LUÍSA VALENTIM MELO DE VASCONCELOS QUEIROZ

CARACTERIZAÇÃO DA ICTIOFAUNA ASSOCIADA A DISPOSITIVOS AGREGADORES DE PEIXES (DAPS) EXPERIMENTAIS ANCORADOS NA PLATAFORMA CONTINENTAL DO ESTADO DE PERNAMBUCO- BRASIL

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PRÓ-REITORIA DE PESQUISA E PÓS-GRADUAÇÃO

PROGRAMA DE PÓS-GRADUAÇÃO EM RECURSOS PESQUEIROS E AQUICULTURA

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Dissertação julgada adequada para obtenção do título de mestre em Recursos Pesqueiros e Aquicultura. Defendida e aprovada em 31/08/2017 pela seguinte Banca Examinadora.

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“Continue a nadar, continue a nadar,
continue a nadar, nadar, nadar...
Para achar a solução, nadar.”

Dory

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Resumo

No Brasil, a pesca no entorno de Dispositivos Agregadores de Peixes (DAPs) vem sendo realizada pelo menos desde meados da década de 80. Apesar da importância econômica, social e ambiental deste tipo de pesca, porém, praticamente nenhum estudo relacionado a este assunto foi realizado no país. No presente trabalho, a primeira caracterização da comunidade de peixes pelágicos associados a DAPs experimentais costeiros, localizados na Plataforma continental do estado de Pernambuco, foi realizada, incluindo a composição das espécies, biomassa e comportamento associativo dos peixes. Além disso, a relação entre fatores físicos (profundidade de ancoragem dos DAPs, presença de estrutura de agregação, diâmetro da boia e distância da PNBOIA), abióticos (temperatura da superfície do mar, fases da lua, velocidade e direção de corrente, visibilidade do mergulho), temporais (tempo de imersão) e/ou bióticos (presença de presas, predadores e cardumes) e a biomassa e períodos de associação dos peixes foram investigados por meio de censos visuais, dados de marcação acústica e modelos aditivos e/ou lineares generalizados (GLMs / GAMs). Um total de 16.690 espécimes, compostos principalmente por indivíduos adultos, de 14 espécies pertencentes a 9 famílias foram registrados. Maiores riquezas de espécies, tamanho de peixe, abundância e biomassa foram registradas em DAPs mais profundos. Com base nas observações feitas, a busca pelo fornecimento de alimentos foi provavelmente a razão mais importante para o comportamento agregativo em torno dos dispositivos ancorados. Os dados de telemetria demonstraram forte fidelidade dos *Caranx crysos* aos DAPs, comportamento diferente do registrado para *Thunnus atlanticus*. É provável que esses períodos de associação possam ser explicados por fatores biológicos (disponibilidade de comida, presença de predadores, comportamento natural das espécies e estresse) e físicos (profundidade de ancoragem dos DAPs, velocidade e direção de corrente). Com o uso dos GAMs / GLMs, foi possível identificar a profundidade de ancoragem dos atratores, a distância de uma boia oceanográfica pré-existente e atemperatura da superfície do mar, como as principais variáveis a influenciarem a biomassa total de peixes. Nos modelos elaborados para a biomassa de espécies individualmente, além das variáveis já citadas, a velocidade da corrente e o tempo de imersão também foram considerados como variáveis significativas. Os resultados do presente trabalho trazem informações inéditas acerca da composição, abundância e comportamento de espécies pelágicas associadas à DAPs no Brasil. Tais informações, além de aprofundarem o conhecimento sobre a fauna pelágica de maneira geral, trazem novos dados para o país sobre a utilização de DAPs costeiros ancorados por espécies alvo da pesca. A expectativa, portanto, é de que os resultados obtidos possam servir como uma primeira base de informação tanto para pesquisadores quanto para gestores, podendo, inclusive, contribuir para a avaliação deste tipo de pescaria na plataforma continental do país. Os resultados, apesar de registrarem a presença de peixes de importância comercial no entorno dos atratores, como cavalas, dourados, peixes rei, arabaianas e atuns, em sua maioria como indivíduos adultos, demonstraram, em geral, uma baixa abundância dessas espécies. Foi possível observar também, para a maioria delas, um comportamento de não fidelidade aos DAPs. A profundidade de ancoragem dos DAPs foi a variável mais significativa, com maior riqueza, abundância, biomassa e tamanho de indivíduos sendo registrados em atratores com maior profundidade. É possível que para o local de estudo, regiões mais rasas da Plataforma, ou talvez até a Plataforma Continental como um todo não sejam as áreas mais adequadas para a instalação de Dispositivos Agregadores de Peixes voltados para a pesca. É importante salientar que mesmo gerando informações relevantes e inéditas acerca da ictiofauna associada a atratores na costa do Brasil e da eficiência de tais dispositivos na Plataforma Continental, o conhecimento da comunidade associada a estas boias ainda precisa ser substancialmente aprofundado.

