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ESTUDO DA ASSEMBLEIA DE PEIXES DO ARQUIPÉLAGO DE SÃO PEDRO E SÃO PAULO COM O USO DE ESTAÇÃO REMOTA DE VÍDEO SUBAQUÁTICO COM ISCA (BRUVS)

Recife
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Dissertação apresentada ao Programa de Pós-Graduação em Oceanografia da Universidade Federal de Pernambuco, como requisito parcial para a obtenção do título de mestre em Oceanografia.

Área de concentração: Oceanografia Biológica.

Orientador: Prof. Dr. Fábio Hissa Vieira Hazin (*in memorian*)

Coorientadora: Dra. Natalia Priscila Alves Bezerra

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RESUMO

Um total de 35 lançamentos de Estações de vídeo subaquáticas com iscas (BRUVS) foram realizados no Arquipélago de São Pedro e São Paulo (ASPSP) para avaliar a abundância, diversidade e comparar a distribuição espacial da comunidade local de peixes, e também, descrever preliminarmente o comportamento dos elasmobrânquios. Cerca de 2.700 minutos de vídeos foram gravados em águas de até 30 metros de profundidade. Um total de 2.991 indivíduos foram contabilizados, pertencentes a 6 ordens, 10 famílias e 19 espécies, sendo quatro espécies de elasmobrânquios e 15 de teleósteos. Análises multivariadas indicaram um diferente uso da área entre as espécies de peixes do lado oeste e leste. Segregação interespecífica entre elasmobrânquios *C. falciformis* e *C. galapagensis* foi também visualizada, além de uma provável segregação sexual intraespecífica para *C. falciformis*. Os comportamentos dos elasmobrânquios contabilizam o total de 2.867 registros em 483.4 minutos de gravação. O comportamento de cautela (1.624 registros e 267 minutos) foi predominante nos elasmobrânquios. Embora ainda existam lacunas sobre o comportamento de peixes na natureza, o uso de BRUVS em um ecossistema insular ocorreu de forma bastante satisfatória, sendo um método de monitoramento contínuo para as espécies registradas no presente estudo. Além disso, a ictiofauna e o seu comportamento registrado pelo BRUVS são importantes para avaliar a efetividade da gestão da Área Marinha Protegida, adicionando assim informações relevantes para explorar de maneira sustentável ou integralmente proteger o ASPSP e as áreas adjacentes.

Palavras-chave: ictiofauna; elasmobrânquios; comportamento; conservação; AMP

ABSTRACT

A total of 35 Baited Remote Underwater View Station (BRUVS) deployments were made in the Saint Peter and Saint Paul Archipelago (SPSPA), an archipelago in the middle of the Atlantic Ocean, to assess the abundance, diversity and compare the spatial distribution of the local fish community, and also, describe preliminary elasmobranch behaviors. About 2,700 minutes of videos recorded in waters up to 30 meters. A total of 2,991 individuals were recorded of 6 orders, 10 families and 19 species. Four elasmobranchs and 15 teleosts species were registered. Elasmobranch behaviors were recorded and photo registered, also other behaviors were added. Multivariate analysis indicates different area use between west and east side fish species. Interspecific elasmobranch segregation between *C. falciformis* and *C. galapagensis* was also supported, besides a probable intraspecific sexual segregation for *C. falciformis*. The cautious behavior was predominant in elasmobranch behavior. The number of behavioral notes taken shows how it is possible to explored and understood behaviors using the BRUVS. Although there are still gaps about fish behavior in the wild. BRUVS performed satisfactorily and can be implemented as a method for continuously monitoring the species registered in this present study, as well as a complementary method to be used with conventional methods of fish sampling. Hence, the ichthyofauna and their behavior recorded by BRUVS are important to evaluate and manage the SPSPA MPA area, adding relevant information to explore sustainably or to integrally protected the SPSPA and adjacent areas.

Keywords: ichthyofauna; elasmobranchs; behavior; conservation; MPA

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1 INTRODUÇÃO GERAL

Diferentes técnicas de amostragens são necessárias para detectar a comunidade de peixes presente em um local, contudo nenhuma metodologia é capaz de produzir resultados que refletem integralmente as espécies de uma determinada assembleia de peixes (Watson et al 2005). Por isso, quanto mais diversos forem os meios de amostragens, melhor será a compreensão da ictiofauna presente em uma região. Métodos de captura são frequentemente utilizados para levantamentos ictiofaunísticos, no entanto poucas vezes as capturas são seletivas, causando a morte de espécies não-alvo das pescarias (*bycatch*), causando prejuízos especialmente para as espécies que já sofrem declínios populacionais (Ebner e Morgan 2013). No grupo dos elasmobrânquios, por exemplo, várias espécies estão inseridas na lista vermelha de espécies ameaçadas de extinção da IUCN (*International Union for Conservation of Nature*) em diferentes categorias e com distintos níveis de ameaça (Dulvy et al 2014), o que denota a necessidade de um método de amostragem não invasivo e não destrutivo para esse grupo, a fim de proteger não apenas essas espécies, mas também os seus habitats essenciais.

O Censo Visual Subaquático (CVS), por sua vez, é uma metodologia capaz de amostrar diferentes localidades sem a necessidade de coletar as espécies, contudo requer a participação de mergulhadores qualificados para identificar as variadas espécie (Schmid et al 2020). Essa técnica é amplamente utilizada por pesquisadores e, embora seja um método não invasivo, se faz necessário que os mergulhadores estejam inseridos no ambiente natural dos peixes, interferindo assim diretamente no comportamento e na ocorrência de alguns organismos (Watson et al 2005; Willis & Babcock 2000, Arckeman & Bellwood 2000; Brock 1982; Stewart & Beukers 2000; Willis 2001).

No intuito de solucionar as problemáticas peculiares as outras técnicas de amostragem, o *Baited Remoted Underwater View Station* ou estação de vídeo subaquática remota iscada (sigla em inglês BRUVS), vem sendo utilizado por diversos pesquisadores na última década. O BRUV é uma estrutura simples, podendo ser construídas de diversos formatos, com uma câmera subaquática acoplada e um braço que se estende dessa estrutura contendo uma caixa para acondicionar as iscas. Os BRUVS são eficientes para amostrar principalmente espécies carnívoras, embora em

estudos anteriores foi possível observar espécies de diferentes níveis tróficos que podem ser atraídos pela estrutura. Quando comparado aos CVS, por exemplo, o uso de BRUVS é uma alternativa eficiente para estudar as assembleias de peixes, sem a interferência de mergulhadores no ambiente, retratando de forma mais fidedigna a paisagem (Kulbricki 1998; Willis & Babcock 2000; Watson, et al 2005).

Os métodos que utilizam iscas se mostram mais eficientes que métodos nos quais não se utilizam iscas para determinar a riqueza e abundância de espécies carnívoras presentes no ambiente (Harvey et al 2007; Hardigne et al 2013; Schmid 2016). Contudo, não foi encontrada diferença na amostragem entre UBRUVS e BRUVS para indivíduos herbívoros, mesmo com iscas que deverim ser atrativas para sua dieta (Schmid 2016). Ainda, a principal vantagem em realizar amostragens com os BRUVS, por exemplo, é o tempo reduzido de operação e manuseio do equipamento quando comparado as técnicas de captura (Ebner & Morgan 2013; Besley & Gilmour 2008). Portanto, as técnicas de amostragem utilizando câmeras são mais eficientes em proporcionar um trabalho de campo em tempo reduzido além de não gerar mínimo impacto ao meio ambiente, visto que não há retirada de espécies do seu habitat. Já as BRUVS, por sua vez, proporcionam um acervo de amostras digitais que não ocupam espaço físico.

No Brasil, Rolim et al (2019) obtiveram, em ambiente marinho, resultados importantes sobre a biodiversidade e manejo da pesca utilizando a BRUVS em áreas de pesca restrita. Do mesmo modo, Schmid et al (2016) já haviam realizado experimentos com BRUVS em ambiente dulcícola. Nos últimos anos, estudos com BRUVS no Brasil têm obtido dados sobre populações de raias e tubarões (elasmobrânquios), especialmente a partir do projeto Global FinPrint (https://globalfinprint.org), que impulsionou diversos trabalhos de levantamento e análise populacional (i.e.: Schmid et al 2020) . No entanto, o uso dos BRUVS como método de investigação de assembleias de peixes no Brasil ainda é incipiente, demandando portanto mais estudos com essa metodologia em águas brasileiras.

O uso de BRUVS tem sido realizado para qualificar e mensurar a riqueza, abundância e grau de recuperação de populações dentro de áreas protegias ou reservas marinhas (Jaiteh, et al 2016; Speed et al 2018; Walsh et al 2016). O arquipélago de São Pedro e São Paulo (ASPSP), a menor das ilhas oceânicas

brasileiras, apresenta uma área decretada (Decreto nº 9313) em 2018 como Monumento Natural (MONA) abrangendo as ilhas Sirius, Sacadura Cabral, Gago Coutinho e área marinha adjacente, não englobando as demais ilhas do Arquipélago. A área do MONA tem o seu uso restrito, por isso nesse local não é permitida qualquer atividade de pesca. Portanto, por apresentar um mínimo impacto ao ecossistema, o BRUVS é uma ferramenta ideal para o monitoramento de áreas com elevado grau de proteção. Neste contexto, o presente trabalho teve por objetivo realizar o levantamento da assembleia de peixes no ASPSP, a fim de obter um quadro compreensível da riqueza, diversidade e abundância de espécies de peixe presentes na área, descrevendo de maneira preliminar o comportamento dos elasmobrânquios.

