were divided by the filming length of each video transect to obtain a standardized value (number of individuals) per meter, henceforth referred to as density (ind/m).

2.3. Data analyses

The variation of habitat types' lengths (in meters) was described in the Leeward and Windward Sides. We also described the relative composition of habitat types per depth classes. Then, density of fish was used to classify the relative abundance of species in High Abundant (HA) and Low Abundant (LA). Species presenting density greater than the average density of fish were considered HA, while species showing density lower than the average density of fish were considered LA (Garcia et al., 2006). We also classified the species according to the Brazilian IUCN Red List (ICMbio, 2016), which comprises 10 levels: 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 IUCN Red List methodology are publically available (IUCN, 2012, 2000). Thus, we built a checklist of fish species including the relative abundance classification in the Leeward and Windward Sides, depth distribution, the habitat types they occurred and the IUCN classification. Fish families were arranged in accordance with Nelson (2016) while genera and species were arranged in alphabetical order. Afterward, we selected the high abundant species to describe their habitat preferences.

Furthermore, we used the density of each species in the 85 video transects to investigate fish assemblage's structures. The density data was log-transformed (Log(x+1)) to reduce the effect of shoals in the analyses and we built a resemblance matrix based on Bray-Curtis similarity index. The Permutational multivariate analysis of variance (PERMANOVA), a non-parametric test, was performed with 4999 random permutations to test for differences between the fish assemblage's structures from the Leeward and Windward Sides and from the four depth classes (Anderson et al., 2008). The similarity percentage routine (SIMPER) was used to determine the species contribution to the dissimilarity between groups (Clarke, 1994). The set of species that cumulatively contributed to over 70% of dissimilarity between groups were classified as discriminating (Gregory et al., 2016).

Additionally, we separated the sample points in Shelf Break Points (SBP) and Remaining Sample Points (RSP) to test for differences between fish assemblages, due to a noticeable singularity we observed at the sample points in the shelf break, especially the ones in the Windward Side. For instance, it was remarkable in the Windward Side a great wall representing the shelf break point, with descending steps on the edge, followed by a sharp decline. It is also important to stress that black corals were the main coral present in these sites. For these reasons, we used PERMANOVA and SIMPER to investigate the differences between fish assemblages from the shelf break points (SBP) and remaining sample points (RSP), following the same statistical process mentioned above.

Finally, to investigate the correlation between habitat types and fish assemblage structure we first performed a RELATE test, using Spearman rank correlation method, to check the relation between the two set of samples (Clarke, 1994). Then, we applied a Distance-Based Linear Model (DistLM) to evaluate the influence of habitat types on the variability of fish data (Anderson et al., 2008). We adopted a stepwise procedure and used Akaike's information criterion (AIC). 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). All statistical analyses mentioned were performed using the software PRIMER6 + Permanova (Anderson et al., 2008) with a significant level of 0.05.

3. Results

In general, 85 video transects were carried out from the coast to the shelf break of the Fernando de Noronha Archipelago, corresponding to a total length of 35236 meters, with a depth range of 2.5 meters to 115.7 meters and approximately 20 hours of video. In the Leeward Side and in the Windward Side 17095 m and 18141 m in length were filmed, respectively. The largest habitat type in length in the insular shelf of FNA was RWCS, followed by SWCS, Sand, Reefs and Algae. RWCS was also the most representative habitat type in the Windward Side, while in the Leeward Side the composition of habitat types was more balanced, though SWCS was the largest in length (Fig. 4).

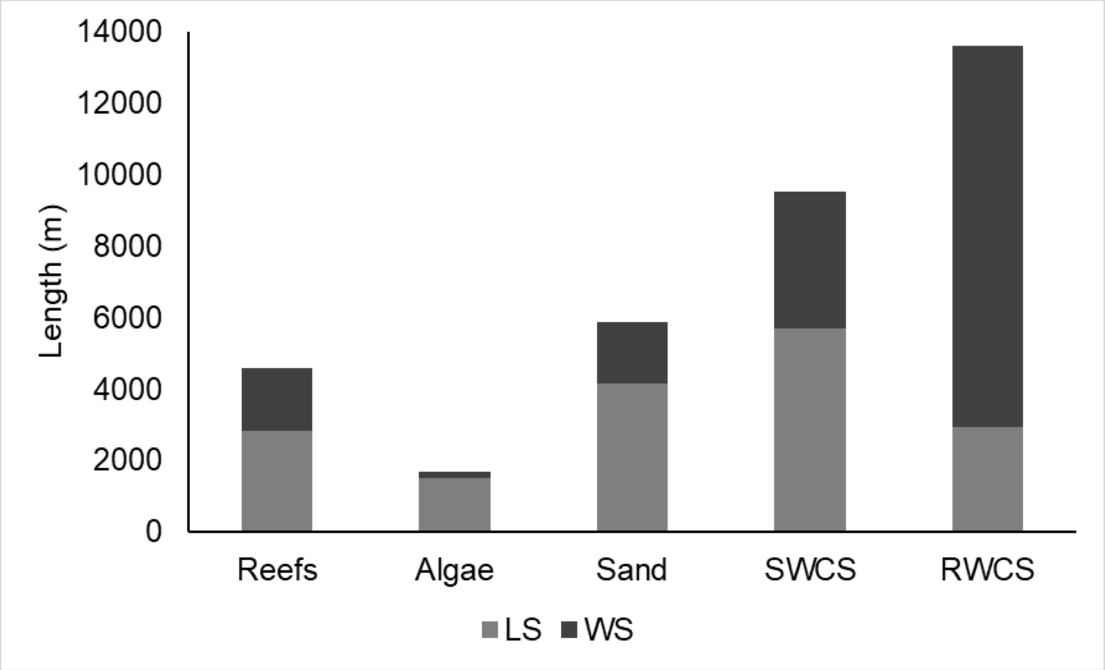


Fig. 4. Length in meters of habitat types (Reefs; Algae; Sand; SWCS – Sand with rocks, coralline formations and sponges; RWCS - Rhodoliths with coralline formation and sponges) filmed in the Leeward Side (LS) and in the Windward Side (WS) of the Fernando de Noronha Archipelago, Brazil.

The composition of habitat types per depth classes showed that Reefs and Algae were only present in Shallow and Upper Mesophotic transects, which indicates these habitat types did not occur at depths over 60 m. RWCS was more representative in the Upper and Lower Mesophotic transects, while SWCS represented the majority of the Middle Mesophotic transects' habitat composition (Fig. 5).

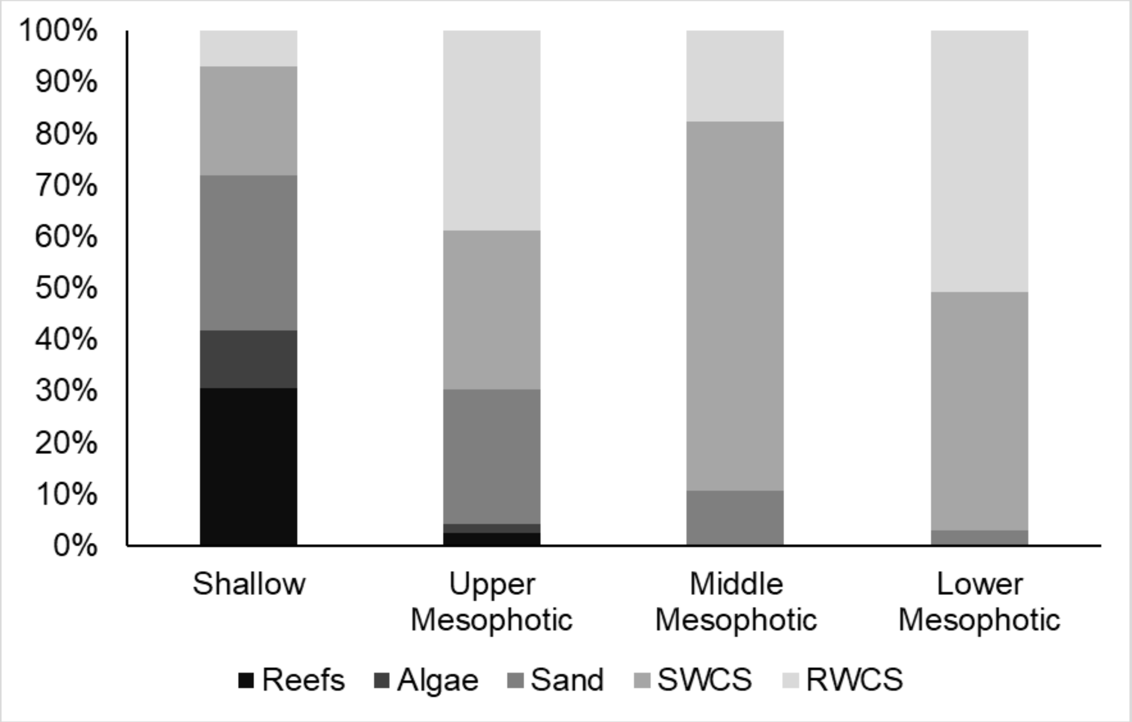


Fig. 5. Composition of habitat types (Reefs; Algae; Sand; SWCS – Sand with rocks, coralline formations and sponges; RWCS - Rhodoliths with coralline formation and sponges) in the four depth classes (Shallow: 0 – 30 m; Upper Mesophotic: 30 – 60 m; Middle Mesophotic: 60 – 90 m; Lower Mesophotic: over 90 m deep) of video transects performed along the insular shelf of the Fernando de Noronha Archipelago, Brazil.

In total, 49171 fishes distributed in 30 families were identified through video analyses, classified in 80 taxa at the level of 61 species, 13 genera and 6 families. In the Leeward Side 31185 fishes were classified in 67 taxa, at the level of 50 species, 12 genera and 5 families. Whereas 17986 fishes were identified in 67 taxa in the Windward Side, at the level of 53 species, 9 genera and 5 families. The average density of species was 7.63 ind/m and it was used to classify the relative abundance of each species in Low Abundant and High Abundant. Solely 11 taxa (10 species and one genus) were considered high abundant and four species were classified as

Vulnerable (*Ginglymostoma cirratum, Carcharhinus perezi, Stegastes rocasensis* and *Sparisoma axillare*) (Table 1).

Most of high abundant species occurred in all 5 habitat types, however distinct habitat preferences were observed among species. For instance, *Chromis multilineata, Paranthias furcifer* and *Thalassoma noronhanum* were more abundant in Reefs while *Heteroconger camelopardalis* and *Xyrichtys martinicensis* were more abundant in the Sand. Additionally, *Cephalopholis fulva, Holocentrus adscensionis, Stegastes pictus* and *Stegastes rocasensis* were more abundant in the RWCS habitat and *Melichthys niger* presented high abundance in Reefs and RWCS habitats (Fig. 6).

Table 1

List of families and species, relative abundance, depth distribution, habitat types and IUCN classification of fish recorded by tow video transects along the insular shelf of the Fernando de Noronha Archipelago, Brazil. Fish families are arranged in accordance with Nelson (2016); genera and species are arranged in alphabetical order. Relative abundance (LS: Leeward Side; WS: Windward Side): LA = Low Abundant; HA = High Abundant. Habitat types: 1 = Reefs; 2 = Algae; 3 = Sand; 4 = Sand with rocks, coraliine formations and sponges (SWCS); 5 = Rhodoliths with coralline formation and sponges (RWCS). IUCN classification: Vulnerable (VU), Near Threatened (NT), Least Concern (LC) and Data Deficient (DD).

Family	Species	Relative Abundance		Depth Distribution (m)	Habitat Types	IUCN
		LS	WS			
Ginglymostomatidae	*Ginglymostoma cirratum (Bonaterre, 1788)*	-	LA	45.4	5	VU
Carcharhinidae	*Carcharhinus perezi (Poey, 1876)*	LA	LA	6.8 - 53.3	1-3-4	VU
Dasyatidae	*Hypanus sp*	LA	LA	7.9 - 33.3	1-3-5	-
Muraenidae	*Gymnothorax funebris (Ranzani, 1840)*	-	LA	80.4	5	DD
Congridae	*Heteroconger camelopardalis (Lubbock, 1980)*	**HA**	**HA**	20.4 - 79.2	1-2-3-4-5	LC
Holocentridae	*Holocentrus adscensionis (Osbeck, 1765)*	**HA**	LA	4.6 - 115.7	1-2-3-4-5	LC
	Myripristis jacobus (Cuvier, 1829)	LA	LA	4.6 - 55.1	1-3-4-5	LC
Pomacentridae	*Abudefduf saxatilis (Linnaeus, 1758)*	LA	-	2.5 - 30	1-2-3-4	LC
	Chromis multilineata (Guichenot, 1853)	**HA**	**HA**	4.5 - 115.7	1-2-3-4-5	LC
	Stegastes pictus (Castelnau, 1855)	**HA**	**HA**	8.4 - 114.4	1-2-3-4-5	LC
	Stegastes rocasensis (Emery, 1972)	**HA**	**HA**	2.5 - 45.4	1-2-3-4-5	VU
	Stegastes sp	LA	LA	6.3 - 67.3	2-3-4-5	-
Opistognathidae	*Opistognathus sp*	LA	-	26.4 - 50.4	2-4	-
Blenniidae	*Blenniidae (not identified)*	LA	LA	5.1 - 54.2	4-5	-

	Ophioblennius sp	LA	-	34.8	3	-
Labrisomidae	*Labrisomidae (not identified)*	LA	-	57.1	5	-
Carangidae	*Carangidae (not identified)*	LA	LA	26.2 - 73.5	3-4-5	-
	Carangoides bartholomaei (Cuvier, 1833)	LA	LA	2.5 - 70.9	1-2-3-4-5	LC
	Caranx crysos (Mitchill, 1815)	LA	LA	14.2 - 46.7	1-2-3-4	LC
	Caranx hippos (Linnaeus, 1766)	-	LA	25.6	5	LC
	Caranx latus (Agassiz, 1831)	LA	-	9.8 - 76.3	1-3	LC
	Caranx lugubris (Poey, 1860)	LA	LA	21.5 - 84.2	1-5	LC
	Caranx ruber (Bloch, 1793)	LA	LA	6.6 - 64.7	1-4-5	LC
	Caranx sp	LA	LA	8.8 - 59.6	1-4-5	-
	Seriola rivoliana (Valenciennes, 1833)	LA	-	21.5 - 51.4	1-3-5	LC
	Trachinotus falcatus (Linnaeus, 1758)	LA	-	22.3 - 51.6	1-4	LC
Sphyraenidae	*Sphyraena barracuda (Edwards, 1771)*	LA	LA	11.2 - 55.3	1-2-3-4-5	LC
Dactylopteridae	*Dactylopterus volitans (Linnaeus, 1758)*	LA	LA	9.3 - 70.9	2-3-4-5	LC
Labridae	*Bodianus pulchellus (Poey, 1860)*	-	LA	36.1	1	LC
	Halichoeres dimidiatus (Agassiz, 1831)	LA	LA	4.6 - 74	1-2-3-4-5	LC
	Halichoeres radiatus (Linnaeus, 1758)	LA	LA	2.5 - 57.8	1-2-3-4-5	LC
	Halichoeres sp	LA	LA	6.7 - 46.9	2-4-5	-
	Labridae (not identified)	LA	LA	26.5 - 74.4	1-3-4-5	-
	Thalassoma noronhanum (Boulenger, 1890)	**HA**	**HA**	2.5 - 63.2	1-2-3-4-5	LC
	Xyrichtys martinicensis (Valenciennes, 1840)	**HA**	LA	4.6 - 73.5	1-2-3-4-5	LC
	Xyrichtys sp	**HA**	LA	14.2 - 69.9	1-2-3-4-5	-
Scaridae	*Sparisoma amplum (Ranzani, 1841)*	LA	LA	5.0 - 45.4	1-2-3-5	LC
	Sparisoma axillare (Steindachner, 1878)	LA	LA	6.7 - 46.6	1-2-3-4-5	VU
	Sparisoma radians (Valenciennes, 1840)	LA	LA	13.7 - 38.6	1-5	LC
	Sparisoma sp	LA	LA	4.6 - 69.9	1-2-3-5	-
Mullidae	*Mulloidichthys martinicus (Cuvier, 1829)*	LA	LA	5.0 - 59.6	1-2-3-4-5	LC
	Pseudupeneus maculatus (Bloch, 1793)	LA	LA	4.6 - 76.3	1-3-4-5	LC
Kyphosidae	*Kyphosus sectatrix (Linnaeus, 1758)*	LA	-	2.5 - 60.9	1-2-3-4-5	LC
Serranidae	*Alphestes afer (Bloch, 1793)*	LA	-	6.7	2	LC
	Cephalopholis fulva (Linnaeus, 1758)	**HA**	**HA**	4.5 - 114.4	1-2-3-4-5	LC
	Dermatolepis inermis (Valenciennes, 1833)	-	LA	79 - 83.3	5	DD
	Menophorus dubius (Smith, 1966)	-	LA	34.9 - 80.4	4-5	-
	Mycteroperca sp	-	LA	79.5 - 81.6	5	-
	Paranthias furcifer (Valenciennes, 1828)	LA	**HA**	4.6 - 84.2	1-3-4-5	LC
Chaetodontidae	*Chaetodon ocellatus (Bloch, 1787)*	LA	LA	9.9 - 114.4	1-2-3-4-5	DD