Palavras-chave: espécies pelágicas, DAPs costeiros, censo visual, telemetria, modelos generalizados.

Abstract

In Brazil, fishing in the vicinity of Fish Aggregating Devices (FADs) has been carried out at least since the mid-1980s. Despite the economic, social and environmental importance of this type of fishing, however, almost no study related to this subject has been carried out in the country. In this work, we provide the first characterization of pelagic fish communities associated to an experimental coastal FAD array located in the continental shelf break of Pernambuco, including the species composition, biomass and associative fish behavior. Additionally, the relation between physical (FAD depth of anchorage, presence of underwater aggregative structure, buoy diameter and distance from the PNBOIA), abiotic (sea surface temperature, moon phases, current velocity and direction, and dive visibility), temporal (immersion time) and/or biotc factors (presence of prey, predators or fish schools) and fish biomass and association periods was investigated using visual census, acoustic tagging data and Generalized Additive and Linear Models (GLMs/GAMs). A total of 16,690 specimens, mainly composed by adult individuals, from 14 species belonging to 9 families were recorded. Higher species richness, fish size, abundance and biomass were recorded at deeper FADs. Based on the observations made, search for food was probably the most important reason for the aggregative behavior seen around the moored devices. According to the telemetry data, *C. crysos* presented strong site fidelity, differently from *T. atlanticus.* Such association periods may be explained by biological (food availability, presence of predators, natural species behavior and stress) and physical factors (FAD depth of anchorage, current velocity and direction). With the use of GAMs/GLMs, FAD depth of anchorage, distance from a pre-existing oceanographic buoy and sea surface temperature were identified as the main variables to influence the total fish biomass. The models done for individual species biomass, besides the variables mentioned above current velocity and immersion time were also considered as significant variables. The results presented in this study provide unprecedented information on the composition, abundance and behavior of pelagic species associated to FADs in Brazil. Such information, in addition to deepening knowledge about pelagic fauna in general, brings new data to the country on the use of coastal moored FADs by fishing target species. The expectation, therefore, is that the results found here, may serve as a first data base for researchers and decision makers and may even contribute to the evaluation of this type of fishery on the Brazilian continental shelf. The results, in spite of registering the presence of commercial importance fish around the FADs, such as wahoos, dolphin fish, rainbow runners, jacks and tunas, mostly as adult individuals, showed, in general, low abundance. It was also possible to observe, for most of them, a non-fidelity behavior to the FADs. The FADs depth of anchorage was the most significant variable, with higher species richness, abundance, biomass and size of individuals being recorded in attractors with greater depths.It is possible that for the study site, shallower regions of the Platform, or perhaps even the Continental Shelf as a whole, are not the most suitable areas for the implementation of Fish Aggregating Devices aiming fishing activities. It is important to note that, even with the generation of relevant and unique information regarding the ichthyofauna associated with fish aggregating devices on the coast of Brazil and the efficiency of such attractors in the Continental Shelf, the knowledge of the community associated with these buoys still needs to be substantially deepened.

Key words: Pelagic species, coastal FADs, visual census, telemetry, generalized models.