2 OBJETIVOS

Seguem abaixos os objetivos,

2.1 OBJETIVO GERAL

Realizar o levantamento da ictiofauna do arquipélago de São Pedro e São Paulo com o uso dos BRUVS, na expectativa de gerar informações relevantes sobre a diversidade, riqueza, abundância, comportamento e uso de área pelas espécies quehabitam a região.

2.2 OBJETIVOS ESPECÍFICOS

- ✓ Realizar um levantamento da ictiofauna presente no ASPSP com aBRUVS;
- ✓ Avaliar o uso da área pelas espécies de peixes ósseos e elasmobraquios;
- ✓ Comparar a diversidade, riqueza e abundância entre o lado leste e o lado oeste do ASPSP de elasmobrânquios;
- ✓ Descrever os padrões de comportamento dos principais elasmobrânquios registrados.

3 DETALHAMENTOS DA METODOLOGIA

Segue abaixo a metodologia.

3.1 ÁREA DE ESTUDO

O Arquipélago de São Pedro e São Paulo (ASPSP) é composto por 10 ilhotas, localizado a 1.010 km da costa NE do Brasil, e 1.890 km da costa SW do Senegal, na África. O arquipélago está situado acima da porção norte da dorsal mesoatlântica na zona de falha transformante de São Paulo, caracterizando-se por ser o menor e mais isolado arquipélago tropical (Edwards & Lubbock 1983; Luiz et al 2015).

A circulação das águas superficiais na região equatorial do Atlântico, onde se localiza o ASPSP, é fortemente influenciada pela variação da cirulação atmosférica, onde os ventos, que além de se intensificarem, influenciam mudanças sazonais deslocando a Zona de Convergência Intertropical (Lumpkin & Garzoli 2005; Stramma & Schott 1999). A Temperatura Superficial do Mar (TSM) é de, em média, 26,5ºC, exceto durante a estação mais quente, de março a abril, quando a TSM atinge valores superiores a 28ºC (Cintra et al 2015).

3. 2 LANÇAMENTOS DOS BRUVS

O BRUVS utilizado consistiu em uma estrutura de alumínio (Figura 1), em formato de pirâmide, com uma caixa estanque que abrigou a câmera, modelo GoPro Hero 5. As estações de coleta foram demarcadas com o auxílio de GPS, e a estrutura foi lançada no ambiente pelágico sem alcançar o fundo oceânico, em profundidades de no máximo 30 m. As gravações foram realizadas por 90 min, com os horários de coleta estabelecidos uma hora após o nascer e uma hora antes do pôr do sol, a fim de evitar a baixa luminosidade nos períodos crepusculares (McCauley et al 2016). Com o objetivo de atrair os peixes, os BRUVS foram guarnecidos com isca composta por vísceras de peixes coletados no próprio ambiente, acondicionados em uma caixa constituída por uma rede e fixada a 1m de distância da câmera. Os BRUVS receberam um cabo e uma boia do tipo bala que confere flutuabilidade à estrutura, a qual foi interligada até a embarcação, evitando assim que o equipamento ficasse a deveria. As coletas foram realizadas nas porções leste e oeste do ASPSP.

Figura 1. BRUVS utilizado no presente trabalho. Estrutura armada e pronta para lançamento, com câmera acoplada no ápice da pirâmide de metal e na ponta do braço guarnecida com iscas.

Fonte: Natália Alves (2021).

3. 3 ANÁLISE DE VÍDEO E COMPORTAMENTOS PRELIMINARES

Primeiramente, as filmagens foram vistas com a velocidade 2x acelerada, para identificar todas as espécies (processo chamado de depuração) e determinar o Tempo de Primeira Observação (TPO). O TPO é o intervalo de tempo até a chegada da primeira espécie na filmagem. Após a depuração das filmagens, as mesmas foram revistas e pausadas para contabilizar o número de exemplares na imagem (Willis &

Babcock 2000). O Nmax é O Número máximo de indivíduos de uma espécie (Nmax) em uma foto da imagem pausada (*frame*), sendo considerada uma metodologia conservadora de abundância, pois é possível que indivíduos diferentes de uma mesma espécie sejam gravados mais de uma vez (Willis & Babcock, 2000). A abundância relativa foi calculada por hora (Nmax h^{-1}), e os Nmax somados são a abundância total de uma espécie na área de coleta, sendo definido como Soma do Nmax (SNmax). A identificação das espécies foi realizada com o auxílio de literatura disponível para os diferentes grupos (Carpenter 2002; FAO 2016) e confirmada por um pesquisador experiente. Os indivíduos foram sexados, no caso dos elasmobrânquios, quando possível. As filmagens foram vistas no aplicativo VLC (VideoLan Client, www.videolan.org).

A diversidade de Shannon (H') e a equitabilidade de Pielou foram calculados. Os status de conservação das espécies foram provenientes da União Internacional para a Conservação da Natureza (IUCN, www.iucnredlist.org) e o nível trófico foi obtido no site FishBase (Froese & Pauly, 2021).

Para analisar os comportamentos dos elasmobrânquios, as filmagens foram revistas, pela terceira vez, e cada vez que um elasmobrânquio entrou no foco da câmera (*time in*) era contabilizado um registro, até o momento de sua saída (*time out*), sendo: *time in* - *time out* = tempo de registro do elasmobrânquio, processo utilizado para saber o tempo de registro de uma espécie durante a filmagem (Schobernd et al 2014). O Tempo de Primeira Observação para Elasmobrânquio (TPOE) foi contabilizado, como uma medida análoga ao TPO, porém válido somente para os elasmobrânquios.

A descrição da distância entre os elasmobrânquios e o BRUVS, assim como as atividades realizadas pelas espécies, foi adaptada de acordo com a metodologia proposta por Bruns & Henderson (2020). A atitude de cruzeiro foi definida como um avistamento de um elasmobrânquio sem um foco preciso da câmera, uma imagem borrada, em um distância maior que 10 m. A atitude de cautela ocorreu quando elasmobrânquio passava em uma distância entre 1 m e 10 m da BRUVS. A atitude exploratória foi definida quando o elasmobrânquio alcançava uma distância menor que 1m da BRUVS. Por último, a atitude interativa ocorria quando o elasmobrânquio tocava na caixa de isca usando o focinho ou a boca. A atitude interativa foi dividida em três tipos de acordo com a resposta do elasmobrânquio a BRUVS: focinho, o

elasmobrânquio tocou na BRUVS com o focinho; mordida, abrir a boca e morder a BRUVS, e a mordida forte, que sempre resulta no fechamento da membrana nictitante, prececida de uma interação de 2 segundos, ou mais, somente utilizando o focinho para em seguida morder a BRUVS. Notas de comportamento também foram realizadas, baseadas em Myrberg & Gruber (1974), relacionadas as seguintes manobras: *hit*, *give away*, *follow-formation*, *follow*, *explosive glide* e *turn-back*, que foram realizadas por tubarões e vistas durante os vídeos.

Notas adicionais foram realizadas para documentar outros comportamentos. Foi adicionado o comportamento: *Rhincodon typus* mergulho vertical (Tyminski 2015). Outros comportamentos foram categorizados para: o *Rhincodon typus* o BRUVS *strike*, um *strike* prolongado onde o BRUVS foi carregado pela nadadeira lateral por mais de três segundos; Fechamento da Membrana Nictitante (FMN) e Abertura da Boca, mas sem mordida (AB), que são comportamentos autoexplicativos.

3.4 ANÁLISE ESTATÍSTICA

A abundância e riqueza de espécies foram calculadas para todas as espécies. Um *plot* de ordenação em duas dimensões *non-metric multidimensional scaling* (nMDS) foi usado para avaliar possíveis similaridades de Bray-Curtis entre amostras nos lados oeste e leste, comparando as abundâncias de todas as espécies.

A análise permutacional de uma via (PERMANOVA, 9999 permutações) (Anderson 2017) utilizando o *software* PAST (Hammer et al 2001) foi testada comparando a abundância para todas as espécies das amostras de lado oeste e leste.

O TPO, TPOE, os números de interação e o tempo de interação para as atitudes dos elasmobrânquios foram testados comparando o lado leste e oeste por meio do teste de Mann-Whitney ($p < 0.05\%$). O teste *qui-quadrado* foi realizado para verificar diferença significativa na proporção sexual dos elasmobrânquios identificados ($p < 0.05\%$). Todos os dados foram testados para a normalidade usando o teste de Shapiro-Wilk. A abundância das 35 estações de amostragem, do lado leste e oeste, foram avaliadas pela *Kernel Density Estimation* (QGIS Development Team 2016), para todas as espécies e apenas para o os tubarões *C. galapagensis* e *C. falciformis*.