	Prognathodes guyanensis (Durand, 1960)	-	LA	80.4	5	LC
Pomacanthidae	*Centropyge aurantonotus (Burgess, 1974)*	LA	LA	24.8 - 55.9	5	DD
	Holacanthus ciliaris (Linnaeus, 1758)	-	LA	46.8	1	DD
	Holacanthus tricolor (Bloch, 1795)	-	LA	83.3	4	DD
	Pomacanthus paru (Bloch, 1787)	LA	LA	17.5 - 78.8	1-4-5	LC
Malacanthidae	*Malacanthus plumieri (Bloch, 1786)*	LA	LA	9.9 - 114.4	1-2-3-4-5	LC
Haemulidae	*Anisotremus surinamensis (Bloch, 1791)*	LA	LA	6.3 - 55.1	1-3-4-5	DD
	Haemulon chrysargyreum (Günther, 1859)	LA	-	2.5 - 18	1-2-4	LC
	Haemulon parra (Desmarest, 1823)	LA	LA	4.6 - 54.2	1-3-4-5	LC
	Haemulon sp	LA	-	8.4 - 30	1-2-3	-
Lutjanidae	*Lutjanus jocu (Bloch & Schneider, 1801)*	LA	LA	2.5 - 81.6	1-2-4-5	NT
Acanthuridae	*Acanthurus chirurgus (Bloch, 1787)*	LA	LA	6.7 - 59.6	1-2-4-5	LC
	Acanthurus coeruleus (Bloch & Schneider, 1801)	LA	LA	6.8 - 54.2	1-2-3-4-5	LC
	Acanthurus sp	LA	LA	4.5 - 114.4	1-2-3-4-5	-
Sparidae	*Calamus pennatula (Guichenot, 1868)*	LA	LA	49.3 - 53.1	5	LC
Antennariidae	*Antennarius sp*	LA	-	50.2 - 70.1	4-5	-
Ostraciidae	*Acanthostracion polygonius (Poey, 1876)*	LA	LA	4.6 - 43	1-2-4-5	LC
	Lactophrys trigonus (Linnaeus, 1758)	LA	LA	9.3 - 74	1-3-4-5	LC
	Ostraciidae (not identified)	LA	LA	18.5 - 73.5	1-4-5	-
Balistidae	*Balistes vetula (Linnaeus, 1758)*	LA	LA	40.9 - 56.1	5	NT
	Melichthys niger (Bloch, 1786)	**HA**	**HA**	4.6 - 57.8	1-2-3-4-5	LC
	Xanthichthys ringens (Linnaeus, 1758)	-	LA	26 - 55.1	1-4-5	LC
Monacanthidae	*Aluterus monoceros (Linnaeus, 1758)*	LA	LA	35.1 - 54.2	4-5	NT
	Aluterus scriptus (Osbeck, 1765)	LA	LA	8.1 - 56.8	1-5	LC
	Aluterus sp	LA	LA	20.2 - 41.4	4-5	-
	Cantherhines macrocerus (Hollard, 1853)	LA	LA	2.5 - 72.3	1-2-3-4-5	LC
	Cantherhines pullus (Ranzani, 1842)	LA	-	6.3	3	LC
	Canthidermis sufflamen (Mitchill, 1815)	LA	LA	21.5 - 78.7	1-2-5	LC
	Monacanthidae (not identified)	-	LA	40.8 - 41.1	5	-
Diodontidae	*Diodon holocanthus (Linnaeus, 1758)*	-	LA	43.9	4	LC

The PERMANOVA results showed significant difference in fish assemblage's structure between sea sides (Leeward Side - LS and Windward Side - WS; p = 0.0006) and among the depth classes (p = 0.0008). The pair-wise test for depth classes showed that the fish assemblage structure of Shallow transects were significantly different from those of Mesophotic transects. There was also significant difference in the structure of fish assemblages between Upper and Middle Mesophotic transects (Table 2).

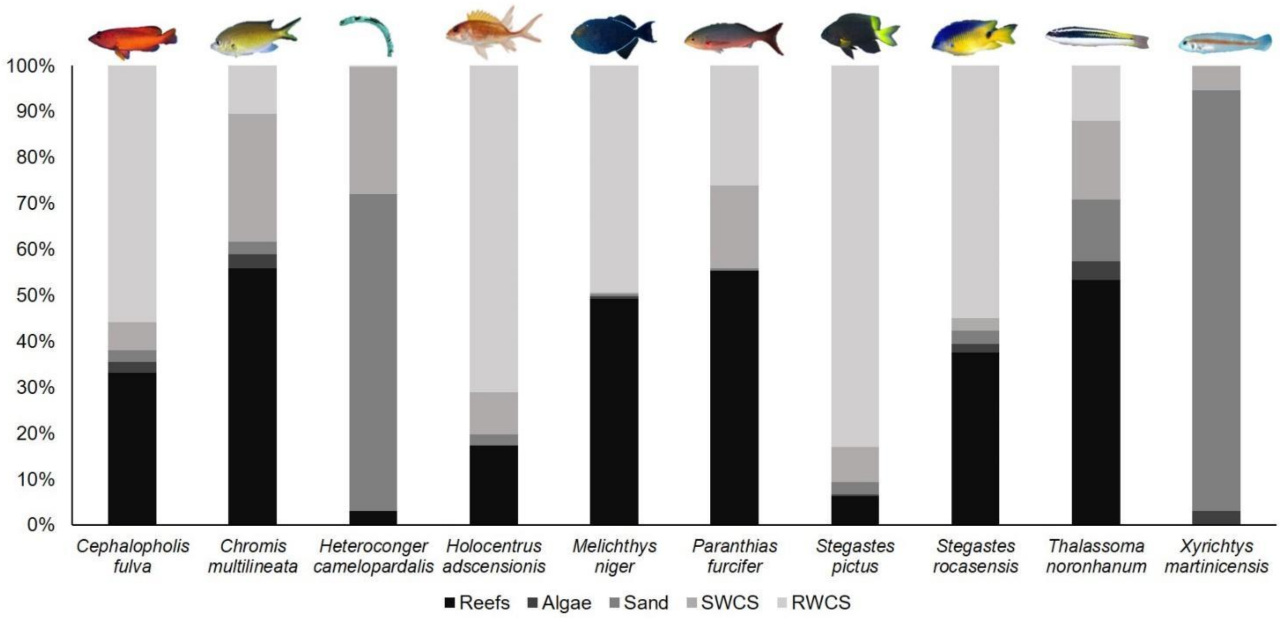


Fig. 6. Habitat types preferences (Reefs; Algae; Sand; SWCS – Sand with rocks, coralline formations and sponges; RWCS - Rhodoliths with coralline formation and sponges) according to the density (ind/m) of the 10 High Abundant fish species from video transects performed along the insular shelf of the Fernando de Noronha Archipelago, Brazil.

Table 2

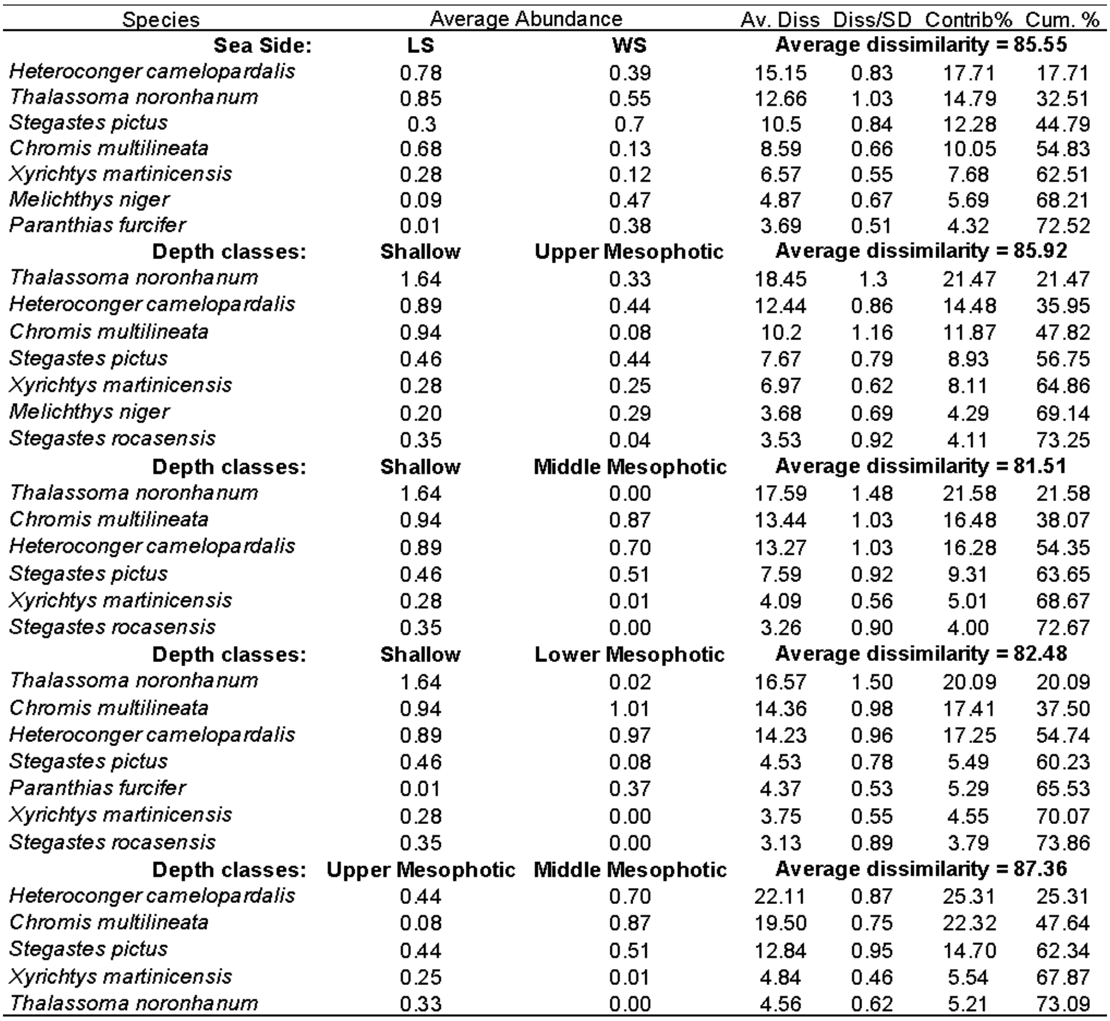
PERMANOVA results regarding the density (ind/m) of fish between Sea Sides (Leeward Side X Windward Side) and among the depth classes (Shallow: 0 – 30 m; Upper Mesophotic: 30 – 60 m; Middle Mesophotic: 60 – 90 m; Lower Mesophotic: over 90 m deep) of video transects performed along the insular shelf of the Fernando de Noronha Archipelago, Brazil. Df = degrees of freedom; SS = sum of squares; MS = mean sum of squares; Pseudo-F = F value by permutation; P (perm) = statistical significance; Unique perms = number of unique permutations; t = Student´s t test.

Source	df	SS	MS	Pseudo-F	P (perm)	Unique perms
Sea Sides	1	10582	10582	3.3185	0.0006	4985
Depth Classes	3	20907	6968.9	2.1855	0.0008	4977
Pair-wise Tests				t	P (perm)	Unique perms
Shallow X Upper Mesophotic				16.7280	0.0052	4981
Shallow X Middle Mesophotic				1.8677	0.0052	4982
Shallow X Lower Mesophotic				1.5771	0.0312	4986
Upper Mesophotic X Middle Mesophotic				1.3864	0.0340	4972
Upper Mesophotic X Lower Mesophotic				1.1614	0.1690	4974
Middle Mesophotic X Lower Mesophotic				0.7516	0.7076	4781

SIMPER analysis showed that discriminating species (those cumulatively contributing to over 70% of the dissimilarity) ranged from 5 to 7 species. *Thalassoma noronhanum, Xyrichtys martinicensis*, *Stegastes pictus, Chromis multilineata* and *Heteroconger camelopardalis* were among the discriminating species of all groups comparisons, where the former was always in the top three. Dissimilarities in the structure of fish assemblages between Leeward and Windward Sides and between depth classes were driven mostly by differences in average abundance rather than presence/absence (Table 3).

Table 3

SIMPER results of fish species cumulatively contributing to over 70% of dissimilarity between Sea Sides (LS = Leeward Side; WS = Windward Side) and between the depth classes (Shallow: 0 – 30 m; Upper Mesophotic: 30 – 60 m; Middle Mesophotic: 60 – 90 m; Lower Mesophotic: over 90 m deep) that presented significant differences in fish assemblage structure at the insular shelf of the Fernando de Noronha Archipelago, Brazil. Av. Diss = average dissimilarity; Diss/SD = ration between dissimilarity and standard deviation; Contrib% = percentage of dissimilarity contribution; Cum% = cumulative percentage of the total dissimilarity.



Species	Average Abundance		Av. Diss	Diss/SD	Contrib%	Cum. %
Sea Side:	**LS**	**WS**	**Average dissimilarity = 85.55**			
Heteroconger camelopardalis	0.78	0.39	15.15	0.83	17.71	17.71
Thalassoma noronhanum	0.85	0.55	12.66	1.03	14.79	32.51
Stegastes pictus	0.3	0.7	10.5	0.84	12.28	44.79
Chromis multilineata	0.68	0.13	8.59	0.66	10.05	54.83
Xyrichtys martinicensis	0.28	0.12	6.57	0.55	7.68	62.51
Melichthys niger	0.09	0.47	4.87	0.67	5.69	68.21
Paranthias furcifer	0.01	0.38	3.69	0.51	4.32	72.52
Depth classes:	**Shallow**	**Upper Mesophotic**	**Average dissimilarity = 85.92**			
Thalassoma noronhanum	1.64	0.33	18.45	1.3	21.47	21.47
Heteroconger camelopardalis	0.89	0.44	12.44	0.86	14.48	35.95
Chromis multilineata	0.94	0.08	10.2	1.16	11.87	47.82
Stegastes pictus	0.46	0.44	7.67	0.79	8.93	56.75
Xyrichtys martinicensis	0.28	0.25	6.97	0.62	8.11	64.86
Melichthys niger	0.20	0.29	3.68	0.69	4.29	69.14
Stegastes rocasensis	0.35	0.04	3.53	0.92	4.11	73.25
Depth classes:	**Shallow**	**Middle Mesophotic**	**Average dissimilarity = 81.51**			
Thalassoma noronhanum	1.64	0.00	17.59	1.48	21.58	21.58
Chromis multilineata	0.94	0.87	13.44	1.03	16.48	38.07
Heteroconger camelopardalis	0.89	0.70	13.27	1.03	16.28	54.35
Stegastes pictus	0.46	0.51	7.59	0.92	9.31	63.65
Xyrichtys martinicensis	0.28	0.01	4.09	0.56	5.01	68.67
Stegastes rocasensis	0.35	0.00	3.26	0.90	4.00	72.67
Depth classes:	**Shallow**	**Lower Mesophotic**	**Average dissimilarity = 82.48**			
Thalassoma noronhanum	1.64	0.02	16.57	1.50	20.09	20.09
Chromis multilineata	0.94	1.01	14.36	0.98	17.41	37.50
Heteroconger camelopardalis	0.89	0.97	14.23	0.96	17.25	54.74
Stegastes pictus	0.46	0.08	4.53	0.78	5.49	60.23
Paranthias furcifer	0.01	0.37	4.37	0.53	5.29	65.53
Xyrichtys martinicensis	0.28	0.00	3.75	0.55	4.55	70.07
Stegastes rocasensis	0.35	0.00	3.13	0.89	3.79	73.86
Depth classes:	**Upper Mesophotic**	**Middle Mesophotic**	**Average dissimilarity = 87.36**			
Heteroconger camelopardalis	0.44	0.70	22.11	0.87	25.31	25.31
Chromis multilineata	0.08	0.87	19.50	0.75	22.32	47.64
Stegastes pictus	0.44	0.51	12.84	0.95	14.70	62.34
Xyrichtys martinicensis	0.25	0.01	4.84	0.46	5.54	67.87
Thalassoma noronhanum	0.33	0.00	4.56	0.62	5.21	73.09

In regard to the shelf break points, we did not find significant difference between the structure of fish assemblages from the shelf break points and the remaining sample points in the insular shelf of FNA. However, when testing separately the Leeward and Windward Sides data, PERMANOVA results showed significant difference in the fish assemblages structure between shelf break points and remaining sample points from the Windward Side (Table 4). Additionally, SIMPER analysis found 7 discriminating species, with dissimilarities caused mainly by differences in average abundance rather than presence/absence (Table 5). However, it is noteworthy that we observed 10 unique species in these shelf break points: *Bodianus pulchellus, Dermatolepis inermis, Diodon holocanthus, Ginglymostoma cirratum, Gymnothorax funebris, Holacanthus ciliaris, Holacanthus tricolor, Menophorus dubius, Mycteroperca sp* and *Prognathodes guyanensis*.