Lista de figuras

Lista de tabelas

ARTIGO CIENTÍFICO I

ARTIGO CIENTÍFICO II

Sumário

1. Introdução

1.1. Contextualização

Em diferentes regiões do mundo, atratores artificiais de peixes vêm sendo ancorados em profundidades de 50 a 2.500 m com o objetivo de agregar espécies pelágicas em áreas mais próximas da costa a fim de permitir sua captura por pescadores esportivos e também artesanais, os quais, devido à limitação dos seus recursos e equipamentos, focam seus esforços na pesca de espécies costeiras (BEVERLY et al., 2012; GUYADER et al., 2013; ALBERT et al., 2014; BELL et al., 2015). Tais iniciativas têm sido importantes para o aumento da produção e consumo de peixes em comunidades locais (ALBERT et al., 2014), além da possibilidade de transferência do esforço de pesca de espécies demersais costeiras, já excessivamente explotadas, para espécies pelágicas de crescimento mais rápido e cujos estoques se encontram, em geral, em melhor condição (TAQUET et al., 2011). Além disso, atratores costeiros podem ser empregados também como uma medida de manejo, podendo oferecer uma fonte alternativa de pesca, quando a explotação de espécies alvo estiver impedida (SOKIMI e BEVERLY, 2010; JUPITER et al., 2014), como no caso de um período reprodutivo (defeso), por exemplo.

Dispositivos Agregadores de Peixes (DAPs) (*Fishing Aggregating Devices*- FADs) já eram utilizados há milênios por antigas civilizações, sendo produzidos com matéria-prima natural como bambus e folhas de bananeira, com o intuito de atrair e facilitar a captura de diversas espécies de peixes pelágicos, principalmente do dourado (*Coryphaena hippurus*, Linnaeus, 1758) (TAQUET et al., 2013). A partir do conhecimento ancestral da utilização de objetos flutuantes naturais para a melhoria da pesca, DAPs oceânicos modernos produzidos com materiais artificiais e tendo os atuns como espécies alvo, passaram a ser liberados à deriva ou ancorados a partir de meados da década de 70, em diferentes locais do mundo, como Filipinas (1974), Havaí (1977), Ilhas Maldivas (1980), Polinésia Francesa (1981), Ilhas Martinica (1982) e Ilhas Mauricio (1982) (TAQUET et al., 2011). Desde então, a utilização desses dispositivos se disseminou por todos os continentes, existindo atualmente dezenas de milhares de DAPs costeiros e oceânicos sendo explorados, principalmente pela pesca de atuns com rede de cerco, cujas capturas respondem por mais da metade (cerca de 55%) do total de atuns pescados mundialmente (PARKER et al., 2014).

No Brasil, embora DAPs não sejam ainda utilizados de forma sistemática, a pesca de atuns associados a plataformas de petróleo ou mesmo a boias oceanográficas ancoradas já demonstraram o seu potencial de utilização na pesca artesanal (SOUZA et al, 2013; SILVA et al., 2013). O projeto PIRATA (*Prediction and Research Moored Array in the Tropical Atlantic*), por exemplo, é composto por 21 boias fundeadas planejadas para monitorar diversas variáveis oceanográficas e atmosféricas no oceano Atlântico Tropical (GOOS-BRASIL, 2016). Uma dessas boias está ancorada na costa do Ceará, a cerca de 323 milhas náuticas de Areia Branca- RN e vem sendo utilizada por pescadores artesanais desta e de outras cidades da região (e.g. Itarema- CE), com capturas consideráveis de tunídeos e outras espécies pelágicas (SILVA et al. 2013). Diversos registros de captura de atuns também têm sido feitos para regiões bem mais próximas à costa, a exemplo da pescaria artesanal de Barra dos Coqueiros e Pirambu- SE, no entorno de plataformas de petróleo (SOUZA et al., 2013), apesar de ser proibida a pesca e/ou a aproximação de embarcações em um raio de 500 m da plataforma, por razões de segurança (MARINHA DO BRASIL, 2014).

Baseando-se nessas informações, o Projeto de Implantação de Atratores de Tunídeos e Afins em Meia Água na Plataforma Externa do Litoral de Pernambuco- ATUNA, aprovado pelo órgão público de fomento FINEP (Financiadora de Estudos e Projetos), instalou cinco dispositivos agregadores de peixes na Plataforma Continental externa do estado de Pernambuco, a fim de avaliar a sua potencialidade na agregação de espécies pelágicas, principalmente de importância comercial. O presente trabalho acompanhou o desenvolvimento desses cinco Dispositivos Agregadores de Peixes ancorados na plataforma continental do estado de Pernambuco, coletando informações acerca da a caracterização e comportamento da ictiofauna pelágica associada aos atratores, por meio de censos visuais e marcação acústica.

Tais informações, além de poderem ser utilizadas como subsídio para a tomada de decisão por gestores, possuem particular relevância científica e ecológica devido à grande escassez de conhecimento acerca de espécies de peixes pelágicas oceânicas, principalmente devido ao comportamento nectônico desses animais e à dificuldade em se acessar os ambientes nos quais habitam, para uma coleta regular de dados (GAERTNER et al., 2008). Além disso, trabalhos relativos à descrição da ictiofauna associada a esses tipos de atratores no Brasil são ainda extremamente escassos.