4 MEMORIES AND MOMENTS IN THE MIDDLE OF THE ATLANTIC OCEAN: VIDEO RECORDS OF FISH AND ELASMOBRANCH SPECIES WITH PRELIMINARY BEHAVIOURAL NOTES

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ABSTRACT

A total of 35 BRUVS station deployments were made in the Saint Peter and Saint Paul Archipelago (SPSPA), to assess the abundance, diversity and compare the spatial distribution of the local fish community and describe preliminary elasmobranch behaviours. About 2,700 minutes of videos recorded and 2,991 individuals were recorded of 6 orders, 10 families and 19 species. Elasmobranch behaviour was categorized. Multivariate analysis indicates significative a samples segregation between west and east side fish species. Interspecific elasmobranch segregation between *C. falciformis* and *C. galapagensis* was also supported, besides a probable intraspecific sexual segregation for *C. falciformis*. The cautious behaviour was predominant in elasmobranch behaviour. BRUVS performed satisfactorily and can be implemented as a method for continuously monitoring. Hence, the BRUVS is important to evaluate and manage the SPSPA MPA area, adding relevant information to explore sustainably or to integrally protected the SPSPA and adjacent areas.

Keywords: Ichthyofauna, fish, elasmobranchs, behaviour, conservation, MPA

INTRODUCTION

Marine environments and marine life have become a social concern and have been more discussed recently. The Marine Spatial Planning Programme of the Intergovernmental Oceanographic Commission (IOC - UNESCO), along with the 14th of the Sustainable Development Goals, is one of main reasons why society as a whole is more closely related and concerned on biodiversity issues about Marine Protected Areas (MPAs). MPAs are important for management of species during breeding season, besides, biodiversity hotspots, endemic areas and migratory routes, which are considerable information to led the creation and regulation of a MPA (Agardy, 2000). Just as many other MPAs around the globe (i.e.: Claudet et al., 2020) the Brazilian MPAs are not completely effective (Giglio et al., 2018). Although, Brazil increased the numbers of MPAs from 1,5% to 25% of his territory recently (Magris and Pressey 2018), covering more than 10% of his coastal and marine area than the agreed by the Members States Parties to the Convention on Biological Diversity (CBD, 2010). Unfortunately, the MPAs in Brazil already suffer with poor management (Diegues, 2008) due to lack of financial support (Gerhardinger et al., 2019).

Therefore, sampling in MPAs need to be according to laws and specific regulations for different levels of protection. Scientific data are preferentially assessed in MPAs using non-lethal methods which preserve the integrity of marine life and the environment. Considering that, the Baited Remote Underwater Video Station (BRUVS) is available for sampling areas with the minimum impact (Murphy and Jenkins, 2010), thus matching the MPAs regulations terms, plus gathering information about fish species abundance and richness (Speed et al., 2018). Also, the BRUVS are being commonly used to assess important recovering data of fish populations inside MPAs, mainly top predators (i.e.: Cappo and Meekan, 2018). Besides, BRUVS performs well inside areas inaccessible to divers and it is a local sampling method which does not required intensive field work (Murphy and Jenkins, 2010). Different fish survey methodologies are used in MPAs but they often present some limitations: the frequency and coverage of Underwater Visual Census (UVC) are restricted by safety regulations, environmental conditions and the availability of skilled divers (Langlois et al., 2010). The capture methods stress or kill the sampled object, generally avoided in MPAs (Marshall et al., 2012; Van Denderen et al., 2015). BRUVS is a non-invasive

and non-lethal methodology, acting according to the MPA regulations where records are executed with minimum disturbance in the environment (Espinoza et al., 2014; Speed et al., 2018). Furthermore, the BRUVS harmonizes the major requirement to collect samples in MPAs with one of its biggest advantages: sampling unseen fish species that avoid the presence of a diver or are killed, or stressed by capture methods (Stewart and Beukers, 2000).

Although BRUVS papers have been published, there remains a gap on the information of behaviour studies in the wild for elasmobranch (Schobernd et al., 2014). Generally, the BRUVS papers focus on quantitative data which do not cover behaviour reports and since the BRUVS generate a record some behavioural information could be missed. Moreover, behaviour studies about marine environment are still financially or timely expensive due (Mallet and Pelletier, 2014). Also, the behaviour of fishes described by ethograms or evidencing some peculiar behaviour are less reported (i.e.: Branconi et al., 2019).

BRUVS had been previous used in the Saint Peter and Saint Paul Archipelago (SPSPA), an Atlantic Ocean MPA, to advance the knowledge of fish biodiversity (Pimentel et al., 2020; Pinheiro et al., 2020). However, studies mostly inventories (Vaske et al., 2005) or calculates the ichthyofauna abundance through capture methods (Viana et al., 2015) or both (Nunes et al., 2016), but the comparison of fish fauna in the SPSPA west and east side has never been done before or elasmobranch behaviour reports were produced. Previous studies in the SPSPA have focused on elasmobranch in a species focused detail, such as mobula ecology and movement patterns (Mendonça, 2018), *C. falciformis* and *C. galapagensis* habitat use (Oliveira, 2017) comparing west and east sides, and the *Carcharhinus galapagensis* populational recovery and movement patterns (Queiroz, 2020). Thus, the objective of this study is to provide a comparison of the ichthyofauna abundance and richness in shallow waters (less than 30m depth) of the SPSPA recorded by the BRUVS methodology, also allowing elasmobranch species to be observed through video footages and register elasmobranch behaviours for the first time.

METHODS

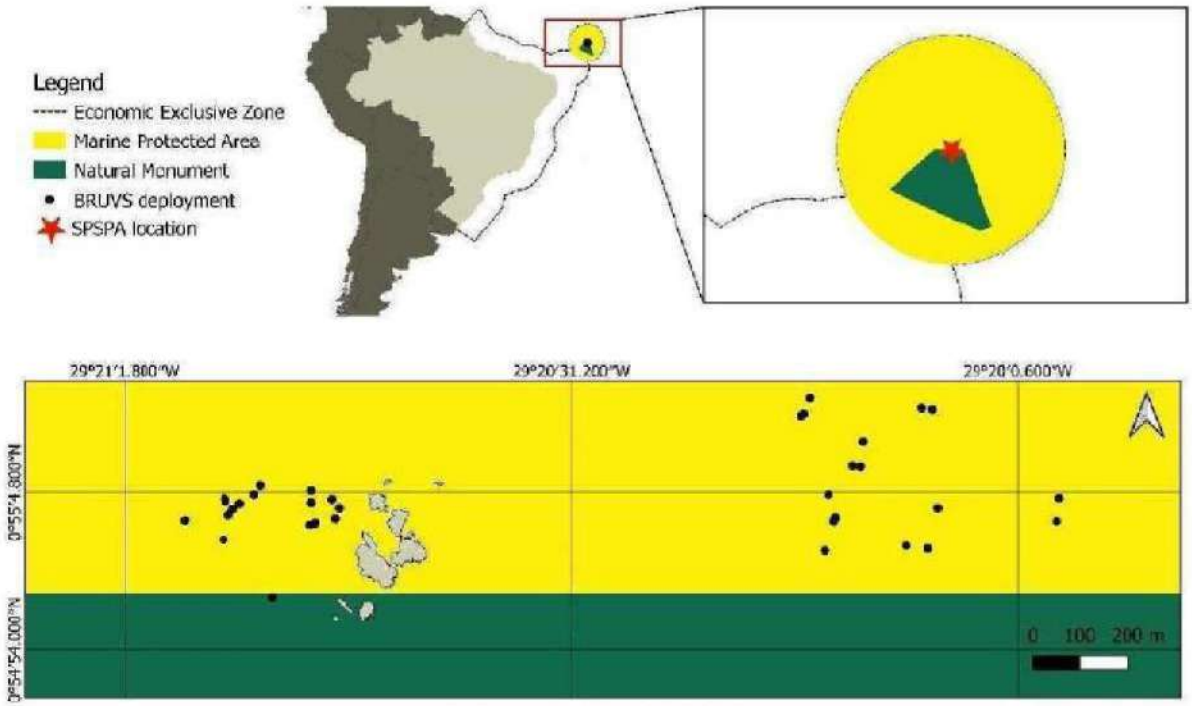
Study Area

The SPSPA is formed by 10 islands, and is located between South America and Africa, 1,100 km from Port of Natal, northeast Brazil (Miguens, 1995) (Figure 1). It is originated from the Meso-Atlantic ridge at 4 km of depth (Miguens, 1995), and the biggest island is 100 m wide. The archipelago has a high number of endemic species, making it an area of relevant importance for conservation (Edwards and Lubbock, 1983; Viana et al., 2015). Nevertheless, the fish richness is low due to SPSPA isolation and restricted reef area, even though some fish species reach a high abundance (Pinheiro et al., 2020). The oceanic dynamics that act on the SPSPA include the Equatorial South Stream (ESS) and the Sub-Equatorial Current (SEC), flowing from east to west (Cintra et al., 2015).