Table 4

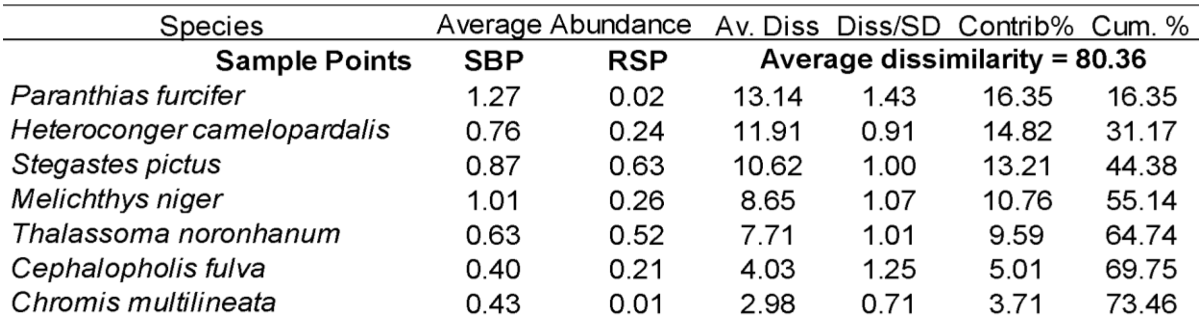
PERMANOVA results regarding the density (ind/m) of fish among sample points (SBP = Shelf Break Points; RSP = Remaining Sample Points) in the insular shelf of the Fernando de Noronha Archipelago, Brazil. Df = degrees of freedom; SS = sum of squares; MS = mean sum of squares; Pseudo-F = F value by permutation; P (perm) = statistical significance; Unique perms = number of unique permutations; t = Student´s t test.

Source	df	SS	MS	Pseudo-F	P (perm)	Unique perms
Sample Points	1	5269.9	5269.9	1.4805	0.1386	4980
Pair-wise Tests				t	P (perm)	Unique perms
Within level LS:						
RSP X SBP				0.8712	0.7042	1424
Within level WS:						
RSP X SBP				1.5002	0.0348	4973

Finally, the correlation between habitat types and fish assemblage structure were confirmed by the RELATE test using the Spearman rank correlation method (Rho = 0.309; p = 0.0002). The DistLM showed that 24% of the total variation in fish assemblage structure are explained by the model, which identified 4 significant habitat types: Sand, which explained the largest proportion of the variation in the fish assemblage (8%), followed by Reefs (7%), RWCS (5%) and SWCS (4%) (Table 6). The graphical response of DistLM provided by dbRDA, which pointed the direction and magnitude of the relationship between habitat types and fish assemblage, also indicated a relationship between Reefs and Algae with the depth class Shallow (Fig. 7).

Table 5

SIMPER results of fish species cumulatively contributing to over 70% of dissimilarity between the Shelf Break Points (SBP) and Remaining Sample Points (RSP) from the Windward Side (WS) of the insular shelf of the Fernando de Noronha Archipelago, Brazil. Av. Diss = average dissimilarity; Diss/SD = ration between dissimilarity and standard deviation; Contrib% = percentage of dissimilarity contribution; Cum% = cumulative percentage of the total dissimilarity.



Species	Average Abundance		Av. Diss	Diss/SD	Contrib%	Cum. %
Sample Points	**SBP**	**RSP**	**Average dissimilarity = 80.36**			
Paranthias furcifer	1.27	0.02	13.14	1.43	16.35	16.35
Heteroconger camelopardalis	0.76	0.24	11.91	0.91	14.82	31.17
Stegastes pictus	0.87	0.63	10.62	1.00	13.21	44.38
Melichthys niger	1.01	0.26	8.65	1.07	10.76	55.14
Thalassoma noronhanum	0.63	0.52	7.71	1.01	9.59	64.74
Cephalopholis fulva	0.40	0.21	4.03	1.25	5.01	69.75
Chromis multilineata	0.43	0.01	2.98	0.71	3.71	73.46

Table 6

DistLM results with p-value of the permutation and the percentage of explanation of habitat types (Reefs; Algae; Sand; SWCS – Sand with rocks, coralline formations and sponges; RWCS - Rhodoliths with coralline formation and sponges) for the total variation in fish assemblage structure at the insular shelf of the Fernando de Noronha Archipelago, Brazil.

Habitat Types	P (perm)	Proportion (%)
Reefs	0.0002	7
Algae	0.3178	1
Sand	0.0002	8
SWCS	0.0012	4
RWCS	0.0002	5

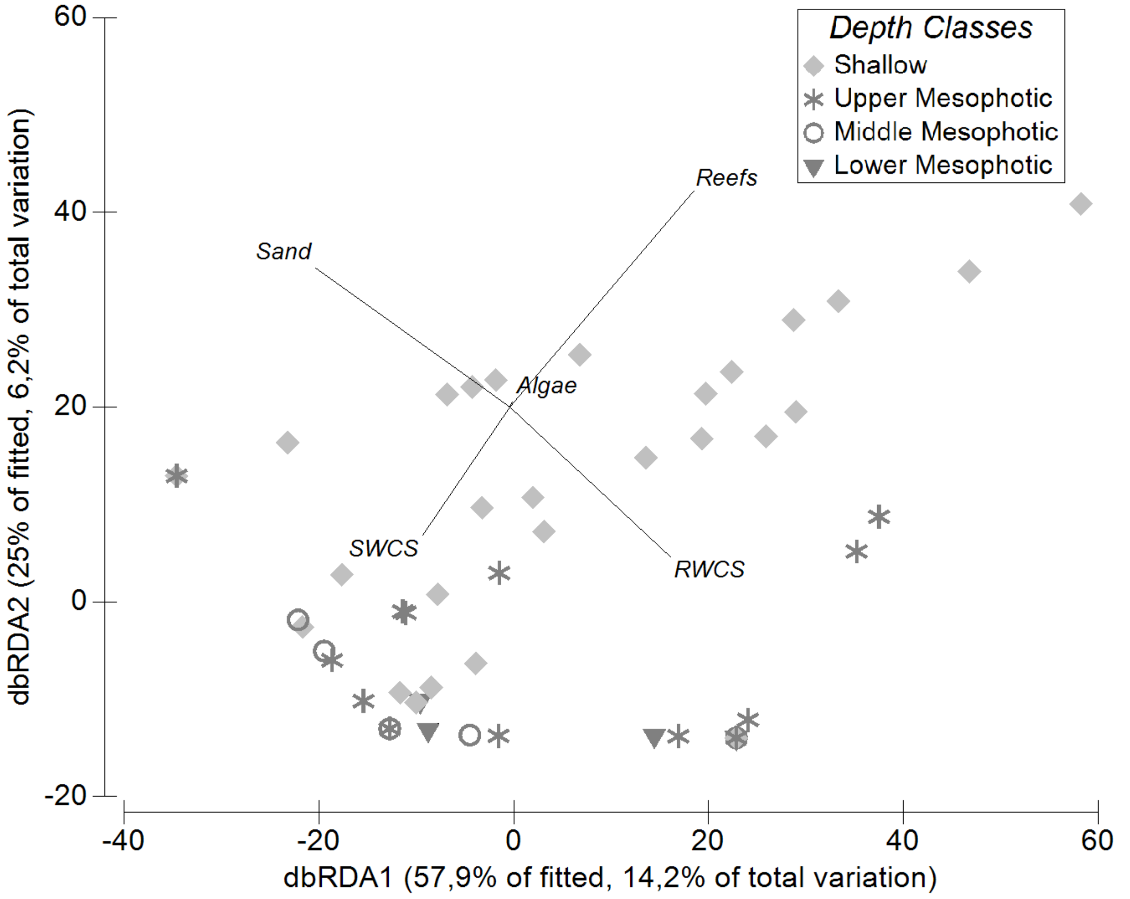


Fig. 7. Distance-based redundancy analysis (dbRDA) plot to visualize in a two-dimensional space the influence of habitat types (Reefs; Algae; Sand; SWCS – Sand with rocks, coralline formations and sponges; RWCS - Rhodoliths with coralline formation and sponges) on the total variation in fish assemblage structure at the insular shelf of the Fernando de Noronha Archipelago, Brazil. Symbols represent the depth classes (Shallow: 0 – 30 m; Upper Mesophotic: 30 – 60 m; Middle Mesophotic: 60 – 90 m; Lower Mesophotic: over 90 m deep) used to classify the video transects. Vectors length is proportional to their contribution to the total variation (see Table 4).

4. Discussion

The seascape of the insular shelf of the Fernando de Noronha Archipelago can be visualized as a series of dispersed patches of reefs, sand bottom, rhodoliths (RWCS) and sand with rocks, corals and sponges (SWCS). The seaweed banks (Algae habitat type) did not have a significant representation in the seascape mosaic. Shallow transects were mostly an alternation of Reefs and Sand patches, with SWCS habitat functioning as a transition zone between them. Although Reefs represented a small percentage in the Upper Mesophotic transects and were absent in the other mesophotic classes, it is noteworthy that corals were present in the SWCS and RWCS, which were the main habitat types in the mesophotic classes, indicating the presence of mesophotic coral ecosystems (MCEs).

MCEs are defined by the presence of light-dependent corals and associated organisms that are commonly found in shallow coral reefs (up to 30 m deep) and extending to over 150 m deep in tropical and subtropical areas (Hinderstein et al., 2010; Baker et al., 2016). They are likely to have physical, chemical and biological connectivity with shallow reefs and associated communities, as well as unique assemblages, and extensions to deep biota (Hinderstein et al., 2010). It is noteworthy that black corals were found in SWCS and RWCS when the video transect sections approached the shelf break zone, where their presence was probably associated to increased productivity caused by possible local upwelling (Campos et al., 2000; Zhang, et al., 2013).

On the other hand, RWCS can be referred as rhodolith beds, since the coverage by rhodoliths is the main feature of this habitat type. Rhodolith beds are formed by aggregates of nodules of crustose coralline algae (CCA), which are rock-hard calcareous red algae (Foster, 2001). The largest rhodolith beds in the world are known to be along the eastern Brazilian continental shelf (Kempf, 1970; Milliman and Amaral, 1974; Foster, 2001). Rhodolith beds have been described in the FNA (Amado-Filho et al., 2012b), Abrolhos (Amado-Filho et al., 2012a), Salvador (Bahia et al., 2010) and Vitória-Trindade Chain (Pereira-Filho, et al., 2012). Although RWCS were observed at all depth classes, they represented the main habitat type in the Upper and Lower mesophotic transects. Nevertheless, our results indicate that the rhodolith beds occur in the same depth window (0 – 70 m depth) pointed by Vecsei (2004) and also in a similar depth distribution (10 – 100 m) found by Amado-Filho et al., (2012b) in Fernando de Noronha.

In general, fish assemblages are dominated by few high abundant species, which is common in oceanic islands in the Atlantic (Floeter et al., 2001; 2008; Ferreira et al., 2004; Krajewski and Floeter, 2011). Pomacentridae and Labridae were the families representing most of high abundant species. This result was expected since the pomacentrids are among the most speciose dwellers on tropical reefs (Allen, 1991) and together with the labrids rank among the ten richest families worldwide (Thresher, 1991). Additionally, previous studies have found the Noronha wrasse *Thalassoma noronhanum* as the most abundant species in Fernando de Noronha (Krajewski and Floeter, 2011; Medeiros et al., 2011).

Most of the research conducted in Fernando de Noronha so far has been restricted to shallow- water depths (up to 30 m) and studies in mesophotic zones are still scarce (Amado-Filho et al., 2012b; Pereira-Filho et al., 2015; Santos et al., 2016). The shallow zone represented a region of high density of fish, since most of high abundant species were found in this zone and presenting higher densities in relation to mesophotic depths. Six out of the 10 high abundant species (*Thalassoma noronhanum, Chromis multilineata, Stegastes rocasensis, Cephalopholis fulva, Melichthys niger* and *Holocentrus adscensionis*) coincided with the top most abundant species of other studies conducted in shallow reefs of Fernando de Noronha (Krajewski and Floeter, 2011).

Although mesophotic zones (especially the upper zone) are regarded as extensions of shallow-water reef fish community, since both ecosystems share some species (Kahng et al., 2017), it is common to find variations in fish biodiversity or a turnover of species (Pinheiro et al., 2016; Rosa et al., 2016; Semmler et al., 2017). The significant differences we found between the structure of fish assemblages from different depth classes are similar to the results of Rosa et al. (2016) and Semmler et al. (2017) studies. The former identified distinct fish assemblages in the depth strata of 30-50 m and of 50-90 m, and the latter found a species turnover at approximately 60 m deep.

Here we identified a clear depth gradient, where the depths of 30 m and 60 m can be considered important marks in the vertical distribution of fish. The discriminating species between Shallow and Upper Mesophotic classes that presented higher differences in average abundance, being more abundant in the Shallow, were the reef fish *Thalassoma noronhanum, Chromis multilineata* and *Stegastes rocasensis*. Though the latter demonstrated a higher preference by RWCS habitat type, which was more common in the Upper Mesophotic zone, these species demonstrated considerable preference by Reefs, which presented larger extensions in the Shallow.

In addition to habitat types, fish swimming capacity and possible interspecies competition interactions may have influenced in these differences. For instance, *Melichthys niger,* which was the only discriminating species more abundant in the Upper Mesophotic than in the Shallow, was observed in the St. Peter and St. Paul’s Archipelago (SPSPA) presenting higher abundances in deeper areas due to its swimming capabilities and competition with other species (Mendes et al., 2019). The balistiform swimming (Sfakiotakis et al., 1999) of this species may have prevented it from reaching high densities in shallow, as well as interactions with potential territorial competitors in the shallow, such as *Stegastes spp,* may have induced *Melichthys niger* into deeper areas (Mendes et al., 2019).

Furthermore, we believe the differences in the structure of fish assemblages between upper and middle mesophotic classes were mainly influenced by other factors rather than habitat types, since species with same habitat preferences presented different distribution patterns. Other aspects such as feeding habits, benthic cover and cross-shelf changes in currents and oceanographic conditions may have influenced for these differences (Pinheiro et al., 2016; Rosa et al., 2016; Semmler et al., 2017).

We also found fish assemblage structure is significantly different in the Leeward and Windward Sides. Colonies of *Heteroconger camelopardalis*, commonly known as “eel garden”, have been registered in the Leeward side, taking shelter in burrows with the tail buried in the sediment and the heads facing the current, about 30 cm apart (Soto, 2001). This species was the one that most contributed to the difference between Leeward and Windward Sides, being more abundant in the Leeward Side. We believe this result and also the higher abundance of *Xyrichtys martinicensis* in this side is related to the predominance of Sand and SWCS habitat types in the Leeward Side, since these species occur mainly on extensive sand bottoms (Victor, 1987; Tyler and Luckhurst, 1994).

Furthermore, the larger extensions of Reefs habitat type in the Leeward Side probably influenced the higher abundance of the reef fish *Thalassoma noronhanum* and *Chromis multilineata*. However, *Melichthys niger,* which showed preference by Reefs and SWCS habitat types, was more abundant in the Windward Side. Although the black durgon *Melichthys niger* is reef-associated, this species is unusual among reef fish and other balistids (Kavanagh and Olney, 2006). It has highly plastic feeding capabilities and it is commonly seeing forming dense aggregations, showing variations among sites in population density and diet (Kavanagh and Olney, 2006). Possibly, the existence of potential reef fish competitors in the Leeward Side, such as *Abudefduf saxatilis* (Mendes et al., 2019) that only occurred in the Leeward Side, may have affected its higher abundance in the Windward Side. Also, its adaptability and ability to perceive its surroundings may be considered as other important aspects (Sazima et al., 2006).

Additionally, *Stegastes pictus* was also more abundant in the Windward Side and we believe this is mainly influenced by the larger extensions of rhodolith beds in the Windward Side, as our results for this species showed a high preference for RWCS habitat type. The rhodolith beds were also a preferred habitat type for *Cephalopholis fulva, Holocentrus adscensionis* and *Stegastes rocasensis.* Amado-Filho et al. (2016) study also found these species associated with rhodolith beds. This habitat has demonstrated to be an important bottom feature in the development of necktobenthic fish, contributing as refuge and with food resources in flattened areas between mesophotic scattered reefs, especially in oligotrophic oceanic areas (Pinheiro et al. 2014; Ordines et al. 2015). The larger extensions of rhodoliths in the Windward Side may be associated to its higher hydrodynamic in relation to the Leeward Side, since the physical transport through currents increases rhodolith dispersion (Prager and Ginsburg, 1989).

The shelf break points in the Windward Side displayed important differences in the structure of fish assemblages related to the remaining sample points. The creole-fish *Paranthias furcifer* was more abundant in the shelf break points and it is the species that most contributed to the differences in the structure of fish assemblages between shelf break points and remaining sample points in the Windward Side. The large aggregations of this species coincided with the dominance of black corals observed at the shelf break and as already observed, associations between *Paranthias furcifer* and these corals are common (Morais and Maia, 2017; Francini-Filho et al., 2018; Soares et al., 2019). Other species were only found in the shelf break, such as the commercially important fish *Mycteroperca spp.,* the hybrid fish *Menophorus dubius* (from *Cephalopholis fulva* and *Paranthias furcifer, or Cephalopholis furcifer, as proposed by* Craig et al. (2001)) (Poey, 1860; Smith, 1966; Thompson and Munro, 1978) and the vulnerable nurse shark *Ginglymostoma cirratum* (Garla et al., 2017).