1.2. Revisão de literatura

Há milênios, pescadores já sabiam e usufruíam da tendência natural de peixes pelágicos se reunirem no entorno de objetos flutuantes (MORALES-NIN et al., 2000), de forma que a história dos DAPs é bem mais antiga do que os primeiros trabalhos científicos relacionados a eles. O primeiro registro do uso de atratores na pesca ocorreu em 200 a.C., quando o autor romano Oppian descreveu em um de seus poemas a pesca de dourados (*Coryphaena hippurus)* no entorno de pedaços de madeira à deriva (citado em TAQUET et al., 2013).

Apesar do uso de objetos flutuantes na pesca em diferentes locais do mundo nos séculos seguintes, como, por exemplo, no Mar Mediterrâneo no século XIV (MORALES-NIN et al., 2000) e nas Filipinas no século XIX (ANDERSON e GATES, 1996), sua disseminação em larga escala só se iniciou em meados do século XX, com a pesca com rede de cerco sendo realizada no entorno de atratores naturais à deriva. Nessa mesma época, iniciou-se também, consequentemente, a publicação dos primeiros trabalhos científicos com objetos flutuantes de superfície (BESEDNOV, 1960; GOODING, 1965; GOODING e MAGNUSON, 1967), focando, principalmente, na relação entre atratores naturais e peixes pelágicos.

No início da década de 80 houve uma expansão em massa do uso de dispositivos flutuantes à deriva (Fig. 1c), que passaram a ser confeccionados, em sua maioria, com materiais artificiais e a serem liberados propositalmente por pescadores industriais, principalmente de atuns com rede de cerco, tendo como alvo grandes peixes pelágicos (DAVIES et al., 2014). Os atratores ancorados costeiros (Fig. 1a), por sua vez, já eram utilizados por povos nômades nas Filipinas e por povos locais de outras regiões como Indonésia e Malásia, desde o início do século XIX (ANDERSON e GATES, 1996). Da mesma forma que na pesca industrial, esses atratores de natureza mais artesanal também começaram a ser modernizados (Fig. 1b) e instalados em águas cada vez mais profundas a partir do final dos anos 70, no Havaí, por exemplo, embora o seu foco tenha sempre permanecido na pesca artesanal local e na pesca esportiva (MATSUMOTO et al., 1979; HOLLAND et al., 2000).

A diferenciação dos DAPs oceânicos, ancorados ou à deriva, utilizados na pesca industrial, dos DAPs costeiros ancorados, utilizados por pescadores artesanais, é de grande importância, uma vez que ambos, apesar da característica comum de atrair espécies pelágicas, possuem enfoques bastante distintos. Atratores oceânicos à deriva são utilizados principalmente por pescadores industriais visando à produção em larga escala e vem sendo bastante discutidos quanto a sua importância para a captura mundial de atuns e os impactos decorrentes do seu uso intensivo (DAGORN et al., 2013; TAQUET et al., 2013; DAVIES et al., 2014). Dispositivos agregadores costeiros e oceânicos ancorados, por sua vez, destinam-se à produção em pequena escala e têm demonstrado sua importância para a pesca artesanal e oceânica (BELL et al., 2015; HOLLAND et al., 2000) e para a segurança alimentar de diversas comunidades costeiras (ALBERT et al., 2014; BELL et al., 2015), apesar de também terem seus impactos discutidos, de forma mais local (CABRAL et al., 2014).

Não se sabe a quantidade exata de DAPs espalhados nos oceanos atualmente, entretanto, uma estimativa calculada pela organização *Pew Environmental Group*, chegou a amplitude aproximada de 50.000 a 100.000 dispositivos flutuantes à deriva lançados por ano em todo o mundo (BASKE et al., 2012), considerando-se apenas os atratores flutuantes industriais, utilizados na pesca de cerco de atuns e afins. Dispositivos agregadores ancorados, por sua vez, são ainda menos contabilizados, uma vez que podem ser facilmente construídos com materiais simples e ancorados por qualquer pescador artesanal, em qualquer zona de costa, tornando o controle ainda mais difícil. Em certos locais onde o monitoramento é realizado, porém, como na Papua Nova Guiné, por exemplo, é possível observar uma enorme quantidade de atratores em pequenas regiões (KUMORU, 2003). A concentração de DAPs em algumas regiões é tão grande, que em certos locais, como no Oceano Índico, os atratores à deriva já são considerados como um habitat flutuante artificial permanente (DAVIE et al., 2014).