BRUVS sampling

A total of 35 BRUVS station deployments were made to assess the ichthyofauna (Figure 1) between September 2018 and January 2020 in SPSPA. The deployment was performed from the boat reaching a range of 5 to 30m of depth, and the time recorded was set to 90 min. The deployments were performed with 1h difference of the crepuscular time (between 7h and 17h), avoiding night hours of no visibility and the crepuscular behaviour of some species. A GoPro Hero 5 with waterproof case was attached on a stainless-steel frame with a bait cage of viscera and fish pieces.

Figure 1. Saint Peter and Saint Paul archipelago (red star) with BRUVS deployments (dark dot). Natural Monument and Marine Protected Area delimitation in the top right position.



Fonte: O Autor (2021).

Video analysis and behavioural notes

The video analyses occurred according to Willis and Babcock (2000). The videos were watched at 2x speed up (depuration procedure), and if there was any species unseen from the Willis and Babcock (2000) method, the species frame was added as an additional frame. Video samples were analyzed using the free VLC media player software (VideoLan Client, www.videolan.org). Fish were identified to species level and validated by two researchers using appropriated literature (Carpenter, 2002; FAO, 2016) The Time of First Sighting (TFS), which is the time of arrival of the first individual to the camera, the Maximum number of individuals (MaxN) in a single frame of the video and the total abundance of each species (SMaxN) were registered. In addition, Shannon diversity (H') and Pielou evenness (J') indexes were calculated for both sides, west and east in the SPSPA. Species conservation status and trophic level were derived from the International Union for Conservation of Nature (IUCN) website (www.iucnredlist.org) and from 'FishBase' (Froese and Pauly, 2021), respectively.

The behaviours of elasmobranchs were analyzed separately using the number of times that any elasmobranch enters in the camera' range (time in) and leave (time out), counting the time spent during the record and number of registers (Schobernd et al., 2014). Time of First Sighting for Elasmobranch (TFSE) were noted and the sex of the elasmobranchs were identified. A chi-square goodness-of-fit test was performed to test for significant differences in elasmobranch sex ratio ($p < 0.05\%$).

The estimate of the distance between the elasmobranchs and BRUVS with the behaviour associated was adapted from Bruns and Henderson (2020). Cruising attitude is defined by a blurred elasmobranch seen during the footage, not focused by the camera, in a distance bigger than 10m. Cautious attitude occurred in a distance between 1m and 10m from the BRUVS. Exploratory attitude was defined as an elasmobranch close to the BRUVS, less than 1m, without any touch on the mesh bag. Finally, the interactive attitude was defined as any touch in the BRUVS mesh bag by an elasmobranch using the snout, or mouth.

The interactive attitude was divided in three kinds depending on the physical response to the BRUVS: snout, the elasmobranch bumped the BRUVS with the snout; bite, opened the mouth and bite the BRUVS, and strong bite always resulted in the closure of the nictating membrane, preceded by a 2 second time of interaction, or more, only with the snout. Notes taken, based on Myrberg and Gruber (1974) of the following maneuvering: hit, give way, follow-formation, follow, explosive glide and turn-back, made for each shark seen during the video footages and registered as behavioural notes.

Additional notes were made to document other behaviours. *Rhincodon typus* vertical dive (Tyminski, 2015) was added according to the literature. Other behaviours were categorized for the whale shark based on the data from the present study: BRUVS strike, a prolonged strike where the BRUVS was carried by the lateral fin for more than 3 seconds; Nictating Membrane Closing (NMC) and Mouth Opened but did not bite the BRUVS (MO), are self-explanatory behaviours.

Data analysis

Relative abundance (MaxN h^{-1}), abundance and richness for each side was calculated. Two-dimensional non-metric multidimensional scaling (nMDS) ordination plots were used to visualize Bray-Curtis similarities between the samples based on the site sides investigated, west and east, comparing the abundance. The One-way permutational multivariate analyzes (PERMANOVA, 9999 permutations, significance level = $p < 0.05\%$) (Anderson, 2017) using the PAST software (Hammer et al., 2001) was tested in the comparison of east and west side abundance between the samples. The TFS, TFSE, numbers of interaction and time of the interaction for elasmobranch attitudes were tested by the Mann-Whitney test (significance level = $p < 0.05\%$) comparing east and west side. All data were tested for normality using the Shapiro-Wilk test (significance level = $p < 0.05\%$). The abundance data per sampling station was evaluated by Kernel Density Estimation (QGIS Development Team, 2016), for *C. galapagensis* and *C. falciformis* species.

RESULTS

The 35 BRUVS deployments summed about 2,700 minutes of videos recorded. A total of 2,991 individuals were recorded of 6 orders, 10 families and 19 species. Four elasmobranchs and 15 teleosts species were registered (Table 1). The species *Melichthys niger* was the most representative in number of individuals (1,822) with 61% of all specimens recorded, also representing an outstanding difference from *Elagatis bipinnulata* with 14% (404), *Caranx crysos* (202) and *Caranx lugubris* (224) each with about 7% of the total numbers of specimens. The most diverse family was Carangidae (6 species) followed by Balistidae (3 species), and both Scombridae (2 species) and Carcharhinidae (2 species).

Table 1. Fishes observed of Saint Peter and Saint Paul Archipelago with Baited Remote Underwater Video Systems (BRUVS). SMaxN = Total (summed) abundance; MaxN = Maximum Number of individuals in a single frame; CR = Critically Endangered; VU = Vulnerable; NT = Near Threatened; LC = Least Concern; DD = Data Deficient; Side = Side of the SPSPA sampled: W = West; E = East. TL = Trophic Level: values between 2 to 2,2 are herbivore, close to 2,9 omnivorous and 4,5 are piscivorous.

	Author(s)	SMaxN	MaxN	IUCN	Side	TL
MYLIOBATIFORMES						
Mobulidae						
Mobula tarapacana	(Philippi, 1892)	13	4	EN	W E	3,8
ORECTOLOBIFORMES						
Rhincodontidae						
Rhincodon typus	(Matsubara, 1936)	2	1	EN	W E	3,6
CARCHARHINIFORMES						
Carcharhinidae						
Carcharhinus galapagensis	(Snodgrass and Heller,1905)	33	6	LC	W E	4,2
Carcharhinus falciformis	(Müller and Henle, 1839)	43	6	VU	W E	4,5
PERCIFORMES						
Carangidae						
Caranx bartholomaei	(Cuvier, 1833)	5	2	LC	W	4,5
Caranx crysos	(Mitchill, 1815)	206	117	LC	W E	4,1
Caranx latus	Agassiz, 1831	4	4	LC	W	4,2
Caranx lugubris	Poey, 1860	224	40	LC	W E	4,5
Elagatis bipinnulata	(Quoy and Gaimard, 1825)	404	52	LC	W E	4,3
Seriola rivoliana	Valenciennes, 1833	30	10	LC	W E	4,5
Kyphosidae						
Kyphosus sectatrix	(Linnaeus, 1758)	77	18	LC	W E	2,0
Lutjanidae						
Lutjanus jocu	(Bloch and Schneider, 1801)	1	1	DD	W	4,4

Pomacentridae						
Abudefduf saxatilis	(Linnaeus, 1758)	4	4	LC	W	3,8
Sphyraenidae						
Sphyraena barracuda	(Edwards, 1771)	14	2	LC	W E	4,5
SCOMBRIFORMES						
Scombridae						
Acanthocybium solandri	(Cuvier, 1832)	28	5	LC	W E	4,3
Thunnus albacares	(Bonnaterre, 1788)	51	32	NT	E	4,4
TETRAODONTIFORMES						
Balistidae						
Balistes capriscus	Gmelin, 1789	1	1	VU	W	4,1
Canthidermis sufflamen	(Mitchill, 1815)	48	8	LC	W E	3,5
Melichthys niger	(Bloch, 1786)	1822	206	LC	W E	2,4

Fonte: O Autor (2021).

Time of First Sighting (TFS) showed no significant difference (Mann-Whitney U-test, n = 35, p> 0.05) between west (2.4 min) and east (3 min). Overall, Time of First Sighting for Elasmobranch TSFE, number of interactions and the total time of interactions for elasmobranch varied across the samples, but did not show significant difference (Mann-Whitney U-test, n = 29, p> 0.05) (Table 2). Although, the mean TSFE for the east side (9.4 min) was higher than the west (4.7 min), for *C. galapagensis* and *C. falciformis* observations per site side showed no significant difference (Table 2) (Mann-Whitney U-test, respectively n = 12 and n = 13, p> 0.05).