In addition, a new species record for the Fernando de Noronha Archipelago was found at the shelf break points: the butterfly fish *Prognathodes guyanensis,* represented by a single individual at the depth of approximately 80 m and nearby black corals. The genus *Prognathodes* contain 13 species, seven from the Atlantic Ocean, including three (*P. brasiliensis, P. guyanensis* and *P. obliquus*) present in Brazil (Copus et al. 2019). These species preferentially inhabit deep waters, rarely seen above 15 meters deep, mostly in oceanic islands (Pinheiro et al. 2015). In Brazil, *Prognathodes guyanensis* is associated with lower mesophotic depths (80–150 m) and it has been registered in Arraial do Cabo and Ilha Grande (RJ), São Paulo, Espírito Santo, Abrolhos, Vitória-Trindade Chain and Rio Grande do Norte (Floeter et al., 2003; Ferreira et al., 2007; Luiz Jr et al., 2008; Francini-Filho et al. 2018). In the FNA only *P. brasiliensis* had been registered and *P. obliquus* is endemic to the St. Peter and St. Paul's Archipelago (SPSP) (Nunes et al., 2019). Rosa et al. (2016) study in the SPSP found dominance of *P. obliquus* in the lower mesophotic zone (50-90 m deep) and associations between this species and black corals. These similar results may suggest that black corals also play an important ecological role in the mesophotic zones of Fernando de Noronha, mainly in the shelf break, and in the distribution of *Prognathodes guyanensis.*

These results reinforce the singularity and importance of the shelf break points and we believe other aspects rather than the habitat types and depth gradients are important, such as shelf break upwelling (Campos et al., 2000; Zhang, et al., 2013). We suggest further investigations in the physical processes of the shelf edge of Fernando de Noronha could better explain the singularities observed in the shelf break points as well as its importance for biodiversity conservation and ecosystem maintenance in the region.

5. Conclusion

In general, the structure of fish assemblages in Fernando de Noronha Archipelago (FNA) are significantly different between the Leeward and Windward Sides and between depth gradients, more specifically between Shallow (0 – 30 m) and mesophotic zones (over 30 m) and between Upper (30 – 60 m) and Middle (60 – 90 m) mesophotic zones. Also, shelf break points in the Windward Side are important fish aggregation sites and presents unique species, including commercially important fish and vulnerable species. Habitat types influenced on 24% of the total variation in fish assemblage structure. Further investigations in cross-shelf changes in currents and oceanographic conditions, especially at the shelf break, may better explained these variations.

Furthermore, we found a new species record for the Fernando de Noronha Archipelago: *Prognathodes guyanensis,* which occurred in the shelf break of the Windward Side, at the depth of approximately 80 m and nearby black corals. This finding not only shows a range extension record for the species, but also represents the incipient knowledge about the mesophotic ecosystems of FNA. Additionally, extensive rhodolith beds were found along the insular shelf, mainly on the Windward Side.

Finally, this study shows the magnitude of investigations that can be performed using the tow video methodology and it validates the efficiency of this non-invasive method in evaluating the structure of fish assemblages and in understanding the spatial variations of fish biodiversity. The presence of species categorized by IUCN as Vulnerable or Data Deficient indicates the insular shelf of the FNA deserves special attention. Considering the well-known importance of rhodolith beds and mesophotic ecosystems, conservation measures for these regions should be considered in the management plan of the Marine Protected Areas of Fernando de Noronha.

Acknowledgements

We acknowledge the Boticário Group Foundation for funding the project “Deep reefs of the Fernando de Noronha Archipelago: Mapping, connectivity and protection” and all the members of this project for their assistance in the field work operations and all support in the data compilation and analyses. We also acknowledge the cooperation with the project Marine Sciences II that enable the development of the system of cameras. This study was partially financed by CNPQ (National Council for Scientific and Technological Development) through a collaboration with the first project mentioned above and through a productivity research grant to Beatrice Padovani Ferreira, and by CAPES (Coordination for the Improvement of Higher Education

Personnel) through the project Marine Sciences II and through a student grant to Maria Jacqueline Gomes de Barros.

Funding

This work was supported by the Boticário Group Foundation, through the project project “Deep reefs of the Fernando de Noronha Archipelago: Mapping, connectivity and protection”, and partially financed by CNPQ (National Council for Scientific and Technological Development) and CAPES (Coordination for the Improvement of Higher Education Personnel).

6. References

Allen, G.R. 1991. Damselfishes of the World. Melle, Germany: Mergus Publishers.

Almeida, F.F.M., 2006. Ilhas oceânicas brasileiras e suas relações com a tectônica atlântica. Terra Didática. 2, 3-18.

Amado-Filho, G.M., Moura, R.L., Bastos, A.C., Salgado, L.T., Sumida, P.Y., Guth, A.Z., Francini-Filho, R.B., Pereira-Filho, G.H., Abrantes, D.P., Brasileiro, P.S., Bahia, R.G., Leal, R.N., Kaufman, L., Kleypas, J.A., Farina, M., Thompson, F.L. 2012a. Rhodolith Beds Are Major CaCO3 Bio-Factories in the Tropical South West Atlantic. PLoS ONE. 7 (4), e35171. http://dx.doi.org/doi:10.1371/journal.pone.0035171

Amado-Filho, G.M., Pereira-Filho, G.H., Bahia, R.G., Abrantes, D.P., Veras, P.C., Matheus, Z. 2012b. Occurrence and distribution of rhodolith beds on the Fernando de Noronha Archipelago of Brazil. Aquatic Botany. 101, 41– 45. http://dx.doi.org/10.1016/j.aquabot.2012.03.016

Amado-Filho, G.M., Moura, R.L., Bastos, A.C., Francini-Filho, R.B., Pereira-Filho, G.H., Bahia, R.G., Moraes, F.C., Motta, F.S. 2016. Mesophotic ecosystems of the unique South Atlantic atol are composed by rhodolith beds and scattered consolidated reefs. Marine Biodiversity. 46, 933–936. http://dx.doi.org/10.1007/s12526-015-0441-6

Anderson, M.J., Gorley, R.N., Clarke, K.R., 2008. PERMANOVA+ for PRIMER: Guide to Software and Statistical Methods. PRIMER-E, Plymouth.

Andradi-Brown, D.A., Gress, E., Wright, G., Exton, D.A., Rogers, D., 2016. Reef fish community biomass and trophic structure changes across shallow to upper-mesophotic reefs in the Mesoamerican barrier reef, Caribbean. PLoS ONE. 11 (6), e0156641. https://doi.org/10.1371/journal.pone.0156641

Aronson, R.B., Swanson, D.W. 1997. Video surveys of coral reefs: uni- and multivariate applications. In: International Coral Reef Symposium, 8, 1996, Panama. Proceedings… Balboa, Panama: Smithsonian Tropical Research Institute. 2, 1441-1448.

Assunção, R.V., Silva, A.C., Martins, J., Montes, M.F., 2016. Spatial-Temporal Variability of the Thermohaline Properties in the Coastal Region of Fernando de Noronha Archipelago, Brazil. Journal of Coastal Research. 75, 512-516. https://doi.org/10.2112/SI75-103.1

Bahia, R.G., Abrantes, D.P., Brasileiro, P.S., Pereira-Filho, G.H., Amado-Filho, G.M. 2010. Rhodolith bed structure along a depth gradiente on the northern coast of Bahia state, Brazil. Brazilian Journal of Oceanography. 58 (4), 323-337.

Baker, E., Puglise, K.A., Harris, P.T. 2016. Mesophotic Coral Ecosystems A Lifeboat for Coral Reefs?. The United Nations Environment Programme and GRID-Arendal, Nairobi and Arendal, 98 p.

Barcellos, R.L., Coelho-Júnior, C., Lins, S.R.R.M., Silva, M.S., Camargo, P.B., Travassos, P.E.P.F. 2011. Island beaches morphological and sedimentary short term variations – the case of SE Fernando de Noronha Island, South Atlantic, Brazil. Journal of Integrated Coastal Zone Management. 11 (4), 471-478.

Bare, A.Y., Grimshaw, K.L., Rooney, J.J., Sabater, M.G., Fenner, D., Carrol, B. 2010. Mesophotic communities of the insular shelf at Tutuila, American Samoa. Coral Reefs. 29, 369–377. https://doi.org/10.1007/s00338-010-0600-y

Berkström, C., Lindborg, R., Thyresson, M., Gullström, M. 2013. Assessing connectivity in a tropical embayment: fish migrations and seascape ecology. Biological Conservation. 166, 43-53. http://dx.doi.org/10.1016/j.biocon.2013.06.013

Brock, E.V. 1954. A preliminary report on a method of estimating reef fish populations. The Journal of Wildlife Management. 18 (3), 297-308.

Campos, E.J.D., Velhote, D., Silveira, I.C.A. 2000. Shelf break upwelling driven by Brazil Current cyclonic meanders. Geophysical Research Letters. 27 (6), 751-754.

Cappo, M., Harvey, E., Malcolm, H., Speare, P., 2003. Potential of video techniques to monitor diversity, abundance and size of fish in studies of Marine Protected Areas. In: Aquatic Protected Areas: what works best and how do we know. 455-464.

Christensen, J.D., Jeffrey, C.F.G., Caldow, C., Monaco, M.E., Kendall, M.S., Appeldoorn, R.S. 2003. Cross-Shelf Habitat Utilization Patterns of Reef Fishes in Southwestern Puerto Rico. Gulf and Caribbean Research. 14 (2), 9–27. https://doi.org/10.18785/gcr.1402.02

Clarke, K., Somerfield, P.J., Warwick, R., 1994. Change in Marine Communities: An Approach to Statistical Analysis and Interpretation, 1st ed. PRIMER-E Ltd, Plymouth.

Copus, J.M., Pyle, R.L., Greene, B.D., Randall, J.E. 2019. *Prognathodes geminus*, a new species of butterflyfish (Teleostei, Chaetodontidae) from Palau. ZooKeys. 835, 125–137. https://doi.org/10.3897/zookeys.835.32562

Craig, M.T., Pondella, D.J., Franck, J.P.C., Hafner, J.C. 2001. On the Status of the Serranid Fish Genus *Epinephelus*: Evidence for Paraphyly Based upon 16S rDNA Sequence. Molecular Phylogenetics and Evolution. 19 (1), 121–130. https://doi.org/10.1006/mpev.2000.0913

Craig, M.T., Hastings, P.A., 2007. A molecular phylogeny of the groupers of the subfamily Epinephelidae (Serranidae) with a revised classification of the Epinephelini. Ichthyological Research. 54, 1-17.

Cruz, I.C.S., Kikuchil, R.K.P., Leão, Z.M.A.N., 2008. Use of the video transect method for characterizing the Itacolomis reefs, eastern Brazil. Brazilian Journal of Oceanography. 56 (4), 271-280.

Dutra, L.X.C., Kikuchi, R.K.P., Leão, Z.M.A.N., 2006. Todos os Santos Bay coral reefs, Eastern Brazil, revisited after 40 years. Proceedings of 10th International Coral Reef Symposium. 1090-1095.

Eduardo, L.N., Frédou, T., Lira, A.S., Ferreira, B.P., Bertrand, A., Ménard, F., Frédou, F.L., 2018. Identifying key habitat and spatial patterns of fish biodiversity in the tropical Brazilian continental shelf. Continental Shelf Research. 166, 108–118. https://doi.org/10.1016/j.csr.2018.07.002

Eschmeyer, W.N., Fricke, R., Fong J.D., Polack, D.A. 2010. Marine fish diversity: history of knowledge and discovery (Pisces). Zootaxa. 2525, 19-50.

Ferreira, C.E.L., Ferreira, C.G.W., Rangel, C.A., Mendonça, J.P., Gerhardinger, L.C., Filho, A.C., Godoy, E.A., Luiz Jr, O., Gasparini, J.L. 2007. Peixes recifais. In Creed JC, Pires DO, Figueiredo MAO (Eds). Biodiversidade Marinha da Baía da Ilha Grande. MMA, Brasília. 291-322.

Floeter, S.R., Guimarães, R.Z.P., Rocha, L.A., Ferreira, C.E.L., Rangel, C.A., Gasparini, J.L. 2001. Geographic variation in reef-fish assemblages along the Brazilian coast. Global Ecology & Biogeography. 10, 423–431.

Floeter, S.R., Gasparini, J.L., Rocha, L.A., Ferreira, C.E.L., Rangel, C.A., Feitoza, B.M. 2003. Brazilian reef fish fauna: checklist and remarks. Brazilian Reef Fish Project: www.brazilianreeffish.cjb.net

Floeter, S.R., Rocha, L.A., Robertson, D.R., Joyeux, J.C., Smith-Vaniz, W.F., Edwards, A.J., Barreiros, J.P., Ferreira, C.E.L., Gasparini, J.L., Brito, A., Falcón, J.M., Bowen, B.W., Berbardi, G. 2008. Atlantic reef fish biogeography and evolution. Journal of biogeography. 35, 22–47.

Foster, M.S., 2001. Mini-review: rhodoliths: between rocks and soft places. Journal of Phycology. 37, 657–659.

Francini-Filho, R., Asp, N.E., Siegle, E., Hocevar, J., Lowyck, K., D'Avila, N., Vasconcelos, A.A., Baitelo, R., Rezende, C.E., Omachi, C.Y., Thompson, C.C., Thompson, F.L. 2018. Perspectives on the Great Amazon Reef: Extension, biodiversity, and threats. Frontiers in Marine Science. 5: 142. https://doi.org/10.3389/fmars.2018.00142

Fuller, B.J.C. 2013. Advances in seascape ecology: applying landscape metrics to marine systems. Ecology of Fragmented Landscapes. 1-5.

Garcia, A.M., Bemvenuti, M.A., Vieira, J.P., Motta Marques, D.M.L., Burns, M.D.M., Moresco, A., Vinicius, M., Condini, L., 2006. Checklist comparison and dominance patterns of the fish fauna at Taim Wetland, South Brazil. Neotrop. Ichthyol. 4, 261–268.

Garla, R.C., Gadig, O.B.F., Garrone-Neto, D. 2017. Movement and activity patterns of the nurse shark, *Ginglymostoma cirratum*, in an oceanic Marine Protected Area of the South-western Atlantic. Journal of the Marine Biological Association of the United Kingdom. 97 (8), 1565–1572. https://doi.org/10.1017/S0025315416001028

Gregory, S., Collins, M.A., Belchier, M., 2016. Demersal fish communities of the shelf and slope of South Georgia and Shag Rocks (Southern Ocean). Polar Biol. 40, 107–121. https://doi.org/10.1007/s00300-016-1929-7

Harvey, E.S., Fletcher, D., Shortis, M., 2002. Estimation of reef fish length by divers and by stereo-video. A first comparison of the accuracy and precision in the field on living fish under operational conditions. Fisheries Research. 57, 255–265.

Hinderstein, L.M., Marr, J.C.A., Martinez, F.A., Dowgiallo, M.J., Puglise, K.A., Pyle, R.L., Zawada, D.G., Appeldoorn, R. 2010. Introduction to mesophotic coral ecosystems: characterization, ecology, and management. Coral Reefs. 29, 247–251. https://doi.org/10.1007/s00338-010-0614-5

Humann, P., Deloach, N., 2002. Reef Fish Identification: Florida, Caribbean and Bahamas. New World Publications, Inc. 3rd Edition, Jacksonville, Florida. 481 p.

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

IUCN, 2012. Guidelines for Application of IUCN Red List Criteria at Regional and National Levels (Version 4.0). IUCN, Gland, Switzerland and Cambridge, UK.

IUCN, 2000. IUCN Red List Categories and Criteria, IUCN Bulletin. IUCN, Gland, Switzerland and Cambridge, UK. https://doi.org/doi:10.9782-8317-0633-5

Ivar do Sul, J.A., Spengler, A., Costa, m.f. 2009. Here, there and everywhere. Small plastic fragments and pellets on beaches of Fernando de Noronha (Equatorial Western Atlantic). Marine Pollution Bulletin. 58, 1229–1244.

Jones, G.P., Andrew, N.L. 1992. Temperate reefs and the scope of seascape ecology. In: Proceedings of the Second International Temperate Reef Symposyum, Battershill, C. N. et al. (eds.). 63-76.

Kahng, S.E., Maragos, J.E. 2006. The deepest, zooxanthellate scleractinian corals in the world?. Coral Reefs. 25, 254. https://doi.org/10.1007/s00338-006-0098-5

Kahng, S., Copus, J.M., Wagner, D. 2017. Mesophotic coral ecosystems. In S. Rossi (Ed.), Marine animal forests. New York, NY: Springer International Publishing. 185–206. https://doi.org/10.1007/978-3-319-21012-4

Kavanagh, K.D., Olney, J.E. 2006. Ecological correlates of population density and behavior in the circumtropical black triggerfish Melichthys niger (Balistidae). Environmental Biology of Fishes. 76, 387–398. https://doi.org/10.1007/s10641-006-9044-1

Kempf, M. 1970. Notes on the benthic bionomy of the N-NE Brazilian shelf. Marine Biology. 5, 213–224.