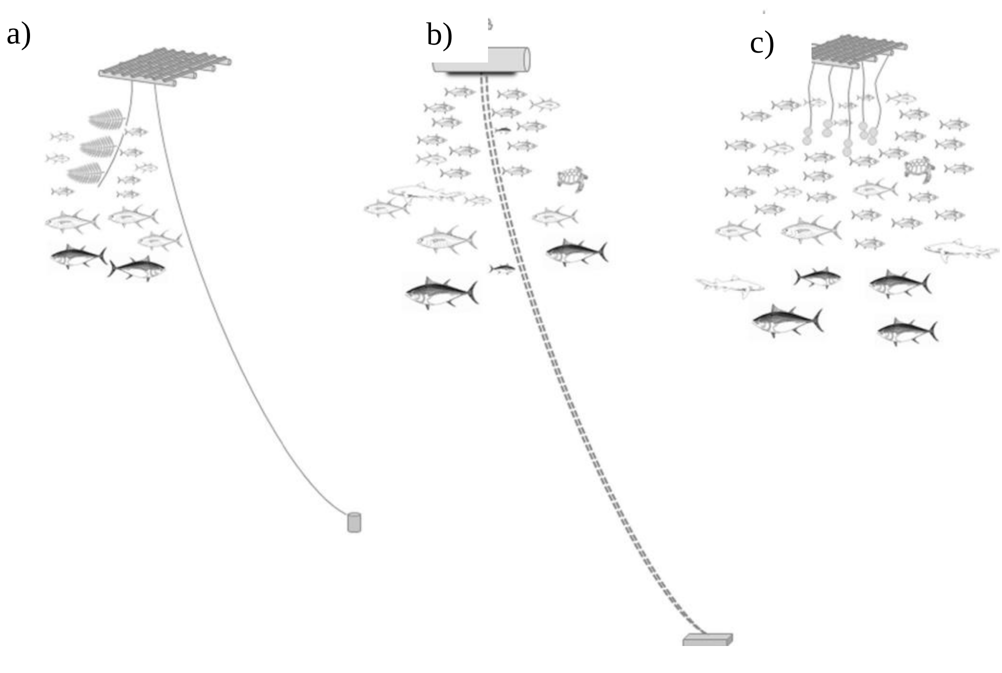

Figura 1. Desenho esquemático de: (a) DAPs ancorados costeiros, (b) DAPs ancorados de águas profundas e (c) DAPs flutuantes à deriva (Bush et al., 2014).

Percebe-se, assim, a grande importância dos Dispositivos Agregadores de Peixes, tanto pela sua contribuição para a economia e produção de pescado, em escalas mundial e local, quanto pelos potenciais impactos ambientais que podem causar. Em consequência, inúmeros trabalhos científicos têm sido realizados no intuito de elucidar essas questões. Taquet et al. (2013) realizaram um extenso levantamento da literatura disponível sobre DAPs em todo mundo, indicando a existência, até o ano de 2011, de 658 referências relacionadas a atratores de peixes, apenas 34% das quais eram de artigos publicados em jornais científicos, com 66% sendo de literatura considerada "cinza", como publicações de reuniões científicas ou conferências. Das variadas temáticas abordadas nos trabalhos, destacam-se, para este estudo, três categorias: "Biologia e Ecologia", "Comportamento e Marcação"; e "Levantamentos Bibliográficos".

Os trabalhos de "Biologia e Ecologia" são relacionados principalmente ao fenômeno de agregação dos peixes no entorno destes atratores, englobando temáticas como, substrato para espécimes juvenis em fase de transição de pelágicos para bentônicos (GOODING e MAGNUSON 1967; HUNTER e MITCHELL 1967), busca por suprimento alimentar, resposta fototrópica positiva de peixes a sombras, substrato para desova, estações de limpeza (GOODING e MAGNUSORN, 1967), proteção contra predadores (HUNTER e MITCHELL, 1968; ROUNTREE,1989), ponto de referência (HOLLAND et al., 1990), áreas de descanso (BATALYANTS, 1993), ponto de encontro de cardumes (DAGORN et al., 1995; FRÉON e DAGORN, 2000), e aumento da chance de sobrevivência de larvas e juvenis (CASTRO et al. 2002). Nessa categoria encontram-se também os trabalhos acerca da composição e caracterização da assembleia de peixes associada aos DAPs, utilizando-se diversos tipos de metodologias (BUBIĆ et al, 2011; JAQUEMET et al, 2011; MATSUMOTO et al., 2014), entre as quais a de censo visual e marcação.