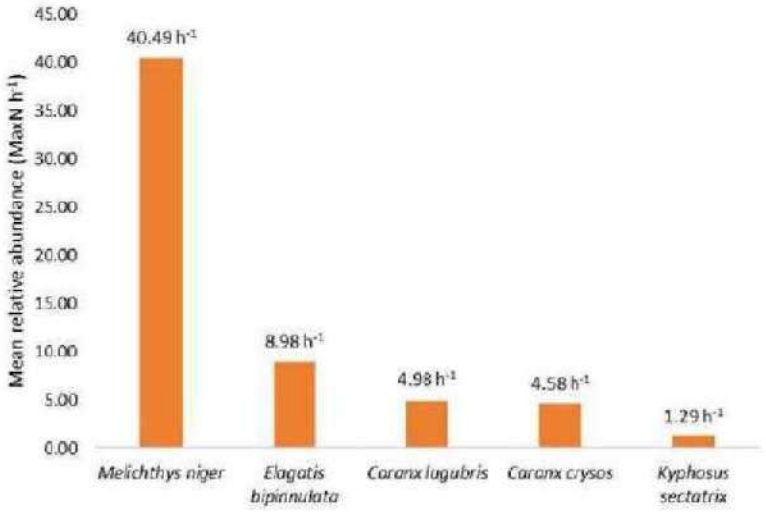
Table 2. Time of First Sighting for Elasmobranch (TSFE) for each sample at the west and east side of the Saint Peter and Saint Paul Archipelago. Rt = *R. typus*, Cf = *C. falciformis*, Cg = *C. galapagensis* e Mt = *M. tarapacana*. TSFE in minutes.

West		East	
Species	TFSE	Species	TFSE
Cg	0.72	Cg	1.08
Cf	1.18	Cf	1.18
Cf	1.52	Cf	1.20
Cg	1.62	Cg	1.55
Cg	2.00	Mt	3.07
Cg	2.03	Cg	3.73
Cf	3.32	Rt	8.15
Mt	4.78	Cf	8.63
Cg	4.80	Mt	9.17
Cf	9.00	Cf	11.27
Cf	11.13	Mt	13.68
Cg	18.42	Cg	20.37
Cf	18.90	Cf	37.72
Cf	21.17	Cf	60.32
		Mt	61.62

Fonte: O Autor (2021).

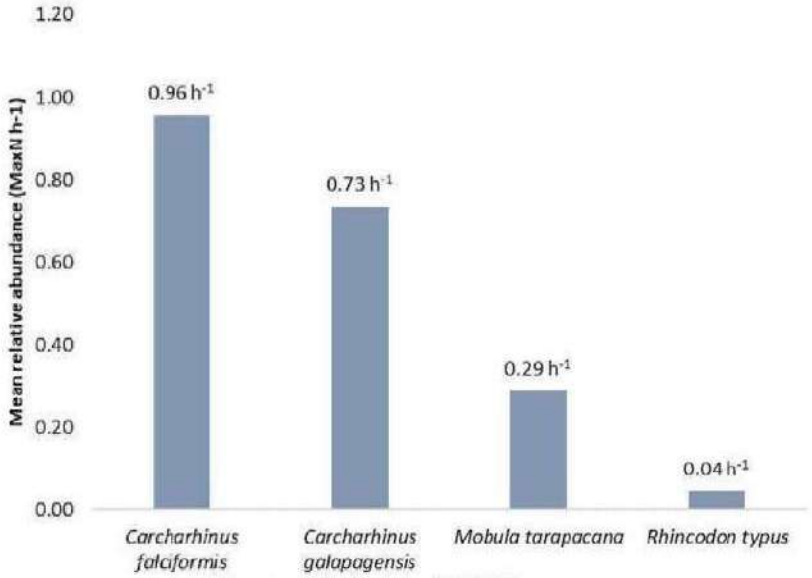
MaxN h^{-1} was mainly represented by *M. niger* (40.49), *E. bipinnulata* (8.98), *C. lugubris* (4.98), *C. crysos* (4.58) and *Kyphosus sectatrix* (1.29) (Figure 2). Elasmobranch MaxN h^{-1} was represented by *C. falciformis* (0.96), *C. galapagensis* (0.73), *Mobula tarapacana* (0.29) and *Rhicodon typus* (0.04) (Figure 3). From the 19 species registered, 13 (68%) are low concerning, 2 (11%) are endangered, 2 (11%) are vulnerable, 1 (5%) is data deficient and 1 (5%) is not threatened, according to the IUCN. Is important to notice that the BRUVS recorded a *Balistes capriscus*, a species recently documented in the Archipelago and *Thunnus albacares* which is a species not commonly reported in BRUVS papers. West side had 10 samples with species about 2,2 trophic level (59%) while the east side showed 12 samples with species trophic level about 4 (67%). 78,9% of species with trophic level about 4 (carnivorous) or more were observed, mainly represented by Carangidae species, as well as 11% of species with trophic level about 2 (herbivorous), represented by *M. niger* and *K. sectatrix*.

Figure 2. Mean relative abundance of individuals per hour of sampling (MaxN h^{-1}) of the most common species recorded in BRUVS surveys of the Saint Peter and Saint Paul Archipelago.



Fonte: O Autor (2021).

Figure 3. Mean relative abundance of elasmobranch per hour of sampling (MaxN h^{-1}) recorded in BRUVS surveys of the Saint Peter and Saint Paul Archipelago.



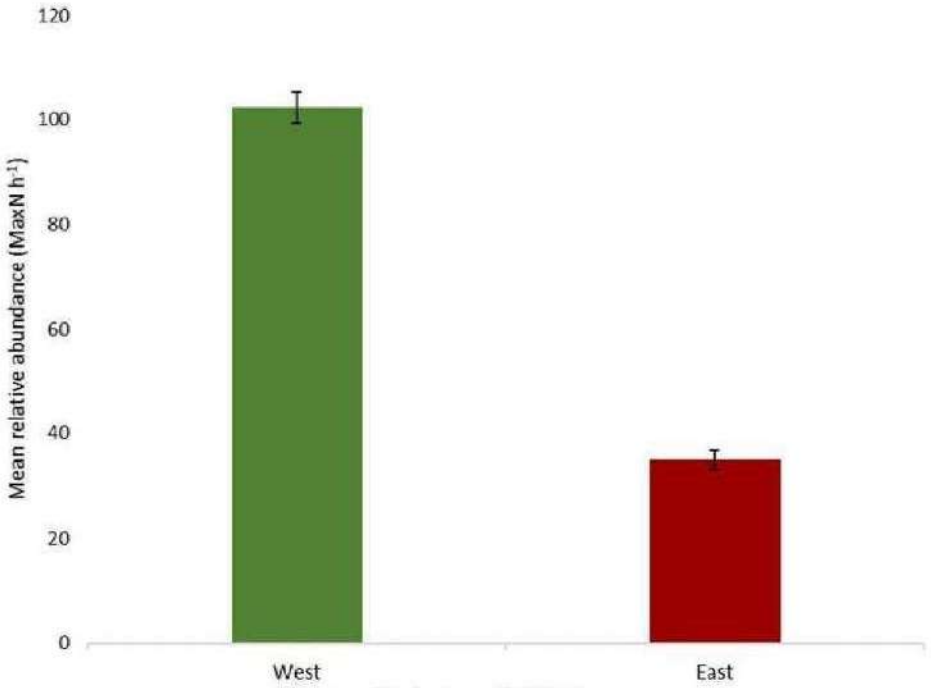
Fonte: O Autor (2021).

Elasmobranch were recorded in 28 samples (80%), sharks in 25 samples (71%) and mobulas in 8 samples (20%). A total of 91 elasmobranch specimens were documented: 13 mobulas and 78 sharks. No significant difference was observed in the sex ratio for *C galapagensis*, 13 females, 18 males and 2 of unidentified sex, (Chi-square test: $X^2 = 7.412$, $p = 0.764$), but for *C. falciformis* a significant difference was observed, 37 females, 3 males and 3 of unidentified sex, (Chi-square test: $X^2 = 29.189$, $p = 0.022$). Both Carcharhinus were observed in schools of 6 individuals and *M. tarapacana* had a single school of 4 individuals. It is important to notice that *C. falciformis* are in a vulnerable status (VU) in IUCN category and represents about almost half (43) of the elasmobranchs sampled. Furthermore, the *M. tarapacana* and the *R. typus* are endangered species (EN) summing a total of 15 (16%) from the elasmobranch total (Table 1).

Seventeen deployments (1,250 minutes) were in the west side and 18 (1,423 minutes) were in the east side. The mean abundance observed in the west side was 102.43 and 35 (MaxN h^{-1}) in the east side (Figure 4). West side showed high abundance for the species of: *M. niger* (1,506), *C. crysos* (189), *C. lugubris* (129), *K. sectatrix* (52), *Seriola rivoliana* (25), *Sphyraena barracuda* (12), and when compared to the east side. East side showed high abundance for the species of: *E. bipinnulata* (243), *Canthidermis sufflamen* (28), and *Acanthocybium solandri* (21), when

compared to the west side. Also, *T. albacares* was solely observed at the east side. Shannon diversity and Pielou's evenness were 1.16 and 0.43 for the west side, while 1.76 and 0.67 for the east side.

Figure 4. Mean relative abundance of individuals per hour of sampling (± SE, MaxN h^{-1}) of fishes observed in BRUVS deployments in each side of the Saint Peter and Saint Paul Archipelago (West and East).



Fonte: O Autor (2021).

East side presented 54 (59%) and west side 37 (41%) from the elasmobranch total. Moreover, elasmobranch highest abundance percentage for species in the east side were: *C. falciformis*, 32 specimens (74%) and *M. tarapacana*, 10 specimens (77%). The highest abundance percentage for the west side was: *C. galapagensis*, 22 specimens (67%). *C. falciformis* and *C. galapagensis* abundance showed no significant difference between the west and east (pseudo-F = 0.1552, $p > 0.05$).