Krajewski, J.P., Floeter, S.R., 2011. Reef fish community structure of the Fernando de Noronha Archipelago (Equatorial Western Atlantic): the influence of exposure and benthic composition. Environmental Biology of Fishes. 92, 25-40. https://doi.org/10.1007/s10641-011-9813-3

Lessa, R., Nóbrega, M.F., 2000. Programa REVIZEE/SCORE-NE - Guia de identificação de peixes marinhos da região Nordeste. Recife, UFRPE-DIMAR, 128p.

Lowe-McConnell, R. H. 1999. Estudos ecológicos de comunidades de peixes tropicais. São Paulo, EDUSP. 536 pages.

Luiz Jr, O.J., Carvalho-Filho, A., Ferreira, C.E.L., Floeter, S.R., Gasparini, J.L, Sazima, I. 2008. The reef fish assemblage of the Laje de Santos Marine State Park, Southwestern Atlantic: annotated checklist with comments on abundance, distribution, trophic structure, symbiotic associations, and conservation. Zootaxa. 1807, 1-25. https://doi.org/10.11646/zootaxa.1807.1.1

Machan, R., Fedra, K., 1975. A New Towed Underwater Camera System for Wide-Range Benthic Surveys. Marine Biology. 33, 75-84.

Maida, M., Ferreira, B.P., 1997. Coral reefs of Brazil: an overview. Proceedings of the 8th International Coral Reef Symposium. 1, 263–274.

Mallet, D., Pelletier, D., 2014. Underwater video techniques for observing coastal marine biodiversity: A review of sixty years of publications (1952–2012). Fisheries Research. 54, 44–62. http://doi.org/10.1016/j.fishres.2014.01.019

Medeiros, P.R., Rosa, R.S., Francini-Filho, R.B. 2011. Dynamics of fish assemblages on a continuous rocky reef and adjacent unconsolidated habitats at Fernando de Noronha Archipelago, tropical western Atlantic. Neotropical Ichthyology. 9 (4), 869-879.

Mendes, T.C., Quimbayo, J.P., Bouth, H.F., Silva, L.P.S., Ferreira, C.E.L. 2019. The omnivorous triggerfish Melichthys niger is a functional herbivore on an isolated Atlantic oceanic island. Journal of Fish Biology. 95, 812-819. http://doi.org/10.1111/jfb.14075

Menza, C., Kendall, M., Rogers, C., Miller, J. 2007. A deep reef in deep trouble. Continental Shelf Research. 27, 2224–2230. http://doi.org/10.1016/j.csr.2007.05.017

Milliman, J.D., Amaral, C.A.B. 1974. Economic potential of Brazilian continental margin sediments. Annals of 28th Brazilian Congress of Geology. 335–344.

Mohr, L.V., Castro, J.W.A., Costa, P.M.S., Alves, R.J.V., 2009. Ilhas oceânicas brasileiras: da pesquisa ao manejo. Vol. II, MMA Secretaria de Biodiversidade e Floresta, Brasilia, Brasil. 496p.

Morais, R.A., Maia, H.A. 2017. Lush underwater forests in mesophotic reefs of the Gulf of Guinea. Coral Reefs. 36, 95. http://doi.org/0.1007/s00338-016-1523-z

Morrison, M., Carbines, G., 2006. Estimating the abundance and size structure of an estuarine population of the sparid Pagrus auratus, using a towed camera during nocturnal periods of inactivity, and comparisons with conventional sampling techniques. Fisheries Research. 82, 150-161. https://doi.org/10.1016/j.fishres.2006.06.024

Murphy, H.M., Jenkins, G.P., 2010.Observational methods used in marine spatial monitoring of fishes and associated habitats: a review. Marine Freshwater Research. 61, 236–252. https://doi.org/10.1071/MF09068

Nelson, J.S., Grande, T., Wilson, M.V.H., 2016. Fishes of the world. 5th Edition, John Wiley & Sons, Inc, Hoboken, New Jersey.

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.

Ordines, F., Bauzá, M., Sbert, M., Roca, P., Gianotti, M., Massutí, E. 2015. Red algal beds increase the condition of nekto-benthic fish. Journal of Sea Research. 95, 115–123. http://dx.doi.org/10.1016/j.seares.2014.08.002

Page, C., Coleman, G., Ninio, R., Osborne, K. 2001. Surveys of benthic reef communities using underwater video. Long-term Monitoring of the Great Barrier Reef - Standard Operational Procedure Number 7. Townsvile: Autralian Institute of Marine Sciences. 49 pages.

Parenti, P., Randall, J.E. 2018. A checklist of wrasses (Labridae) and parrotfishes (Scaridae) of the world: 2017 update. Journal of the Ocean Science Foundation, 30, 11–27. http://dx.doi.org/10.5281/zenodo.1247552

Pelletier, D., Leleu, K., Mou-Tham, G., Guillemot, N., Chabanet, P., 2011. Comparison of visual census and high definition video transects for monitoring coral reef fish assemblages. Fisheries Research. 107, 84–93. http://doi.org/10.1016/j.fishres.2010.10.011

Pereira-Filho, G.H., Amado-Filho, G.M., Moura, R.L., Bastos, A.C., Guimarães, S.M.P.B., Salgado, L.T., Francini-Filho, R.B., Bahia, R.G., Abrantes, D.P., Guth, A.Z., Brasileiro, P.S. 2012. Extensive Rhodolith Beds Cover the Summits of Southwestern Atlantic Ocean Seamounts. Journal of Coastal Research. 28 (1), 261-269. http://doi.org/10.2112/11T-00007.1

Pereira-Filho, G.H., Francini-Filho, R.B., Peirozzi-Jr, I., Pinheiro, H.T., Bastos, A.C., Moura, R.L., Moraes, F.C., Matheus, Z., Bahia, R.G., Amado-Filho, G.M. 2015. Sponges and fish facilitate succession from rhodolith beds to reefs. Bulletin of Marine Science. 91 (1), 45-46. http://doi.org/10.5343/bms.2014.1067

Pinheiro, H.T., Joyeux, J.C., Moura, R.L. 2014. Reef oases in a seamount chain in the southwestern Atlantic. Coral Reefs. 33, 1113. http://doi.org/10.1007/s00338-014-1211-9

Pinheiro, H.T., Mazzei, E., Moura, R.L., Amado-Filho, G.M., Carvalho-Filho, A., Braga, A.C., Costa, P.A.S., Ferreira, B.P., Ferreira, C.E.L., Floeter, S.R., Francini-Filho, R.B., Gasparini, J.L., Macieira, R.M., Martins, A.S., Olavo, G., Pimentel, C.R., Rocha, L.A., Sazima, I., Simon, T., Teixeira, J.B., Xavier, L.B., Joyeux, J-C. 2015. Fish biodiversity of the Vitória-Trindade Seamount Chain, southwestern Atlantic: an updated database. PLoS One. 10, e0118180. https://doi.org/10.1371/journal.pone.0118180

Pinheiro, H.T., Goodybody-Gringley, G., Jessup, M.E., Shepherd, B., Chequer, A.D., Rocha, L.A. 2016. Upper and lower mesophotic coral reef fish communities evaluated by underwater visual censuses in two Caribbean locations. Coral Reefs. 35, 139–151. https://doi.org/10.1007/s00338-015-1381-0

Poey, F. (1858–1861). “Memorias Sobre la Historia Natural de la Isla de Cuba . . . ,” Vol. 2. Havana.

Prager, E.J., Ginsburg, R.N., 1989. Carbonate nodule growth on Florida’s outer shelf and its implications for fossil interpretations. Palaios. 4, 310–317.

Rocha, L.A., Pinheiro, H.T., Shepherd, B., Papastamatiou, Y.P., Luiz, O.J., Pyle, R.L., Bongaerts, P. 2018. Mesophotic coral ecosystems are threatened and ecologically distinct from shallow water reefs. Science. 361, 281–284. http://doi.org/10.1126/science.aaq1614

Rosa, M.G., Alves, A.C., Medeiros, D.V., Coni, E.O.C., Ferreira, C.M., Ferreira, B.P., Rosa, R.S., Amado-Filho, G.M., Pereira-Filho, G.H., Moura, R.L., Thompson, F.L., Sumida, P.Y.G., Francini-Filho, R.B. 2016. Mesophotic reef fish assemblages of the remote St. Peter and St. Paul’s Archipelago, Mid-Atlantic Ridge, Brazil. Coral Reefs. 35, 113–123. http://doi.org/10.1007/s00338-015-1368-x

Santos, C.S.G., Lino, J.B., Veras, P.C., Amado-Filho, G.M., Francini-Filho, R.B., Motta, F.S., Moura, R.L., Pereira-Filho, G.L. 2016. Environmental licensing on rhodolith beds: insights from a worm. Natureza e Conservação. 14, 137-141. http://dx.doi.org/10.1016/j.ncon.2016.06.002

Sazima, I., Sazima, C., Silva-Jr, J.M. 2006. Fishes associated with spinner dolphins at Fernando de Noronha Archipelago, tropical Western Atlantic: an update and overview. Neotropical Ichthyology. 4 (4), 451-455.

Semmler, R.F., Hoot, W.C., Reaka, M.L. 2017. Are mesophotic coral ecosystems distinct communities and can they serve as refugia for shallow reefs?. Coral Reefs. http://dx.doi.org/10.1007/s00338-016-1530-0

Sfakiotakis, M., Lane, D.M., Davies, J.B.C. 1999. Review of fish swimming modes for aquatic locomotion. IEEE Journal of Oceanic Engineering. 24, 237–252.

Smith, C.L. 1966. Menophorus Poey, a serranid genus based on two hybrids of Cephalopholis fulva and Paranthias furcifer, with comments on the systematic placement of Paranthias. Am. Mus. Novit. 2276, 1–11.

Soares, M.O., Tavares, T.C.L., Carneiro, P.B.M. 2019. Mesophotic ecosystems: Distribution, impacts and conservation in the South Atlantic. Diversity and Distributions. 25, 255–268. http://doi.org/10.1111/ddi.12846

Soto, J.M.R. 2001. Fishes of the Fernando de Noronha Archipelago. Mare Magnum. 1 (2), 147-169.

Tessier, A., Pastor, J., Francour, P., Saragoni, G., Crec'hriou, R., Lenfant, P., 2013. Video transects as a complement to underwater visual census to study reserve effect on fish assemblages. Aquatic Biology. 18, 229-241. http://doi.org/10.3354/ab00506

Thresher, R.E. 1991. Geographic variability in the ecology of coral reef fishes: evidence, evolution and possible implications. In: The Ecology of Fishes on Coral Reefs (Sale, P. F., ed.). San Diego: Academic Press. 401–436.

Thompson, R., Munro, J. 1978. Aspects of the biology and ecology of Caribbean reef fishes: Serranidae (hinds and groupers). Journal of Fish Biology. 12, 115–146.

Tyler, J.C., Luckhurst, B.E. 1994. Unusual Features of the Colonies of the Common Western Atlantic Garden Eel (Heterocongrinae), with a New Record for Bermuda. Northeast Gulf Science. 13 (2), 89-99.

Vecsei, A. 2004. Carbonate production on isolated banks since 20 k.a. BP: climatic implications. Palaeogeography, Palaeoclimatology, Palaeoecology. 214, 3–10.

Victor, B.C., 1987. The mating system of the caribean rosy razorfish, *Xyrichtys martinicensis.* Bulletin of Marine Science. 40 (1), 152-160.

Wilson, S.K., Bellwood, D.R., Choat, J.H., 2003. Detritus in the epilithic algal matrix and its use by coral reef fishes. Oceanography and Marine Biology - An Annual Review. 41, 279–309.

Zhang, W.G., McGillicuddy Jr., D.J., Gawarkiewicz, G.G. 2013. Is biological productivity enhanced at the New England shelfbreak front?, Journal of Geophysical Research: Oceans. 118, 517–535. http://doi.org/doi:10.1002/jgrc.20068

5 CONSIDERAÇÕES FINAIS

De modo geral, a partir do primeiro estudo podemos concluir que a capturabilidade de peixes pela pesca de arrasto de fundo varia de acordo com o comportamento das espécies, morfologia e capacidade natatória. Além disso, concluímos que os vídeos são uma alternativa eficiente ao arrasto de fundo científico para estudar a abundância e distribuição de peixes.

Em relação ao segundo estudo, realizado na plataforma insular do Arquipélago de Fernando de Noronha, vimos que a estrutura das assembleias de peixes é diferente entre o Mar de Dentro e Mar de Fora e entre as categorias de profundidade Rasa (0 – 30 m) e Mesofóticas (abaixo de 30 m) e entre as zonas Mesofótica Superior (30 – 60 m) e Mesofótica Média (60 – 90 m). Além disso, foram encontradas longas extensões de rodolitos, agregações de peixes na quebra da plataforma e um novo registro de espécie: *Prognathodes guyanensis.*

Para finalizar, este trabalho mostra que a utilização de vídeos como método para estudo da estrutura e distribuição das assembleias de peixes marinhos é apropriada. No primeiro estudo foi visto que o arrasto de fundo, um método destrutivo, pode ser substituído pela metodologia de vídeos, um método não-invasivo. O segundo trabalho apresenta o potencial do método tow video, o qual é sugerido como alternativa ao arrasto de fundo, e comprova sua eficiência. Ambos estudos podem auxiliar na identificação de áreas prioritárias para conservação e contribuir na criação de estratégias de manejo necessárias para a manutenção da biodiversidade marinha e seu uso sustentável.

REFERÊNCIAS

ADAMS, P. B.; BUTLER, J. L.; LAIDING, T. E.; DAHLIN, K. A.; WAKEFIELD, W. W. 1995. Population estimates of Pacific coast groundfishes from video transects and swept-area trawls. **Fishery Bulletin**, v. 93, p. 446-455.

ALBERT, O. T.; HARBITZ, A.; HØINES, A. S. 2003. Greenland halibut observed by video in front of survey trawl: behaviour, escapement, and spatial pattern. **Journal of Sea Research**, v. 50, p. 117– 127. DOI 10.1016/S1385-1101(03)00063-7.

ALEVIZON, W. S.; BROOKS, M. G. 1975. The comparative structure of two Western Atlantic reef-fish assemblages. Bulletin of Marine Science, v. 25, n. 4, p. 482–490.
ANDRADI-BROWN, D. A.; GRESS, E.; WRIGHT, G.; EXTON, D. A.; ROGERS, D. 2016. Reef fish community biomass and trophic structure changes across shallow to upper-mesophotic reefs in the Mesoamerican barrier reef, Caribbean. **PLoS ONE**, v. 11, n. 6, p. 1-19.

ALLEN, G. R. 1991. Damselfishes of the World. **Melle**, Germany: Mergus Publishers.

ALMEIDA, F. F. M. 2006. Ilhas oceânicas brasileiras e suas relações com a tectônica atlântica. **Terra Didática**, v. 2, p. 3-18.

AMADO-FILHO, G. M.; MOURA, R. L.; BASTOS, A. C.,; SALGADO, L. T.; SUMIDA, P. Y.; GUTH, A. Z.; FRANCINI-FILHO, R. B.; PEREIRA-FILHO, G. H.; ABRANTES, D. P.; BRASILEIRO, P. S.; BAHIA, R. G.; LEAL, R. N.; KAUFMAN, L.; KLEYPAS, J. A.; FARINA, M.; THOMPSPN, F. L. 2012a. Rhodolith Beds Are Major CaCO3 Bio-Factories in the Tropical South West Atlantic. **PLoS ONE**, v. 7, n. 4, e35171. DOI 10.1371/journal.pone.0035171.

AMADO-FILHO, G. M.; PEREIRA-FILHO, G. H.; BAHIA, R. G.; ABRANTES, D. P.; VERAS, P. C.; MATHEUS, Z. 2012b. Occurrence and distribution of rhodolith beds on the Fernando de Noronha Archipelago of Brazil. **Aquatic Botany**, v. 101, p. 41–45. DOI 10.1016/j.aquabot.2012.03.016.

AMADO-FILHO, G. M.; MOURA, R. L.; BASTOS, A. C.; FRANCINI-FILHO, R. B.; PEREIRA-FILHO, G. H.; BAHIA, R. G.; MORAES, F. C.; MOTTA, F. S. 2016. Mesophotic ecosystems of the unique South Atlantic atol are composed by rhodolith beds and scattered consolidated reefs. **Marine Biodiversity**, v. 46, p. 933–936. DOI 10.1007/s12526-015-0441-6.

AMOROSO, R. O.; PITCHER, C. R.; RIJNSDORP, A. D.; McCONNAUGHEY, R. A.; PARMA, A. M.; SUURONEN, P.; et al. 2018. Bottom trawl fishing footprints on the world's continental shelves. **Proceedings of the National Academy of Sciences**, USA. 115 (43) E10275-E10282. DOI 10.1073/pnas.1802379115.