A maior parte desses trabalhos foi realizada em atratores costeiros ancorados (ADDIS et al., 2006; DORAY et al., 2007; SINOPOLI et al., 2012 e 2011), mas mesmo com um número reduzido de levantamentos ictiofaunísticos em DAPs oceânicos (HUNTER e MITCHELL 1967; GOODING e MAGNUSON, 1967; TAQUET et al., 2008) e com a utilização de dois tipos diferentes de metodologias (censo visual e pesca experimental), ainda assim, é possível perceber claras similaridades e distinções nas espécies de peixes associadas às duas categorias de DAPs. Em geral, tanto DAPs oceânicos quanto costeiros possuem em seu entorno, jovens e adultos de espécies importantes economicamente, sendo compostos principalmente por peixes da Família Carangidae, como: peixes-rei (*Elagatis bipinnulata*, (Quoy & Gaimard, 1825)), arabaianas (*Seriola* spp.) e xaréus (*Caranx* spp.). Na maioria das vezes, também é possível observar a presença de dourados (*Coryphaena hippurus*) em ambos os DAPs. Nos DAPs oceânicos, entretanto, diferentemente dos costeiros, há a ocorrência constante de enormes cardumes, alvos da pesca industrial, compostos por espécies da família Scombridae, como atuns (*Thunnus* spp.) e bonitos (*Katswomus pelamis*, (Linnaeus, 1758), *Euthynnus affinis,* Cantor, 1849), além de exemplares de cavala (*Acanthocybrium solandri,* Cuvier, 1832, *Scomberomorus* spp.) e de agulhões (Istiophoridae). Ocorrem, também, espécies de outras Famílias de pequeno porte, em grandes quantidades, como os cangulos (*Balistes* spp.) e piranjicas (*Kyphosus* spp.), além de espécies pelágicas vulneráveis como os tubarões lombo-preto (*Carcharhinus falciformes,* (Müller & Henle, 1839)) e galha-branca oceânico (*Carcharhinus longimanus,* (Poey, 1861)). Os DAPs costeiros, por sua vez, agregam, em sua maioria, indivíduos jovens, que tendem a se localizar em áreas mais próximas dos mesmos. Apesar de também serem visitados, em menor frequência e quantidade, por predadores de topo, como atuns e afins, não registram, em geral, a ocorrência de tubarões. De acordo com Taquet et al. (2013), a similaridade entre as espécies visualizadas nesses censos, nos diferentes oceanos, deve impulsionar trabalhos internacionais de comparação de diversidade pelágica, tendo em vista o potencial de utilização de DAPs como importantes ferramentas de manejo, como a criação de áreas marinhas protegidas em alto mar, por exemplo.

A segunda categoria de trabalhos, acerca de "Comportamento e Marcação", contem, principalmente, estudos relacionados à movimentação e localização de atuns e afins na proximidade dos DAPs devido à grande importância econômica e ambiental da captura dessas espécies (STEHFEST et al., 2013, GOVINDEN et al., 2013; MATSUMOTO et al., 2014; HALLIER e FONTENEAU, 2015). Outros peixes encontrados e capturados no entorno dos DAPs, incluindo espécies de importância comercial, especialmente para a pescaria artesanal, como dourados, cavalas, peixes-rei e xaréus, são, na maioria das vezes, capturados como fauna acompanhante (DAGORN et al., 2013), aumentando a preocupação com os impactos, no ambiente pelágico, deste tipo de pescaria (MORENO et al., 2015). De 17,4 a 89,3 t de fauna acompanhante são capturadas por cada 1.000 t de atuns pescados junto aos DAPs, com essa proporção variando de oceano para oceano. Esses valores são 2,8 a 6,7 vezes mais altos do que a fauna acompanhante capturada em pescarias em cardumes errantes de atuns, por exemplo. O oceano Atlântico apresenta os valores mais altos de pesca incidental de espécies indesejadas, com a pesca no entorno de DAPs apresentando 3 vezes mais fauna acompanhante do que em cardumes errantes (DAGORN et al., 2013). Capturas de espécies pelágicas associadas a DAPs, além de atuns, também têm sido discutidas com relação a seu valor para a pesca esportiva e segurança alimentar de comunidades costeiras (HOLLAND et al., 2000; ALBERT et al., 2014; BELL et al., 2015). Apesar da importância ambiental, econômica e social dessas espécies, poucas pesquisas têm focado na caracterização e comportamento desses peixes (SINOPOLI et al., 2011, CAPELLO et al., 2012; FORGET et al., 2015), permanecendo, ainda, uma grande lacuna de informação tanto para espécies pelágicas quanto para estoques não-alvo (MORENO et al., 2015; TAQUET et al., 2008).