The median time spent for all elasmobranch species behaviour attitudes in the west (5.9 min) and the east (5.8 min) sides were almost identical. From all attitudes observed the cautious attitude was predominant for elasmobranchs with 1,624 registers and 267 minutes. The majority total amount of elasmobranch attitude registers was from *C. galapagensis* and *C. falciformis* both summing 2,867 from 2,900

(99%). Significant difference between elasmobranch behaviour attitudes in west (2,151) and east (840) side was evident (pseudo-F = 7,457; p = 0.0002).

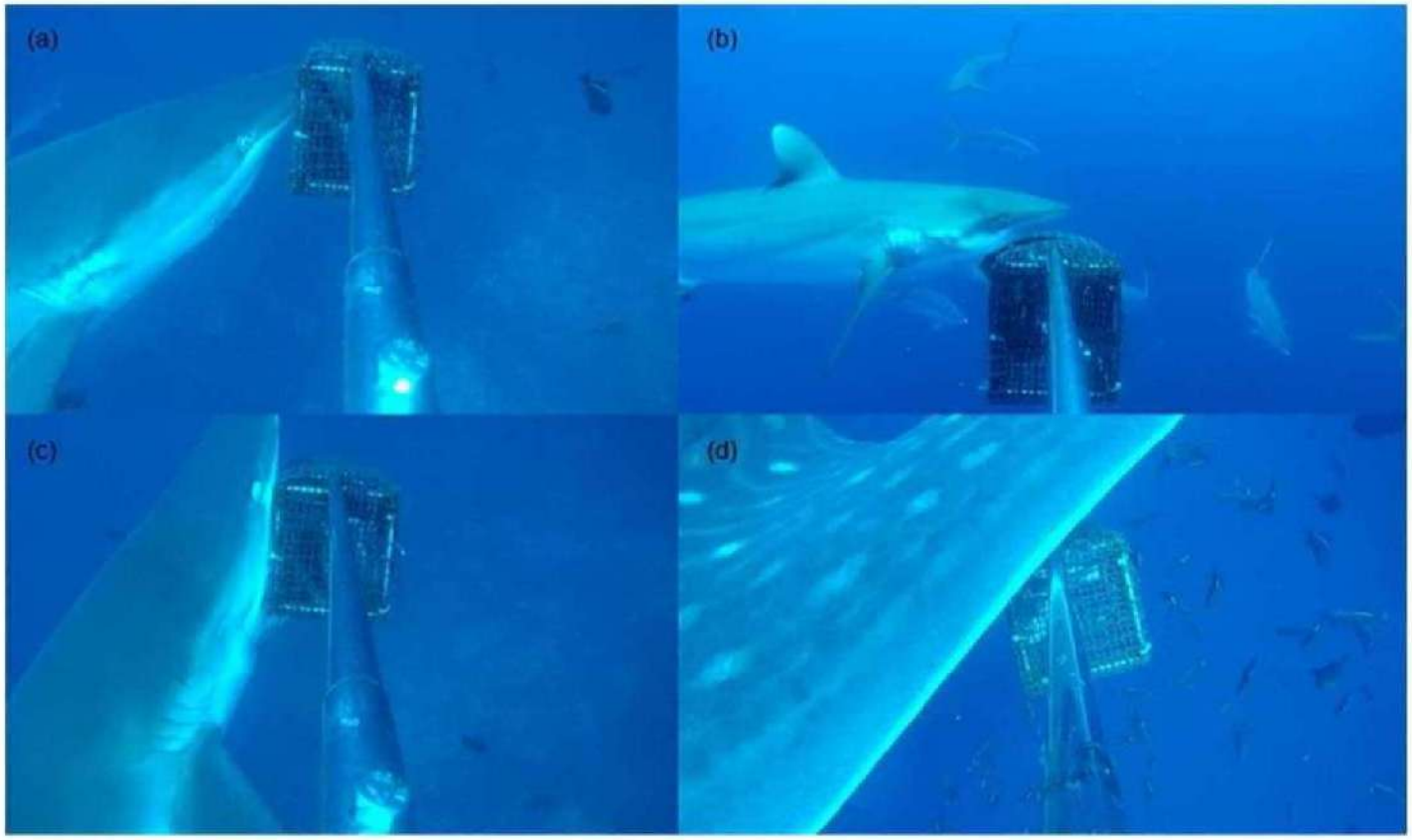
C. galapagensis spent most time in the west side for behaviour cautious, 96 minutes, but had more registers in the east side for the behaviours cruising (238), cautious (484) and interactive snout (Figure 5a) (150) (Table 3). Except interactive snout (39), *C. falciformis* spent most time in the east side for all behaviours (45 min cruising, 90 min cautious, 31 min exploratory and 13 min interactive snout), but had more registers in the west side for other behaviours (75 cruising, 641 cautious and 100 exploratory). Also, for *C. falciformis*, in the east side, the interactive bite (Figure 5b) had the highest number of registers, 24 (53%) and highest total time, 4 minutes (50%). Just the interactive strong bite was registered for *C. galapagensis* (Figure 5c).

Table 3. Number and recorded time (min) of registered elasmobranchs attitudes in the Saint Peter and Saint Paul Archipelago adapted from Bruns and Henderson (2020). The blank squares are equal to no register. Cf = *C. falciformis* and Cg = *C. galapagensis*.

	Cf				Cg					
	West		East		West		East		Total	
Behavioural Attitudes	Registers	Time (min)	Registers	Time (min)	Registers	Time (min)	Registers	Time (min)	Registers	Time (min)
Cruising	75	7	55	45	40	11	238	14	408	76
Cautios	641	57	112	90	387	96	484	24	1624	267
Exploratory	100	23	39	31	134	13	150	15	423	82
Interactive Snout	39	4	86	13	131	14	101	19	357	50
Interactive bite			24	4	8	1.18	13	2.65	45	8
Interactive Strong bite					2	0.07	8	0.33	10	0.4
Total	855	91	316	183	702	135.25	994	74.98	2867	483.4

Fonte: O Autor (2021).

Figure 5. Behaviour of elasmobranchs adapted from Bruns and Henderson (2020): (a) a snout interaction, *Carcharhinus galapagensis* spinning the BRUVS by the mesh bag using the tip of the snout, (b) an interactive bite, *Carcharhinus falciformis* biting the mesh bag without covering the eye with the nictating membrane, (c) A strong bite, *Carcharhinus galapagensis* closing the eyes with the nictating membrane and in sequence striking the mesh bag. (d) *Rhincodon typus* pectoral fin in detail before performing a BRUVS strike.



Fonte: O Autor (2021).

M. tarapacana main attitude was cruising 12 observations, followed by 1 cautious and 2 exploratory, with a total recorded time for the species of 184 seconds. Also, during the exploratory the *M. tarapacana* fin smoothly touched the equipment twice, one for each individual, without damaging the BRUVS or changing the camera focus. The *R. typus* had just 8 attitudes, 7 cautious, 1 interactive but with the fin, and the total time recorded for the species was 256 seconds. For *Rhicodon typus* and *Mobula tarapacana* the sex identification was not possible due to camera range and focus, since the *M. tarapacana* were seen blurred, and the camera was unable to completely register the *R. typus* body.

The maneuverings only observed in *C. falciformis* were: hit, give way, follow and follow-formation (Table 4). Although, the follow maneuvering was observed in almost equal numbers for *C. falciformis* for east and west side, follow-formation, the hit and give way maneuverings had about 5 observations for the east side. The turn-back was only observed for *C. falciformis*. The explosive-glide was observed 9 times in *C. falciformis* in the east side and twice in *C. galapagensis* for the west side.

Table 4. Elasmobranch maneuvering registered in the Saint Peter and Saint Paul Archipelago based on Myrberg and Gruber (1974). Time is approximated in minutes. The blank squares are equal to no register. Cf = *C. falciformis* and Cg = *C. galapagensis*. No maneuvering registers for *C. galapagensis* in the east side.