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

ANDRADI-BROWN, D. A.; GRESS, E.; WRIGHT, G.; EXTON, D. A.; ROGERS, D. 2016. Reef fish community biomass and trophic structure changes across shallow to upper-mesophotic reefs in the Mesoamerican barrier reef, Caribbean. **PLoS ONE**, v. 11, n. 6, e0156641. DOI 10.1371/journal.pone.0156641.

ARONSON, R. B. E.; SWANSON, D. W. 1997. Video surveys of coral reefs: uni- and multivariate applications. Em: **International Coral Reef Symposium**, 8, 1996, Panama. Proceedings… Balboa, Panama: Smithsonian Tropical Research Institute, v. 2, p. 1441-1448.

ARRENGUÍN-SANCHEZ, F. 1996. Catchability: a key parameter for fish stock assessment. **Reviews in Fish Biology and Fisheries**, v. 6, p. 221-242.

ASSIS, J.; NARVÁEZ, K.; HAROUN, R. 2007. Underwater towed video: a useful tool to rapidly assess elasmobranch populations in large marine protected areas. **Journal of Coastal Conservation**, v. 11, p. 153-157. DOI 10.1007/s11852-008-0015-x.

ASSUNÇÃO, R. V.; SILVA, A. C.; MARTINS, J.; MONTES, M. F. 2016. Spatial-Temporal Variability of the Thermohaline Properties in the Coastal Region of Fernando de Noronha Archipelago, Brazil. **Journal of Coastal Research**, v. 75, p. 512-516. DOI 10.2112/SI75-103.1.

AUSTER, P. J.; MALATESTA, R. J.; LANGTON, R. W.; WATLING, W.; VALENTINE, P. C.; DONALDSON, C. L. S.; LANGTON, E. W.; SHEPARD, A. N.; BABB, I. G. 1996. The impacts of mobile fishing gear on seafloor habitats in the Gulf of Maine (northwest Atlantic): Implications for conservation of fish populations. **Reviews in Fisheries Science**, v. 4, n. 2, p. 185–202.

BAHIA, R. G.; ABRANTES, D. P.; BRASILEIRO, P. S.; PEREIRA-FILHO, G. H.; AMADO-FILHO, G. M. 2010. Rhodolith bed structure along a depth gradiente on the northern coast of Bahia state, Brazil. **Brazilian Journal of Oceanography**, v. 58, n. 4, p. 323-337.

BAKER, E.; PUGLISE, K. A.; HARRIS, P. T. 2016. Mesophotic Coral Ecosystems A Lifeboat for Coral Reefs?. **The United Nations Environment Programme and GRID-Arendal**, Nairobi and Arendal, 98 p.

BARCELLOS, R. L.; COELHO-JÚNIOR, C.; LINS, S. R. R. M.; SILVA, M. S.; CAMARGO, P. B.; TRAVASSOS, P. E. P. F. 2011. Island beaches morphological and sedimentary short term variations – the case of SE Fernando de Noronha Island, South Atlantic, Brazil. **Journal of Integrated Coastal Zone Management**, v. 11, n. 4, p. 471-478.

BARE, A. Y.; GRIMSHAW, K. L.; ROONEY, J. J.; SABATER, M. G.; FENNER, D.; CARROL, B. 2010. Mesophotic communities of the insular shelf at Tutuila, American Samoa. **Coral Reefs**, v. 29, p. 369–377. DOI 10.1007/s00338-010-0600-y.

BARKER, B. A. J.; HELMOND, I.; BAX, N. J.; WILLIAMS, A.; DAVENPORT, S.; WADLEY, V. A. 1999. A vessel-towed camera platform for surveying seafloor habitats of the continental shelf. **Continental Shelf Research**, v. 19, p. 1161-1170.

BARNES, H. 1952. Under-water television and marine biology. Nature, 169, 477-479.

BEENTJES, M. P.; SMITH, M.; PHILLIPS, N. L. 2004. Analysis of catchability for east coast South Island trawl surveys and recommendations on future survey design. **New Zealand Fisheries Assessment Report**. 68 pages. ISSN 1175-1584.

BENEVIDES, L. J.; NUNES, J. A. C. C.; COSTA, T. L. A.; SAMPAIO, C. L. S. 2016. Flight response of the barber surgeonfish, Acanthurus bahianus Castelnau, 1855 (Teleostei: Acanthuridae), to spearfisher presence**. Neotropical Ichthyology**, v. 14, n. 1, e150010. DOI 10.1590/1982-0224-20150010.

BERKSTRÖM, C.; LINDBORG, R.; THYRESSON, M.; GULLSTRÖM, M. 2013. Assessing connectivity in a tropical embayment: fish migrations and seascape ecology. **Biological Conservation**, v. 166, p. 43-53.

BERTRAND, A. 2017. ABRACOS 2 cruise, RV Antea. doi: 10.17600/17004100.

BLYTH-SKYRME, V. J.; ROONEY, J. J.; PARRISH, F. A.; BOLAND, R. C. 2013. Mesophotic coral ecosystems – Potential candidates as essential fish habitat and habitat areas of particular concern**. Pacific Islands Fisheries Science Center, Natl. Mar. Fish. Sci. Cent. Admin**. Rep. H-13-02, 53 p.

BRADSHAW, C.; TJENSVOLL, I.; SKÖLD, M.; ALLAN, I. J.; MOLVAER, J.; MAGNUSSON, J.; NAES, K.; NILSSON, H. C. 2012. Bottom trawling resuspends sediment and releases bioavailable contaminants in a polluted fjord. **Environmental Pollution**, v. 170, p. 232-241. DOI 10.1016/j.envpol.2012.06.019.

BRIND'AMOUR, A.; LAFFARGUE, P.; MORIN, J.; VAZ, S.; FOVEAU, A.; BRIS, H. L. 2014. Morphospecies and taxonomic sufficiency of benthic megafauna in scientific bottom trawl surveys. **Continental Shelf Research**, v. 72, p. 1-9. DOI 10.1016/j.csr.2013.10.015.

BROCK, E. V. 1954. A preliminary report on a method of estimating reef fish populations. **The Journal of Wildlife Management**, v. 18, n. 3, p. 297-308.

BRYAN, D. R.; BOSLEY, K. L.; HICKS, A. C.; HALTUCH, M. A.; WAKEFIELD, W. W. 2014. Quantitative video analysis of flatfish herding behavior and impact on effective area swept of a survey trawl. **Fisheries Research**, v. 154, p.120–126. DOI 10.1016/j.fishres.2014.02.007.

CAMARGO, J. M. R.; ARAÚJO, T. C. M.; FERREIRA, B. P.; MAIDA, M. 2015. Topographic features related to recent sea level history in a sediment-starved tropical shelf: Linking the past, present and future. **Regional Studies in Marine Science**, v. 2, p. 203–211. DOI 10.1016/j.rsma.2015.10.009.

CAMPOS, E. J. D.; VELHOTE, D.; SILVEIRA, I. C. A. 2000. Shelf break upwelling driven by Brazil Current cyclonic meanders. **Geophysical Research Letters**, v. 27, n. 6, p. 751-754.

CAPPO, M.; HARVEY, E.; MALCOLM, H.; SPEARE, P. 2003. Potential of video techniques to monitor diversity, abundance and size of fish in studies of Marine Protected Areas. Em: **Aquatic Protected Areas: what works best and how do we know**, p. 455-464.

CARPENTER, K. E. (ed). 2002a. The living marine resources of the Western Central Atlantic. Volume 2: Bony fishes part 1 (Acipenseridae to Grammatidae). **FAO Species Identification Guide for Fishery Purposes and American Society of Ichthyologists and Herpetologists Special Publication No. 5**. Rome, FAO, p. 601-1374.

CARPENTER, K. E. (ed). 2002b. The living marine resources of the Western Central Atlantic. Volume 3: Bony fishes part 2 (Opistognathidae to Molidae), sea turtles and marine mammals. **FAO Species Identification Guide for Fishery Purposes and American Society of Ichthyologists and Herpetologists Special Publication No. 5**. Rome, FAO, p. 1375-2127.

CHRISTENSEN, J. D.; JEFFREY, C. F. G.; CALDOW, C.; MONACO, M. E.; KENDALL, M. S.; APPELDOORN, R. S. 2003. Cross-Shelf Habitat Utilization Patterns of Reef Fishes in Southwestern Puerto Rico. **Gulf and Caribbean Research**, v. 14, n. 2, p. 9–27. DOI 10.18785/gcr.1402.02.

CHOLLETT, I.; PRIEST, M.; FULTON, S.; HEYMAN, W. D. 2020. Should we protect extirpated fish spawning aggregation sites?. **Biological Conservation**, v. 241, 108395. DOI 10.1016/j.biocon.2019.108395.

CHOSID, D. M.; POL, M.; SZYMANSKI, M.; MIRARCHI, F.; MIRARCHI, A. 2012. Development and observations of a spiny dogfish Squalus acanthias reduction device in a raised footrope silver hake Merluccius bilinearis trawl. **Fisheries Research**, v. 114, p. 66–75. DOI 10.1016/j.fishres.2011.03.007.

CLARK, E.; RABIN, J. S.; HOLDERMAN, S. 1988. Reproductive behavior and social organization in the sand tilefish, Malacanthus plumieri**. Environmental Biology of Fishes**, v. 22, n. 4, p. 273-286.

CLARKE, K. R. 1993. Non-parametric multivariate analyses of changes in community structure. **Australian Journal of Ecology**, v. 18, p. 117–143.

CLARKE, K.; SOMERFIELD, P. J.; WARWICK, R. 1994. Change in Marine Communities: An Approach to Statistical Analysis and Interpretation, 1st ed. **PRIMER-E Ltd**, Plymouth.

CLAYDON, J. A. B.; KROETZ, A. M. 2007. The Distribution of Early Juvenile Groupers Around South Caicos, Turks and Caicos Islands. In**: Proceedings of the 60th Gulf and Caribbean Fisheries Institute**, v. 60, p. 345-350.

COPUS, J. M.; PYLE, R. L.; GREENE, B. D.; RANDALL, J. E. 2019. Prognathodes geminus, a new species of butterflyfish (Teleostei, Chaetodontidae) from Palau. **ZooKeys**, v. 835, p. 125–137. DOI 10.3897/zookeys.835.32562.

CRAIG, M. T.; PONDELLA, D. J.; FRANCK, J. P. C.; HAFNER, J. C. 2001. On the Status of the Serranid Fish Genus Epinephelus: Evidence for Paraphyly Based upon 16S rDNA Sequence. **Molecular Phylogenetics and Evolution**, v. 19, n. 1, p. 121–DOI 10.1006/mpev.2000.0913.

CRAIG, M. T.; HASTINGS, P. A. 2007. A molecular phylogeny of the groupers of the subfamily Epinephelidae (Serranidae) with a revised classification of the Epinephelini. **Ichthyological Research**, v. 54, p. 1-17.

CRUZ, I. C. S.; KIKUCHIL, R. K. P.; LEÃO, Z. M. A. N. 2008. Use of the video transect method for characterizing the Itacolomis reefs, eastern Brazil. **Brazilian Journal of Oceanography**, v. 56, n. 4, p. 271-280.

CUMMINGS, W. C.; BRAHY, B. D.; SPIRES, J. Y. 1966. Sounds production, schooling, and feeding habits of the margate, Haemulon album Cuvier, off North Bimini, Bahamas. **Bulletin of Marine Science**, v. 16, p. 626–640.

DOUNAS, C.; DAVIES, I.; TRIANTAFYLLOU, G.; KOULOURI, P.; PETIHAKIS, G.; ARVANITIDIS, C.; SOURLATZIS, G.; ELEFTHERIOU, A. 2007. Large-scale impacts of bottom trawling on shelf primary productivity. **Continental Shelf Research**, v. 27, p. 2198–2210. DOI 10.1016/j.csr.2007.05.006.

DUTRA, L. X. C.; KIKUCHI, R. K. P; LEÃO, Z. M. A. N. 2006. Todos os Santos Bay coral reefs, Eastern Brazil, revisited after 40 years. **Proceedings of 10th International Coral Reef Symposium**, p. 1090-1095.

EDUARDO, L. N.; FRÉDOU, T.; LIRA, A. S.; FERREIRA, B. P.; BERTRAND, A.; MÉNARD, F.; FRÉDOU, F. L. 2018. Identifying key habitat and spatial patterns of fish biodiversity in the tropical Brazilian continental shelf. **Continental Shelf Research**, v. 166, p. 108–118. DOI 10.1016/j.csr.2018.07.002.

EGGLETON, J. D.; DEPESTELE, J.; KENNY, A. J.; BOLAM, S. G.; GARCIA, C. 2018. How benthic habitats and bottom trawling affect trait composition in the diet of seven demersal and benthivorous fish species in the North Sea. **Journal of Sea Research**, v. 142, p. 132–146. DOI 10.1016/j.seares.2018.09.013.

ELLIS, D.; DeMARTINI, E. 1995. Evaluation of a video camera technique for indexing abundances of juvenile pink snapper, Pristipomoides filamentosus, and other Hawaiian insular shelf fishes. **Fishery Bulletin**, v. 93, p. 67–77.

ESCHMEYER, W. N.; FRICKE, R.; FONG J. D.; POLACK, D. A. 2010. Marine fish diversity: history of knowledge and discovery (Pisces). **Zootaxa**, v. 2525, p. 19-50.

FAO. 1996. Report of the technical consultation on reduction of wastage in fisheries. **FAO Fish. Rep.**, v. 547, 27 p.

FERREIRA, C. E. L.; FERREIRA, C. G. W.; RANGEL, C. A.; MENDONÇA, J. P.; GERHARDINGER, L. C.; FILHO, A. C.; GODOY, E. A.; LUIZ Jr, O.; GASPARINI, J.

L. 2007. Peixes recifais. In Creed JC, Pires DO, Figueiredo MAO (Eds). **Biodiversidade Marinha da Baía da Ilha Grande**, MMA, Brasília, p. 291-322.

FERREIRA, B. P.; MAIDA, M. 2007. Características e Perspectivas para o Manejo da Pesca na Área de Proteção Ambiental Marinha da Costa dos Corais. In: **Áreas Aquáticas Protegidas Como Instrumento de Gestão Pesqueira**, Serie Areas Protegidas, Brasília, p. 39–51.

FIORENTINI, L.; DREMIÈRE, P. Y.; LEONORI, I.; SALA, A.; PALUMBO, V. 1999. Efficiency of the bottom trawl used for the Mediterranean international trawl survey (MEDITS). **Aquatic Living Resources**, v. 12 /, n. 3, p. 187−205.

FITZPATRICK, B. M.; HARVEY, E. S.; HEYWARD, A. J.; TWIGGS, E. J.; COLQUHOUN, J. 2012. Habitat specialization in tropical continental shelf demersal fish assemblages. **PLoS ONE**, v. 7, n. 6, p. 1-14.

FLOETER, S. R.; GUIMARÃES, R. Z. P.; ROCHA, L. A.; FERREIRA, C. E. L.; RANGEL, C. A.; GASPARINI, J. L. 2001. Geographic variation in reef-fish assemblages along the Brazilian coast. **Global Ecology & Biogeography**, v. 10, p. 423–431.

FLOETER, S. R.; GASPARINI, J. L.; ROCHA, L. A.; FERREIRA, C. E. L.; RANGEL, C. A.; FEITOZA, B. M. 2003. Brazilian reef fish fauna: checklist and remarks. **Brazilian Reef Fish Project**: www.brazilianreeffish.cjb.net.

FLOETER, S. R.; ROCHA, L. A.; ROBERTSON, D. R.; JOYEUX, J. C.; SMITH-VANIZ, W. F.; EDWARDS, A. J.; BARREIROS, J. P.; FERREIRA, C. E. L.; GASPARINI, J. L.; BRITO, A.; FALCÓN, J. M.; BOWEN, B. W.; BERBARDI, G. 2008. Atlantic reef fish biogeography and evolution. **Journal of biogeography**, v. 35, p. 22–47.

FOSTER, M. S. 2001. Mini-review: rhodoliths: between rocks and soft places. **Journal of Phycology**, v. 37, p. 657–659.

FRANCINI-FILHO, R.; ASP, N. E.; SIEGLE, E.; HOCEVAR, J.; LOWYCK, K.; D’AVILA, N.; VASCONCELOS, A. A.; BAITELO, R.; REZENDE, C. E.; OMACHI, C. Y.; THOMPSON, C. C.; THOMPSON, F. L. 2018. Perspectives on the Great Amazon Reef: Extension, biodiversity, and threats. **Frontiers in Marine Science**, v. 5, p. 142. DOI 10.3389/fmars.2018.00142.

FRITZSCHE, R. A. 1976. A Review of the Cornetfishes, Genus Fistularia (Fistulariidae), with a Discussion of Intrageneric Relationships and Zoogeography. **Bulletin of Marine Science**, v. 26, n. 2, p. 196-204.

FULLER, B. J. C. 2013. Advances in seascape ecology: applying landscape metrics to marine systems. **Ecology of Fragmented Landscapes**, p. 1-5.