Trabalhos nas temáticas “Socioeconômicos” e “Bibliográficos”, respectivamente, apesar da sua enorme importância para o desenvolvimento sustentável da pesca no entorno de DAPs, ainda são bastante raras, somando ambas menos de 5% do total de referências. Esses números, entretanto, podem mudar, à luz da crescente quantidade de trabalhos recentes sendo publicados nessas áreas, incluindo revisões bibliográficas acerca do histórico, uso, perspectivas e gerenciamento de DAPs em diferentes regiões do mundo (BASKE et al., 2012; DEVIE et al.; 2014; BUSH e MOL, 2014), impactos dos DAPs, principalmente de DAPs oceânicos à deriva (SEMPO et al., 2013; FILMALTER et al., 2013; DAGORN et al., 2013; PARKER et al., 2014; CABRAL et al., 2014), e importância de DAPs costeiros na segurança alimentar de populações locais (ALBERT et al., 2014; BELL et al., 2015). É importante citar, que em muitos dos trabalhos acerca da contribuição dos DAPs para a segurança alimentar de comunidades costeiras, paralelamente aos benefícios decorrentes do aumento da oferta de peixes e da consequente melhoria na nutrição e renda locais, foram também enfatizados os riscos ecológicos do uso desses dispositivos e a consequente necessidade de planejamento, monitoramento e pesquisa para uma melhor compreensão e garantia dos benefícios reais e duradouros que os DAPs costeiros ancorados podem trazer (ALBERT et al., 2014; BELL et al., 2015).

No Brasil, os primeiros Dispositivos Agregadores de Peixes artificiais registrados datam de 1984, com a colocação, por uma empresa de pesca, de jangadas de bambu e boias na borda da plataforma continental dos estados do Rio de Janeiro, São Paulo e Paraná, com o intuito de restaurar e desenvolver a pesca do bonito-listrado (*Katsuwonus pelamis* (Linnaeus, 1758)). Embora o experimento tenha apresentado resultados positivos, as estruturas não resistiram às condições adversas do mar (SILVA et al., 2013). Em 1998, um convênio firmado entre o Instituto Brasileiro do Meio Ambiente e Recursos Naturais Renováveis (IBAMA), o Centro de Pesquisa e Gestão de Recursos Pesqueiros do Litoral Sudeste e Sul (CEPSUL), o Sindicato dos Armadores e das Indústrias da Pesca de Itajaí e Região (SINDIPI) e o Conselho Nacional de Aquicultura e Pesca (CONAPE), foi responsável pela instalação de seis boias ancoradas na costa de Santa Catarina (LIMA et al., 2000). Os resultados desse convênio também foram promissores, tendo sido registradas capturas de cerca de 702,5t de peixe, sendo 512t de bonito-listrado, 185t de albacora-laje (*Thunnus albacares* (Bonnaterre, 1788)) e 5,5t de dourado. Por falta de recursos, o acompanhamento das boias e das capturas associadas foi encerrado, mas estima-se que a partir desses experimentos, armadores e empresários de pesca venham lançando neste estado, em média 6 a 8 atratores artificiais simples por embarcação (LIMA et al., 2000).