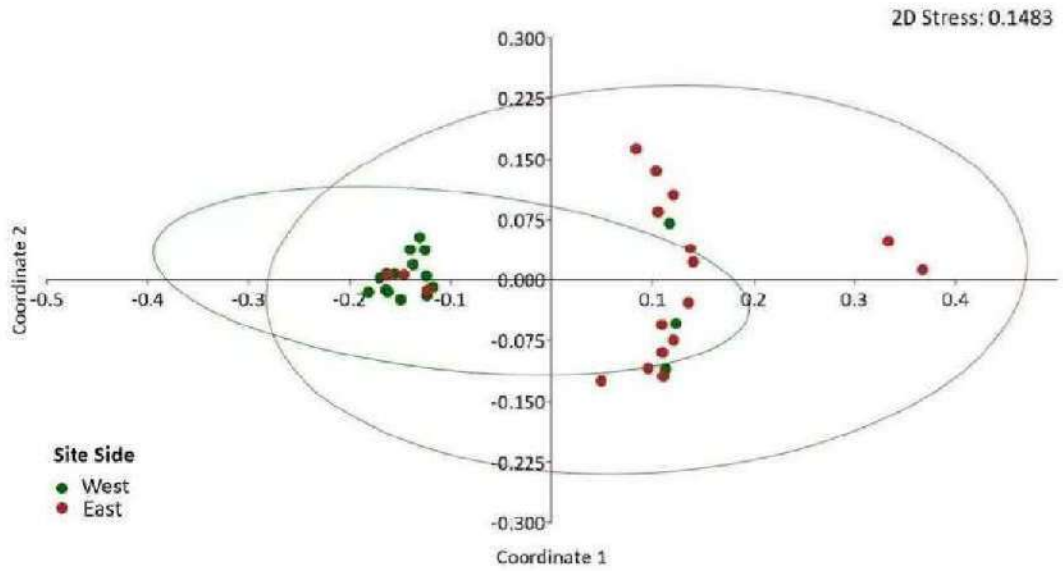
	Cf				Cg			
	West		East		West		Total	
	Registers	Time	Registers	Time	Registers	Time	Registers	Time
Follow	10	2	8	2			18	4
Follow Formation	3	1	3	1			6	1
Give way			6	0			6	0
Hit			4	0			4	0
Explosive Glide			9	1	2	6	11	7
Total	13	2	30	4	2	6	45	12

Fonte: O Autor (2021).

The total time of elasmobranch behaviour notes added had 502 minutes with 3,623 registers, also the mean number of interactions was higher for the west side (31) than the east (24), however were not significantly different (Mann-Whitney U-test, $p > 0.05$). Behavioural notes added for: *Rhincodon typus*, vertical dive and a BRUVS strike (Figure 5d). The *R. typus* was recorded in two dives, in different samples and the strike once. The NMC and MO had the time removed, only the number of registers were counted. *C. galapagensis* had 71 registers (84%) of the NMC behaviour while *C. falciformis* had 14 (16%). Also, *C. galapagensis* in the east side had 11 from 16 MO (69%).

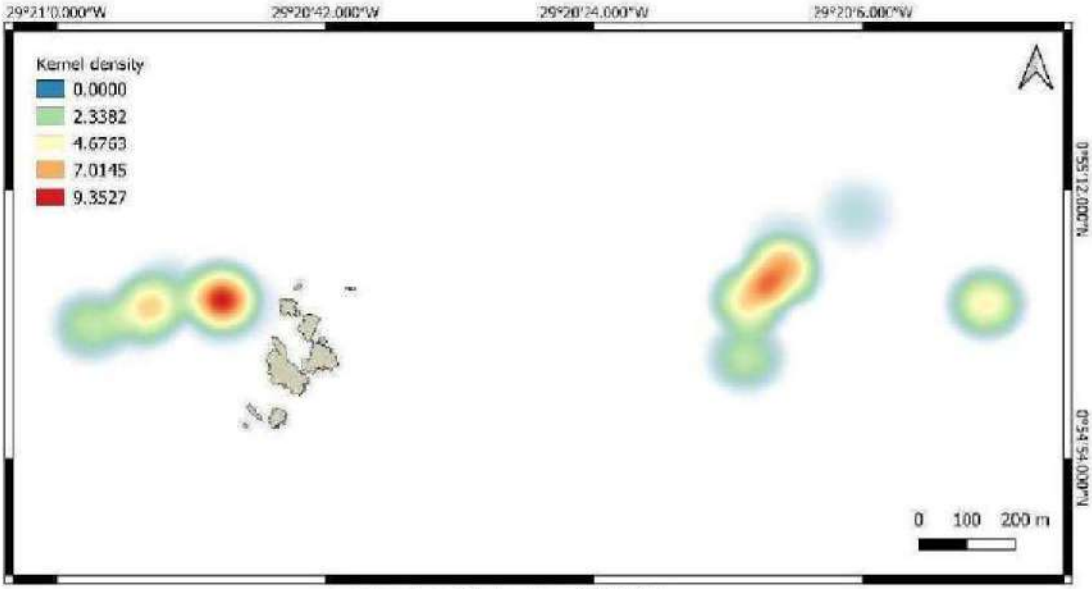
The nMDS plot west vs. east abundance concentrated the samples in two groups, where each point is a sample station (Figure 6). The distance of the points indicates dissimilarities and the 2D stress valor is acceptable. The Kernel density indicate both sides of the archipelago exhibiting high abundance areas; however, the west side exhibited a highest abundance area which is close to the SPSPA (Figure 7). *C. falciformis* showed high abundance in the west side and in the east side, while the *C. galapagensis* showed high abundance only in the west side (Figure 8).

Figure 6. Two-dimensional non-metric multi-dimensional scaling (nMDS) plot ordination similarity of fish assemblages per site side (West and East) in the Saint Peter and Saint Paul Archipelago. Each point represents a BRUVS deployment. 95% confidence ellipses were plotted.



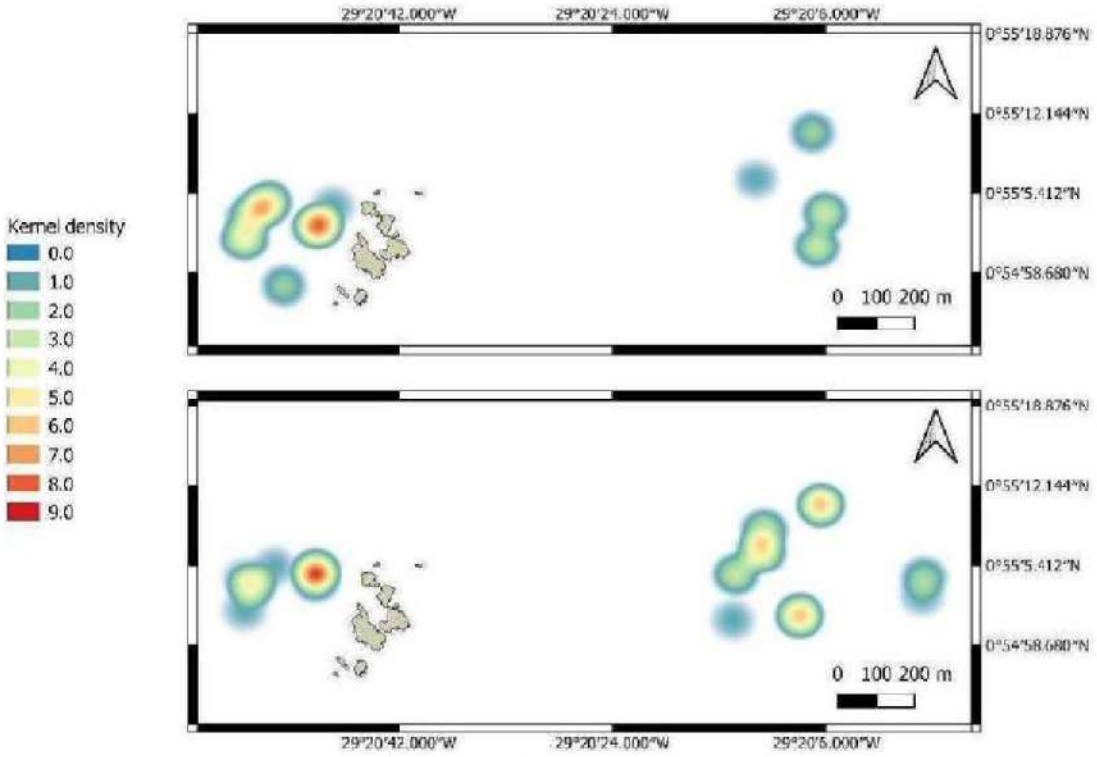
Fonte: O Autor (2021).

Figure 7. Density areas for fishes observed in each site side at the Saint Peter and Saint Paul Archipelago.



Fonte: O Autor (2021).

Figure 9. Density areas for each shark species in the Saint Peter and Saint Paul Archipelago. The top map represents the distribution of the *C. galapagensis* and bottom map represents the distribution of the *C. falciformis*.



Fonte: O Autor (2021).

DISCUSSION

The BRUVS data results show valuable information for reef, pelagic and elasmobranch species. Even for some coral generalist and herbivore fish, high abundance values were registered, which is not generally expected for a method that uses fish as bait. Also, when compared to other studies (i.e.: Brooks et al., 2011; Santana-Garcon et al., 2014) valuable data were acquired in less recorded time, demonstrating how the SPSPA is important for reef and pelagic species foraging.

Even though the BRUVS is known to attract apex predators, herbivore fishes were abundant for the west side (more protected area), that fact elucidate the BRUVS performance during samplings and has also been reported by the literature (Correa, 2014; Harvey et al., 2007; Schmid, 2016). Probably, this occurs due to the west side samples had been perform close to the archipelago which are inhabited by reduce areas of coral reefs (Mendes et al., 2019) and may support herbivore and omnivorous trophic level fishes. While the east side constitutes a pelagic area, lack of coral reefs, with more apex predators when compared to the west side. Besides, an interesting fact, M. *niger* and *K. sectatrix* are known for been found close to coral reefs, and both species were found even in the east side, a pelagic area from the Archipelago, but were not abundant.