GARCIA, A. M.; BEMYENUTI, M. A.; VIEIRA, J. P.; MOTTA MARQUES, D. M. L.; BURNS, M. D. M.; MORESCO, A.; VINICIUS, M.; CONDINI, L. 2006. Checklist comparison and dominance patterns of the fish fauna at Taim Wetland, South Brazil. **Neotrop. Ichthyol**, v. 4, p. 261–268.

GARCIA JÚNIOR, J.; MENDES, L. F.; SAMPAIO, C. L. S.; LINS, J. E. 2010. Biodiversidade marinha da Bacia Potiguar: Ictiofauna. **Série Livros**, 38, Rio de Janeiro, Museu Nacional, 195 p.

GARCIA JÚNIOR, J.; MENDES, L. F.; SAMPAIO, C. L. S.; NÓBREGA, M. F.; OLIVEIRA, J. E. L. 2015. Biodiversidade marinha da Bacia Potiguar/RN: Peixes da Plataforma Continental. **Série Livros**, 54, Rio de Janeiro, Museu Nacional, 217 p.

GARLA, R. C.; GADIG, O. B. F.; GARRONE-NETO, D. 2017. Movement and activity patterns of the nurse shark, Ginglymostoma cirratum, in an oceanic Marine Protected Area of the South-western Atlantic. **Journal of the Marine Biological Association of the United Kingdom**, v. 97, n. 8, p. 1565–1572. DOI 10.1017/S0025315416001028.

GODO, O. R.; WALSH, S. J.; ENGAS, A. 1999. Investigating density-dependent catchability in bottom-trawl surveys. **ICES Journal of Marine Science**, v. 56, p. 292–298.

GREENFIELD, D. W. 1981. Holocentridae. In: W. Fischer, G. Bianchi and W.B. Scott (eds.) **FAO species identification sheets for fishery purposes**, Eastern Central Atlantic; fishing areas, v. 2, n. 34, p. 47 (in part). Department of Fisheries and Oceans Canada and FAO.

GREGORY, S.; COLLINS, M. A.; BELCHIER, M. 2016. Demersal fish communities of the shelf and slope of South Georgia and Shag Rocks (Southern Ocean). **Polar Biol.**, v. 40, p. 107–121. DOI 10.1007/s00300-016-1929-7.

GROBER-DUNSMORE, R.; PITTMAN, S. J.; CALDOW, C.; KENDALL, M. S.; FRAZER, T. K. 2009. A Landscape Ecology Approach for the Study of Ecological Connectivity across Tropical Marine Seascapes. Em: **Ecological Connectivity among Tropical Coastal Ecosystems**, I. Nagelkerken (ed.), p. 493-550.

GUIDETTI, P.; VIERUCCI, E.; BUSSOTTI, S. 2008. Differences in escape response of fish in protected and fished Mediterranean rocky reefs. **Journal of the Marine Biological Association of the United Kingdom**, v. 88, n. 3, p. 625–627. DOI 10.1017/S0025315408000933.

HAMMER, Ø.; HARPER, D. A. T.; RYAN, P. D. 2001. PAST: Paleontological statistics software package for education and data analysis. **Palaeontologia Electronica**, v. 4, n. 1, 9 p.

HANNAH, R. W.; JONES, S. A. 2012. Evaluating the behavioral impairment of escaping fish can help measure the effectiveness of bycatch reduction devices. **Fisheries Research**, v. 131, p. 39–44. DOI 10.1016/j.fishres.2012.07.010.

HARVEY, E. S.; FLETCHER, D.; SHORTIS, M. 2002. Estimation of reef fish length by divers and by stereo-video. A first comparison of the accuracy and precision in the field on living fish under operational conditions. **Fisheries Research**, v. 57, p. 255–265.

HE, P. 1993. Swimming speeds of marine fish in relation to fishing gears. **ICES Marine Science Symposia**, v. 196, p. 183-189.

HIDDINK, J. G.; JENNINGS, S.; KAISER, M. J. 2006. Indicators of the Ecological Impact of Bottom-Trawl Disturbance on Seabed Communities. **Ecosystems**, v. 9, p. 1190–1199. DOI 10.1007/s10021-005-0164-9.

HIDDINK, J. G.; JOHNSON, A. F.; KINGHAM R.; HINZ, H. 2011. Could our fisheries be more productive? Indirect negative effects of bottom trawl fisheries on fish condition. **Journal of Applied Ecology**, v. 48, p. 1441–1449. DOI 10.1111/j.1365-2664.2011.02036.x.

HIN, H.; PRIETO, V.; KAISER, M. J. 2009. Trawl disturbance on benthic communities: chronic effects and experimental predictions. **Ecological Applications**, v. 19, n. 3, p. 761–773.

HINDERSTEIN, L. M.; MARR, J. C. A.; MARTINEZ, F. A.; DOWGIALLO, M. J.; PUGLISE, K. A.; PYLE, R. L.; ZAWADA, D. G.; APPLEDOORN, R. 2010. Introduction to mesophotic coral ecosystems: characterization, ecology, and management. **Coral Reefs**, v. 29, p. 247–251. DOI 10.1007/s00338-010-0614-5.

HOFFMAN, J. C.; BONZEK, C. F.; LATOUR, R. J. 2009. Estimation of Bottom Trawl Catch Efficiency for Two Demersal Fishes, the Atlantic Croaker and White Perch, in Chesapeake Bay. **Marine and Coastal Fisheries**, v. 1, n. 1, p. 255-269. DOI 10.1577/C08-048.1.

HUMANN, P.; DELOACH, N. 2002. Reef Fish Identification: Florida, Caribbean and Bahamas. **New World Publications**, Inc. 3rd Edition, Jacksonville, Florida. 481 p.

HUMBORSTAD, O.-B.; NOTTESTAD, L.; LOKKEBORG, S.; RAPP, H. T. 2004. RoxAnn bottom classification system, sidescan sonar and video-sledge: spatial resolution and their use in assessing trawling impacts. **Journal of Marine Science**, v. 61, p. 53-63.

ICMbio, 2016. Executive Summary Brazil Red Book of Threatened Species of Fauna sumario, Livro Vermelho. **Instituto Chico Mendes de Conservação da Biodiversidade**, Ministério de Meio Ambiente, Brasília, DF.

IUCN, 2012. Guidelines for Application of IUCN Red List Criteria at Regional and National Levels (Version 4.0). **IUCN**, Gland, Switzerland and Cambridge, UK.

IUCN, 2000. IUCN Red List Categories and Criteria, IUCN Bulletin. **IUCN**, Gland, Switzerland and Cambridge, UK.DOI 10.9782-8317-0633-5.

IVAR DO SUL, J. A.; SPENGLER, A.; COSTA, M. F. 2009. Here, there and everywhere. Small plastic fragments and pellets on beaches of Fernando de

Noronha (Equatorial Western Atlantic). **Marine Pollution Bulletin**, v. 58, p. 1229–1244.

JENNINGS, S.; KAISER, M. J. 1998. The Effects of Fishing on Marine Ecosystems. **Advances in Marine Biology**, v. 34, 153 p. ISBN 0-12-0261344.

JONES, G. P.; ANDREW, N. L. 1992. Temperate reefs and the scope of seascape ecology. Em: **Proceedings of the Second International Temperate Reef Symposyum, Battershill**, C. N. et al. (eds.), p. 63-76.

JONES, D. O. B.; BETT, B. J.; WYNN, R. B.; MASSON, D. G. 2009. The use of towed camera platforms in deep-water science. **Underwater Technology**, v. 28, p. 41–50. DOI 10.3723/ut.28.041.

KAISER, M. J.; COLLIE, J. S.; HALL, S. J.; JENNINGS, S.; POINER, I. R. 2002. Modification of marine habitats by trawling activities: prognosis and solutions. **Fish and Fisheries**, v. 3, p. 114-136.

KAISER, M. J.; CLARKE, K. R.; HINZ, H.; AUSTEN, M. C. V.; SOMERFIELD, P. J.; KARAKASSIS, I. 2006. Global analysis of response and recovery of benthic biota to fishing. **Marine Ecology Progress Series**, v. 311, p. 1-14. DOI 10.3354/meps311001.

KAHNG, S. E.; MARAGOS, J. E. 2006. The deepest, zooxanthellate scleractinian corals in the world?. **Coral Reefs**, v. 25, p. 254. DOI 10.1007/s00338-006-0098-5.

KAHNG, S.; COPUS, J. M.; WAGNER, D. 2017. Mesophotic coral ecosystems. In S. Rossi (Ed.), Marine animal forests. New York, NY: **Springer International Publishing**, p. 185–206. DOI 10.1007/978-3-319-21012-4.

KAVANAGH, K. D.; OLNEY, J. E. 2006. Ecological correlates of population density and behavior in the circumtropical black triggerfish Melichthys niger (Balistidae). **Environmental Biology of Fishes**, v. 76, p. 387–398. DOI 10.1007/s10641-006-9044-1.

KEMPF, M. 1970. Notes on the benthic bionomy of the N-NE Brazilian shelf. **Marine Biology**, v. 5, p. 213–224.

KRAJEWSKI, J. P.; FLOETER, S. R. 2011. Reef fish community structure of the Fernando de Noronha Archipelago (Equatorial Western Atlantic): the influence of exposure and benthic composition. **Environmental Biology of Fishes**, v. 92, p. 25-DOI 10.1007/s10641-011-9813-3.

KROHN, M. M.; BOISCLAIR, D. 1994. Use of a stereo-video system to estimate the energy expenditure of free swimming fish. **Canadian Journal of Fisheries and Aquatic Sciences**, v. 51, p. 1119–1127.

KUMAR, A. B.; DEEPTHI, G. R. 2006. Trawling and by-catch: Implications on marine ecosystem. **Current Science**, v. 90, n. 7, p. 922-931.

LAUTH, R. R.; WAKEFIELD, W. W.; SMITH, K. 2004. Estimating the density of thornyheads, Sebastolobus spp., using a towed video camera sled. **Fisheries Research**, v. 70, p. 39-48. DOI 10.1016/j.fishres.2004.06.009.

LEMBKE, C.; GRASTY, S.; SILVERMAN, A.; BROADBENT, H.; BUTCHER, S.; MURAWSKI, S. 2017. The camera-based assessment survey system (C-BASS): A towed camera platform for reef fish abundance surveys and benthic habitat characterization in the Gulf of Mexico. **Continental Shelf Research**, v. 151, p. 62-71.

LESSA, R.; NÓBREGE, M. F. 2000. Programa REVIZEE/SCORE-NE - Guia de identificação de peixes marinhos da região Nordeste. Recife, UFRPE-DIMAR, 128 p.

LOWE-McCONNELL, R. H. 1999. Estudos ecológicos de comunidades de peixes tropicais. São Paulo, **EDUSP**, 536 p.

LOWRY, M.; FOLPP, H.; GREGSON, M.; SUTHERS, I. 2012. Comparison of baited remote underwater video (BRUV) and underwater visual census (UVC) for assessment of artificial reefs in estuaries. **Journal of Experimental Marine Biology and Ecology**, v. 416-417, p. 243–253. DOI 10.1016/j.jembe.2012.01.013.

LUIZ Jr, O. J.; CARVALHO-FILHO, A.; FERREIRA, C. E. L.; FLOETER, S. R.; GASPARINI, J. L.; SAZIMA, I. 2008. The reef fish assemblage of the Laje de Santos Marine State Park, Southwestern Atlantic: annotated checklist with comments on abundance, distribution, trophic structure, symbiotic associations, and conservation. **Zootaxa**, v. 1807, p. 1-25. DOI 10.11646/zootaxa.1807.1.1.

MACHAN, R.; FEDRA, K. 1975. A New Towed Underwater Camera System for Wide-Range Benthic Surveys. **Marine Biology**, v. 33, p. 75-84.

MAIDA, M.; FERREIRA, B. P. 1997. Coral reefs of Brazil: an overview. **Proceedings of the 8th International Coral Reef Symposium**, v. 1, p. 263–274.

MALLET, D.; PELLETIER, D. 2014. Underwater video techniques for observing coastal marine biodiversity: A review of sixty years of publications (1952–2012). **Fisheries Research**, v. 154, p. 44–62.

MANSO, V.; CORREA, I.; GUERRA, N. 2003. Morfologia e sedimentologia da Plataforma Continental Interna entre as praias Porto de Galinhas e Campos-Litoral Sul de Pernambuco, Brasil. **Pesquisas em Geociências**, v. 30, n. 2, p. 17–25. DOI 10.22456/1807-9806.19587.

MARTÍN, J.; PUIG, P.; PALANQUES, A.; RIBÓ, M. 2014. Trawling-induced daily sediment resuspension in the flank of a Mediterranean submarine canyon. **Deep-Sea Research II**, v. 104, p. 174-183. DOI 10.1016/j.dsr2.2013.05.036.

MATSUURA, K. 2003. Ostraciidae. Boxfishes (trunkfishes, cowfishes). In K.E. Carpenter (ed.) FAO species identification guide for fishery purposes. **The living marine resources of the Western Central Atlantic**, v. 3, p. 1980-1987. Bony fishes part 2 (Opistognathidae to Molidae), sea turtles and marine mammals.

McINTYRE, F. D.; NEAT, F.; COLLIE, N.; STEWART, M.; FERNANDES, P. G. 2015. Visual surveys can reveal rather different 'pictures' of fish densities: Comparison of trawl and video camera surveys in the Rockall Bank, NE Atlantic Ocean. **Deep-Sea Research I**, v. 95, p. 67-74. DOI 10.1016/j.dsr.2014.09.005.

MEDEIROS, P. R.; ROSA, R. S.; FRANCINI-FILHO, R. B. 2011. Dynamics of fish assemblages on a continuous rocky reef and adjacent unconsolidated habitats at Fernando de Noronha Archipelago, tropical western Atlantic. **Neotropical Ichthyology**, v. 9, n. 4, p. 869-879.

MELLI, V.; KRAG, L. A. B.; HERRMANN, B.; KARLSEN, J. D. 2019. Can active behaviour stimulators improve fish separation from Nephrops (Nephrops norvegicus) in a horizontally divided trawl codend?. **Fisheries Research**, v. 211, p. 282–290. DOI 10.1016/j.fishres.2018.11.027.

MENDES, T. C.; QUIMBAYO, J. P.; BOUTH, H. F.; SILVA, L. P. S.; FERREIRA, C. E. L. 2019. The omnivorous triggerfish Melichthys niger is a functional herbivore on an isolated Atlantic oceanic island. **Journal of Fish Biology**, v. 95, p. 812-819. DOI 10.1111/jfb.14075.

MENZA, C.; KENDALL, M.; ROGERS, C.; MILLER, J. 2007. A deep reef in deep trouble. **Continental Shelf Research**, v. 27, p. 2224–2230. DOI 10.1016/j.csr.2007.05.017.

MÉRILLET, L.; ROBERT, M.; SALAÜN, M.; SCHUCK, L.; MOUCHET, M.; KOPP, D. 2018. Underwater video offers new insights into community structure in the Grande Vasière (Bay of Biscay). **Journal of Sea Research**, v. 139, p. 1–9. DOI 10.1016/j.seares.2018.05.010.

MILKOV, A.; VOGT, P.; CHERKASHEV, G.; GINSBURG, G.; CHERNOVA, N.; ANDRIASHEV, A. 1999. Sea-floor terrains of Haskon Mosby Mud Volcano as surveyed by deep-tow video and still photography. **Geo-Marine Letters**, v. 19, p. 38-47. DOI 10.1007/s003670050091.

MILLIMAN, J. D.; AMARAL, C. A. B. 1974. Economic potential of Brazilian continental margin sediments. **Annals of 28th Brazilian Congress of Geology**, p. 335–344.

MITCHILL, S. L. 1815. The fishes of New York, described and arranged. **Trans. Lit. Philos. Soc.**, New York, v. 1, p. 355-492.

MOHR, L. V.; CASTRO, J. W. A.; COSTA, P. M. S.; ALVES, R. J. V. 2009. Ilhas oceânicas brasileiras: da pesquisa ao manejo. Vol. II, **MMA Secretaria de Biodiversidade e Floresta**, Brasilia, Brasil. 496 p.

MORAIS, R. A.; MAIA, H. A. 2017. Lush underwater forests in mesophotic reefs of the Gulf of Guinea. **Coral Reefs**, v. 36, p. 95. DOI 10.1007/s00338-016-1523-z

MORRISON, M.; CARBINES, G. 2006. Estimating the abundance and size structure of an estuarine population of the sparid Pagrus auratus, using a towed camera during nocturnal periods of inactivity, and comparisons with conventional sampling techniques. **Fisheries Research**, v. 82, p. 150-161. DOI 10.1016/j.fishres.2006.06.024.

MURPHY, H. M.; JENKINS, G. P. 2010.Observational methods used in marine spatial monitoring of fishes and associated habitats: a review. **Marine Freshwater Research**, v. 61, p. 236–252. DOI 10.1071/MF09068.

NELSON, J. S.; GRANDE, T.; WILSON, M. V. H. 2016. Fishes of the world. 5th Edition, **John Wiley & Sons**, Inc, Hoboken, New Jersey.

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.

NOACK, T.; STEPPUTTIS, D.; MADSEN, N.; WIELAND, K.; HAASE, S.; KRAG, L. A. 2019. Gear performance and catch process of a commercial Danish anchor seine. **Fisheries Research**, v. 211, p. 204–211. DOI 10.1016/j.fishres.2018.11.012.

O’NEILL, F. G.; SUMMERBELL, K. 2011. The mobilisation of sediment by demersal otter trawls. **Marine Pollution Bulletin**, v. 62, p. 1088–1097. DOI 10.1016/j.marpolbul.2011.01.038.

ORDINES, F.; BAUZÁ, M.; SBERT, M.; ROCA, P.; GIANOTTI, M.; MASSUTÍ, E. 2015. Red algal beds increase the condition of nekto-benthic fish. **Journal of Sea Research**, v. 95, p. 115–123. DOI 10.1016/j.seares.2014.08.002.

PAGE, C.; COLEMAN, G.; NINIO, R.; OSBORNE, K. 2001. Surveys of benthic reef communities using underwater video. **Long-term Monitoring of the Great Barrier Reef - Standard Operational Procedure Number 7**. Townsvile: Autralian Institute of Marine Sciences, 49 pages.

PARENTI, P.; RANDALL, J. E. 2018. A checklist of wrasses (Labridae) and parrotfishes (Scaridae) of the world: 2017 update. **Journal of the Ocean Science Foundation**, v. 30, p. 11–27. DOI 10.5281/zenodo.1247552.

PEARCY, W. G.; STEIN, D. L.; HIXON, M. A.; PIKITCH, E. K.; BARSS, W. H., STARR, R. M. 1989. Submersible Observations of Deep-Reef Fishes of Heceta Bank, Oregon. **Fishery Bulletin**, U.S., v. 87, p. 955-965.

PELLETIER, D.; LELEU, K.; Mou-Tham, G.; Guillemot, N.; Chabanet, P. 2011. Comparison of visual census and high definition video transects for monitoring coral reef fish assemblages. **Fisheries Research**, v. 107, n. 1–3, p. 84–93.

PELLETIER, D.; LELEU, K.; MALLET, D.; MOU-THAM, G.; HERVÉ, G.; BOUREAU, M.; GUILLEMOT, N. 2012. Remote High-Definition Rotating Video Enables Fast Spatial Survey of Marine Underwater Macrofauna and Habitats. **PLoS ONE**, v. 7, n. 2, e30536.

PEREIRA-FILHO, G. H.; AMADO-FILHO, G. M.; MOURA, R. L.; BASTOS, A. C.; GUIMARÃES, S. M. P. B.; SALGADO, L. T.; FRANCINI-FILHO, R. B.; BAHIA, R. G.; ABRANTES, D. P.; GUTH, A. Z.; BRASILEIRO, P. S. 2012. Extensive Rhodolith Beds Cover the Summits of Southwestern Atlantic Ocean Seamounts. **Journal of Coastal Research,** v. 28, n. 1, p. 261-269. DOI 10.2112/11T-00007.1.

PEREIRA-FILHO, G. H.; FRANCINI-FILHO, R. B.; PEIROZZI-JR, I.; PINHEIRO, H. T.; BASTOS, A. C.; MOURA, R. L.; MORAES, F. C.; MATHEUS, Z.; BAHIA, R. G.; AMADO-FILHO, G. M.; 2015. Sponges and fish facilitate succession from rhodolith beds to reefs. **Bulletin of Marine Science**, v. 91, n. 1, p. 45-46. DOI 10.5343/bms.2014.1067.

PILSKALN, C. H.; CHURCHILL, J. H.; MAYER, L. M. 1998. Resuspension of sediments by bottom trawling in the Gulf of Maine and potential geochemical consequences. **Conservation Biology**, v. 12, n. 6, p. 1223–1229.

Pinheiro, H.T., Joyeux, J.C., Moura, R.L. 2014. Reef oases in a seamount chain in the southwestern Atlantic. Coral Reefs. 33, 1113. http://doi.org/10.1007/s00338-014-1211-9

PINHEIRO, H. T.; MAZZEI, E.; MOURA, R. L.; AMADO-FILHO, G. M.; CARVALHO-FILHO, A.; BRAGA, A. C.; COSTA, P. A. S.; FERREIRA, B. P.; FEREIRA, C. E. L.; FLOETER, S. R.; FRANCINI-FILHO, R. B.; GASPARINI, J. L.; MACIEIRA, R. M.; MARTINS, A. S.; OLAVO, G.; PIMENTEL, C. R.; ROCHA, L. A.; SAZIMA, I.; SIMON, T.; TEIXEIRA, J. B.; XAVIER, L. B.; JOYEUX, J. C. 2015. Fish biodiversity of the Vitória-Trindade Seamount Chain, southwestern Atlantic: an updated database. **PLoS One**, v. 10, e0118180. DOI 10.1371/journal.pone.0118180.

PINHEIRO, H. T.; GOODYBODY-GRINGLEY, G.; JESSUP, M. E.; SHEPHERD, B.; CHEQUER, A. D.; ROCHA, L. A. 2016. Upper and lower mesophotic coral reef fish communities evaluated by underwater visual censuses in two Caribbean locations. **Coral Reefs**, v. 35, p. 139–151. DOI 10.1007/s00338-015-1381-0.

POEY, F. (1858–1861). “Memorias Sobre la Historia Natural de la Isla de Cuba . . . ,” Vol. 2. Havana. Prager, E.J., Ginsburg, R.N., 1989. Carbonate nodule growth on **Florida’s outer shelf and its implications for fossil interpretations**, Palaios, v. 4, p. 310–317.

ROCHA, L. A.; PINHEIRO, H. T.; SHEPHERD, B.; PAPASTAMATIOU, Y. P.; LUIZ, O. J.; PYLE, R. L.; BONGAERTS, P. 2018. Mesophotic coral ecosystems are threatened and ecologically distinct from shallow water reefs. **Science**, v. 361, p. 281–284. DOI 10.1126/science.aaq1614.

ROLIM, F. A.; RODRIGUES, P. F. C.; GADIG, O. B. F. 2019. Baited videos to assess semi-aquatic mammals: occurrence of the neotropical otter *Lontra longicaudis* (Carnivora: Mustelidae) in a marine coastal island in São Paulo, Southeast Brazil. **Marine Biodiversity**, v. 49, p.1047–1051.

ROSA, M. G.; ALVES, A. C.; MEDEIROS, D. V.; CONI, E. O. C.; FERREIRA, C. M.; FERREIRA, B. P.; ROSA, R. S.; AMADO-FILHO, G. M.; PEREIRA-FILHO, G. H.;

MOURA, R. L.; THOMPSON, F. L.; SUMIDA, P. Y. G.; FRANCINI-FILHO, R. B. 2016. Mesophotic reef fish assemblages of the remote St. Peter and St. Paul's Archipelago, Mid-Atlantic Ridge, Brazil. **Coral Reefs**, v. 35, p. 113–123. DOI 10.1007/s00338-015-1368-x.

SANTOS, C. S. G.; LINO, J. B.; VERAS, P. C AMADO-FILHO, G. M.; FRANCINI-FILHO, R. B.; MOTTA, F. S.; MOURA, R. L.; PEREIRA-FILHO, G. H. 2016. Environmental licensing on rhodolith beds: insights from a worm**. Natureza e Conservação**, v. 14, p. 137-141. DOI 10.1016/j.ncon.2016.06.002.

SAZIMA, I.; SAZIMA, C.; SILVA-Jr, J. M. 2006. Fishes associated with spinner dolphins at Fernando de Noronha Archipelago, tropical Western Atlantic: an update and overview. **Neotropical Ichthyology**, v. 4, n. 4, p. 451-455.

SCHANER, T.; FOX, M. G.; TARABORELLI, A. C. 2009. An inexpensive system for underwater video surveys of demersal fishes. **Journal of Great Lakes Research**, v. 35, p. 317–319. DOI 10.1016/j.jglr.2008.12.003.

SEMMLER, R. F.; HOOT, W. C.; REAKE, M. L. 2017. Are mesophotic coral ecosystems distinct communities and can they serve as refugia for shallow reefs?. **Coral Reefs**. DOI 10.1007/s00338-016-1530-0.

SFAKIOTAKIS, M.; LANE, D. M.; DAVIES, J. B. C. 1999. Review of fish swimming modes for aquatic locomotion**. IEEE Journal of Oceanic Engineering**, v. 24, p. 237–252.

SHIPP, R. L. 2003. Tetraodontidae. In Carpenter K.E. (ed) FAO species identification guide for fishery purposes. **The living marine resources of the Western Central Atlantic**, v. 3, p. 1988–2006. Rome, Italy: FAO of the United Nations.

SHUCKSMITH, R.; HINZ, H.; BERGMANN, M.; KAISER, M. J. 2006. Evaluation of habitat use by adult plaice (Pleuronectes platessa L.) using underwater video survey techniques. **Journal of Sea Research**, v. 56, p. 317–328. DOI 10.1016/j.seares.2006.06.001.

SINGH, W.; ÖRNÓLFSDÓTTIR, E. B.; STEFANSSON, G. 2013. A camera-based autonomous underwater vehicle sampling approach to quantify Scallop Abundance. **Journal of Shellfish Research**, v. 32, n. 3, p. 725–732.

SMITH, C. L. 1966. Menophorus Poey, a serranid genus based on two hybrids of Cephalopholis fulva and Paranthias furcifer, with comments on the systematic placement of Paranthias. **Am. Mus. Novit.**, v. 2276, p. 1–11.

SMITH, C. J.; PAPADOPOULO, K. N.; DILIBERTO, S. 2000. Impact of otter trawling on an eastern Mediterranean commercial trawl fishing ground. **Journal of Marine Science**, v. 57, p. 1340-1351.

SOARES, M. O.; TAVARES, T. C. L.; CARNEIRO, P. B. M. 2019. Mesophotic ecosystems: Distribution, impacts and conservation in the South Atlantic. **Diversity and Distributions**, v. 25, p. 255–268. DOI 10.1111/ddi.12846.

SOTO, J. M. R. 2001. Fishes of the Fernando de Noronha Archipelago. **Mare Magnum**, v. 1, n. 2, p. 147-169.

SPENCER, M. L.; STONER, A. W.; RYER, C. H.; MUNK, J. E. 2005. A towed camera sled for estimating abundance of juvenile flatfishes and habitat characteristics: Comparison with beam trawls and divers. **Estuarine, Coastal and Shelf Science**, v. 64, p. 497-503.

SPIER, D.; STAMPAR, S. N.; PRANTONI, A. L. 2012. New record of the endangered cerianthid *Ceriantheomorphe brasiliensis* (Cnidaria: Hexacorallia) in Paranaguá Bay, southern Brazil. **Marine Biodiversity Records**, p.1-4.

STONER, A. W.; SPENCER, M. L.; RYER, C. H. 2007. Flatfish-habitat associations in Alaska nursery grounds: Use of continuous video records for multi-scale spatial analysis. **Journal of Sea Research**, v. 57, p. 137–150. DOI 10.1016/j.seares.2006.08.005.

TESSIER, E.; CHABANET, P.; POTHIN, K.; SORIA, M.; LASSERRE, G. 2005. Visual censuses of tropical fish aggregations on artificial reefs: slate versus video recording techniques. **Journal of Experimental Marine Biology and Ecology**, v. 315, p. 17–30. DOI 10.1016/j.jembe.2004.08.027.

TESSIER, A.; PASTOR, J.; FRANCOUR, P.; SARAGONI, G.; CREC'HRIOU, R.; LENFANT, P. 2013. Video transects as a complement to underwater visual census to study reserve effect on fish assemblages. **Aquatic Biology**, v. 18, p. 229-241. DOI 10.3354/ab00506.

THOMAS, J. V.; SREEDEVI, C., KURUP, B. M. 2006. Variations of the infaunal polychaetes due to bottom trawling along the inshore waters of Kerala (south-west coast of India). **Indian Journal of Marine Sciences**, v. 35, n. 3, p. 249-256.

TRENKEL, V. M.; FRANCIS, R. I. C. C.; LORANCE, P.; MAHÉVAS, S.; ROCHET, M.; TRACEY, D. M. 2004a. Availability of deep-water fish to trawling and visual observation from a remotely operated vehicle (ROV). **Marine Ecology Progress Series**, v. 284, p. 293-303.

TRENKEL, V. M.; LORANCE, P.; MAHÉVAS, S. 2004b. Do visual transects provide true population density estimates for deepwater fish?. **ICES Journal of Marine Science**, v. 61, n. 7, p. 1050-1056. DOI 10.1016/j.icesjms.2004.06.002.

TRENKEL, V. M.; VAZ, S.; ALBOUY, C.; BRIND'AMOUR, A.; DUHAMEL, E.; LAFFARGUE, P.; ROMAGNAN, J. B.; SIMON, J.; LORANCE, P. 2019. We can reduce the impact of scientific trawling on marine ecosystems. **Marine Ecology Progress Series**, v. 609, p. 277–282. DOI 10.3354/meps12834.

THRESHER, R. E. 1991. Geographic variability in the ecology of coral reef fishes: evidence, evolution and possible implications. In: The Ecology of Fishes on Coral Reefs (Sale, P. F., ed.). San Diego: **Academic Press**, p. 401–436.

THOMPSON, R.; MUNRO, J. 1978. Aspects of the biology and ecology of Caribbean reef fishes: Serranidae (hinds and groupers). **Journal of Fish Biology**, v. 12, p. 115–146.

TYLER, J. C.; LUCKHURST, B. E. 1994. Unusual Features of the Colonies of the Common Western Atlantic Garden Eel (Heterocongrinae), with a New Record for Bermuda. **Northeast Gulf Science**, v. 13, n. 2, p. 89-99.

UZMANN, J. R.; COOPER, R. A.; THEROUX, R. B.; WIGLEY, R. L. 1977. Synoptic Comparison of Three Sampling Techniques for Estimating Abundance and Distribution of Selected Megafauna: Submersible VS Camera Sled VS Otter Trawl. **Marine Fisheries Review**, v. 39, n. 12, p. 11-19.

VECSEI, A. 2004. Carbonate production on isolated banks since 20 k.a. BP: climatic implications. **Palaeogeography, Palaeoclimatology, Palaeoecology**, v. 214, p. 3–10.

VERGÉS, A.; BENNETT, S.; BELLWOOD, D. 2012. Diversity among macroalgae-consuming fishes in coral reefs: a transcontinental comparison. **PLoS ONE**, v.7, n. 9, e45543.

VICTOR, B. C. 1987. The mating system of the caribean rosy razorfish, Xyrichtys martinicensis. **Bulletin of Marine Science**, v. 40, n. 1, p. 152-160.

VITAL, H.; GOMES, M. P.; TABOSA, W. F.; FRAZÃO, E. P.; SANTOS, C. L. A.; PLACIDO JUNIOR, J. S. 2010. Characterization of the Brazilian continental shelf adjacent to Rio Grande do Norte State, NE Brazil. **Brazilian Journal of Oceanography**, v. 58, p. 43–54. DOI 10.1590/S1679-87592010000500005.

WARNOCK, W.; HARVEY, E. S.; NEWMAN, S. J. 2016. Remote drifted and diver operated stereo–video systems: A comparison from tropical and temperate reef fish assemblages. **Journal of Experimental Marine Biology and Ecology**, v. 478, p. 45–53. DOI 10.1016/j.jembe.2016.02.002.

WATLING, L.; NORSE, E. A. 1998. Disturbance of the Seabed by Mobile Fishing Gear: A Comparison to Forest Clearcutting. **Conservation Biology**, v. 12, n. 6, p. 1180-1197.

WATSON, D. L.; Harvey, E. S.; ANDERSON, M. J.; KENDRICK, G. A. 2005. A comparison of temperate reef fish assemblages recorded by three underwater stereo-video techniques. **Marine Biology**, v. 148, p. 415–425.

WILSON, S. K.; BELLWOOD, D. R.; CHOAT, J. H. 2003. Detritus in the epilithic algal matrix and its use by coral reef fishes. **Oceanography and Marine Biology - An Annual Review**, v. 41, p. 279–309.

YOUNG, H. J.; RAOULT, V.; PLATELL, M. E.; WILLIAMSON, J. E.; GASTON, T. F. 2019. Within-genus differences in catchability of elasmobranchs during trawling. **Fisheries Research**, v. 211, p. 141–147. DOI 10.1016/j.fishres.2018.11.015.

YULE, D. L.; ADAMS, J. V.; STOCKWELL, J. D.; GORMAN, O. T. 2008. Factors Affecting Bottom Trawl Catches: Implications for Monitoring the Fishes of Lake Superior. **North American Journal of Fisheries Management**, v. 28, p. 109–122.

ZHANG, W. G.; McGILLICUDDY Jr., D. J.; GAWARKIEWICZ, G. G. 2013. Is biological productivity enhanced at the New England shelfbreak front?, **Journal of Geophysical Research: Oceans**, v. 118, p. 517–535. DOI 10.1002/jgrc.20068.