Elasmobranch register by the present study show results that corroborate with the shark population register (Hazin et al., 2018; Queiroz et al., 2021), although *C. galapagensis* had been considered locally extinct (Luiz and Edwards, 2011). In the middles of 80 decade the shark population abundance was high (Edwards and Lubbock, 1982) however, the registers from *C. galapagensis* and *C. falciformis* were lower through the years until 2012 (Hazin et al., 2018). Moreover, both shark species were recorded in SPSPA by BRUVS as well as other methods in the last years (Queiroz et al., 2021). Although the sharks population around the world declined more than 70% through the last 30 years (Pacoureau et al., 2021), the present study elucidate that the SPSPA is an area where the shark population to growth considerable in number of registers when compared to the past data (Hazin et al., 2018; Queiroz et al., 2021). The *C. falciformis* is a species in vulnerable to extinction (IUCN, 2021) and was the most abundant elasmobranch registered. Thus, these results show the importance of preserving, or using sustainably, the SPSPA adjacent areas, and those

informational video records shall be taken into account to maintain the population of *C. falciformis* and *C. galapagensis*.

In this study, the *C. galapagensis* and *C. falciformis* showed a spatial segregation in the SPSPA. Besides, previous studies already reported a spatial segregation for both species: *C. galapagensis* has an archipelago resident behaviour while the *C. falciformis* is an oceanic migratory species (Oliveira, 2017; Queiroz et al., 2021). There was reported a clear interspecific segregation between *C. galapagensis* and *C. falciformis* in the SPSPA, with the *C. galapagensis* been more captured in west side and the *C. falciformis* been more captured in the east side (Queiroz et al., 2021), a similar result also obtained by (Oliveira, 2017). Thus the *C. falciformis* and *C. galapagensis* interspecific segregation is supported by different studies methods: video images (the present study), longline (Oliveira, 2017) and tagging (Queiroz et al., 2021). The SPSPA area presented an equal sex ratio for *C. galapagensis*, corroborating with Queiroz (2021) results, sex ratio 1:1.3 (male:female), and were found many times swimming in pairs during the video footages (a female and a male). The predominance of *C. falciformis* females over males suggests a sexual segregation or a dominance of females around the SPSPA. This sexual segregation for *C. falciformis* is seen in other areas of the globe and is the general rule (Clarke et al., 2019; Galván-Tirado et al., 2015; García-Cortés et al., 2011) and the exception occurs during the reproducing period when the sex ratio is 1:1 (Wourms, 1977).

It is important to notice that *M. niger*, although considered as herbivore by the literature (IUCN, 2021), this species was already reported as either herbivorous and omnivorous at the SPSPA, eating almost everything available and, thus could be inserted in a different trophic level (Mendes et al., 2019). The *M. niger* trophic level could change our results changing the west side of the SPSPA from herbivore to omnivore, yet this interpretation leads to a distinction between the west to the east side of the SPSPA trophic levels, but with different implications. The *T. albacares* shoal registered raise questions about how much the BRUVS methodology could be adapted for incorporate better samplings results for the species and available the cost benefit, yet this is a first step to get data about *T. albacares* shoal without any capture method and without an exhausting tagging field time.

In the present study, describing elasmobranch behaviour was challenging due to a limited camera focus, and blurred records due to: range distance, low temperature

sampling stations lead to water drops concentration between the camera lens and the waterproof box. Describe behaviours seen or construct an ethogram are limited in literature (i.e.: Oliver et al., 2011). One exception is for the White shark (*Carcharodon carcharias*) with complete ethograms and well described behaviours, mainly in South Africa for superficial waters when feeding (Martin et al., 2005). When considering behavioural studies about elasmobranch in the wild the challenge increase, and become scarce due to their size or/and free ranging in the ocean, therefore the majority of detailed behavioural studies about elasmobranch are done inside aquariums (Ari and D'Agostino, 2016; Myrberg and Gruber, 1974). Thus, any behavioural record about sharks in the wild are remarkable tools to assisting future studies, and even with the limitations our results are stimulating.

The *M. tarapacana* had most registers at a cruising distance and was not possible to identify any behaviour or even the sex. The *M. tarapacana* interest for the BRUVS equipment constitute integrally only one passage through the camera without any additional appearance during the rest of the video footage. The attraction of *M. tarapacana* for the BRUVS includes the light reflected by the metal equipment, a visual sensory perception. *M. tarapacana* are pelagic species known for large migrations (Thorrold et al., 2014) and population studies are scarce, even though, the SPSPA is a place of constant aggregation for the species (Mendonça, 2011; Mendonça, 2018).

R. typus pectoral fin is rarely used for another purpose than body trim while swimming and steering, but could be used in other shark species to remove undesirable sharksuckers (Ritter, 2012). The visual acuity of *R. typus* is probably moderate to low, and just follow divers at a close range of 3 meters (Quiros, 2007), suggesting that the *R. typus* may detected some peculiar sensorial cue, not involving vision, of the BRUVS and touched it by accident in the way. Thus, the curiosity, could be an approaching factor analogue to the fact that *R. typus* often got curious under the presence of divers (Martin, 2007).

Totally covering the eye with the nictating membrane (Gruber, 1977) occurs during feeding moments to protect against possible damages (Bell & Satchell, 1963). Interestingly, the shape of placoid scales over the nictating membrane could be related to the need of protection in different degrees by shark species (Poscai et al., 2017). Ritter and Godknecht (2000) described a behaviour of opening the mouth and covering the eye with the nictating membrane at same time, but for *C. galapagensis* covering

the eye with the nictitating membrane occurred before the striking bite in the present study.

Assembling the literature information, *C. galapagensis* could easily broke the BRUVS, since the bite force of species inside the same genus reach from 900N (Huber et al., 2006) to 6000N (Habegger et al., 2012), but it probably opted to not break the BRUVS on purpose. Predatory behaviours expend energy and abandoning the attempt occurs when there is no significant energetic gain (Bennett, 1986). Elucidating a predatory behaviour, useful explanations from foraging models, according to Gerking (1994), comprise: (1) decisions made by a predator to attack or not attack a prospective prey, (2) currency, such as energy costs or gains, and (3) constrains, or factors defining the relationship between decision and currency. Moreover, taste in shark are felt by taste buds within papillae, covering oral and pharyngeal epithelium of the mouth, basihyal (a 'tongue'), and gill arches (Hart and Collin, 2015). Giving up the meal could occur in cases which are probably unpalatable, after bites with an investigative purpose (Strong, 1996). The other possible hypothesis comprehension starts with sharks inside aquariums which are properly fed and experiments which rewards sharks with food (Heinrich et al., 2020), what is called positive reinforcement.

The number of behavioral notes taken shows how it is possible to explored and understood behaviours using the BRUVS methodology. Although there are still many gaps about fish behaviour in the wild and recent records made by videos been recently popularized. Also, was not expected by us many types of elasmobranch behaviours recorded by the BRUVS since most of them have been recorded for schools, about more than 3 sharks, and our records were usually less than that. Nevertheless, the number of fishes during the records leads to data for studies about fish species interaction with themselves and the equipment. In the other hand, for studies with focus on a single species some adaptations in the equipment or in the methodology may be done. Always considering the feeding habitat of the species in question, because different results depending on the bait type could be assessed.

BRUVS performed satisfactorily in SPSPA and can be implemented as a method for continuously monitoring the species registered as well as a complementary method to be used with conventional methods of fish sampling. Furthermore, our study provides remarkably direct observations for elasmobranch interactions and social behaviour records. Moreover, records about fish species behaviour were in the wild for

shallow depths and never registered to the SPSPA. Hence, the ichthyofauna and their behaviour recorded by BRUVS are important to evaluate and manage the SPSPA MPA area, adding relevant information to explore sustainably or to integrally protected the SPSPA and adjacent areas.

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5 CONSIDERAÇÕES FINAIS

A necessidade de métodos que não fragilizem a fauna endêmica e tão pouco causam estresse, faz do BRUVS um método de coleta ideal para as unidades de conservação (UC). O BRUVS se mostrou eficiente como método de coleta, não dispendioso financeiramente, além de mostrar ser possível seu uso para identificar espécies da ictiofauna, principalmente, de topo de cadeia, assim, fornecendo informações relevantes sobre espécies de importância econômica ou de conservação que transitam ou habitam no Arquipélago.

O conhecimento gerado com o uso dos BRUVS forneceu estimativas de abundância e riqueza das espécies de peixes e elasmobrânquios, complementando os estudos já realizados sobre a ictiofauna do ASPSP através de outros métodos. Além disso, a quantificação e qualificação dos comportamento para os elasmobrânquios foram inéditas para o ASPSP, elaborando hipóteses sobre atitudes comportamentais mais complexas e simples, servindo também de uso futuro para estudos de comportamento sobre as espécies envolvidas.

Logo, existe uma urgência em ampliar o monitoramento da biodiversidade no Arquipélago de São Pedro e São Paulo, em decorrência do seu potencial ecológico e econômico. Sendo assim, se faz necessária a continuidade dos estudos com o uso de BRUVS, tanto na APA como no MONA, no intuito de elucidar alguns aspectos importantes sobre o comportamento da fauna do ASPSP, assim como entender a efetividade da UC.

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