Além da pesca no entorno de dispositivos agregadores de peixes colocados no mar exclusivamente para esse fim, sabe-se da captura de diversas espécies pelágicas no entorno de plataformas de petróleo, que funcionam como atratores, a exemplo das existentes na costa de Aracaju, as quais, segundo Santos e Andrade (2004), juntamente com boias ancoradas, foram comprovadamente responsáveis por um importante aumento nos desembarques de albacora-laje pela frota brasileira de vara e isca viva em anos recentes. Foram registradas também capturas consideráveis de tunídeos, principalmente albacora-bandolim (*Thunnus obesus* (Lowe, 1839)), utilizando-se o próprio barco como dispositivo agregador, por meio de uma nova estratégia de pesca desenvolvida no sul do Brasil, chamada de “Cardume Associado” (SCHROEDER e CASTELLO, 2007). Por fim, capturas significativas de tunídeos vêm sendo registradas também no entorno de uma das boias do programa PIRATA, fundeada a 323 milhas náuticas do porto pesqueiro de Areia Branca- RN, com o intuito de coletar dados oceanográficos (SILVA et al., 2013).

Apesar dos trabalhos que citam a pesca no entorno desses dispositivos (HAZIN et al., 2000; LIMA et al, 2000; SANTOS e ANDRADE, 2004; LIMA et al., 2011; SILVA et al., 2013), há apenas uma nota acerca da instalação de DAPs experimentais, na região sudeste do país (SCOTT, 1985), e um capítulo de tese sobre a descrição de espécies e peso de indivíduos capturados no entorno de uma boia oceanográfica atuando como um DAP (SILVA, 2013), não havendo, ainda, quaisquer trabalhos relativos à implementação de DAPs experimentais na região nordeste do Brasil, nem muito menos descrições da comunidade íctia associada a esses dispositivos ou do comportamento associativo das espécies, alvo e não-alvo, encontradas no entorno dessas estruturas.

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3. Artigo científico I

BIOMASS AND BEHAVIOR OF PELAGIC FISH AROUND EXPERIMENTAL MOORED FISH AGGREGATING DEVICES (FADS) OFF NORTHEASTERN BRAZIL.

Artigo científico a ser encaminhado a Revista
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BIOMASS AND BEHAVIOR OF PELAGIC FISH AROUND EXPERIMENTAL MOORED FISH AGGREGATING DEVICES OFF NORTHEASTERN BRAZIL.

ABSTRACT

The present study provides the first characterization of pelagic fish communities associated to an experimental coastal FAD array located in the continental shelf-break off northeast Brazil, including the species composition, biomass and behavior of recorded fish. Additionally, whether biomass could be explained by physical, abiotic or biotic factors was investigated. A total 14 species, mainly composed by adult individuals, belonging to 9 families were recorded. Higher species richness, fish size, abundance and biomass were found at deeper FADs. Based on the observations, search for food supply was probably the most important reason for the aggregative behavior seen around the devices. The GAMs/GLM showed total fish biomass around FADs could be explained by the FAD depth of anchorage, distance from a pre-existing oceanographic buoy and sea surface temperature. The models for individual species, also presented current velocity and immersion time as significant variables. The results provide unprecedented information on pelagic species associated with DAPs in the country and may be used as a first data base for researchers and even decision makers. These data are also of particular scientific and ecological relevance due to the knowledge scarcity regarding oceanic pelagic fish species.

Key words: pelagic species, coastal FADs, visual census, generalized models.

INTRODUCTION

In different regions of the world, floating structures have been anchored at depths of 50 to 2,500 m specifically to concentrate pelagic species closer to the coast, facilitating their capture by sport and artisanal fisherman (GUYADER et al., 2013; ALBERT et al., 2014; BELL et al., 2015), but few information regarding the fish communities associated to these devices is still known (DORAY et al., 2007; SINOPOLI et al., 2011 and 2012). These structures, also called as fish aggregating devices (FADs), have been used by fishers since ancient times, firstly consisting of floating debris such as trunks and palm leaves naturally found in the ocean (JONES, 1772) and later being constructed primarily of bamboos and palm leaves (MORALES-NIN et al., 2000).

Modern oceanic FADs, with tunas (*Thunnus* spp, *Katswomus pelamis*, (Linnaeus, 1758), *Euthynnus affinis*, Cantor, 1849) as the main target, started to be deployed or anchored from the mid-1970s in different parts of the world, such as the Philippines (1974), Hawaii (1977), Maldives (1980), French Polynesia (1981), Martinique (1982) and Mauritius (1982) (TAQUET et al., 2011). Since then, the use of these devices has spread to all continents, with about 54% of current global tunas catches occurring at these buoys (about 425,000 tonnes in 2009) (PARKER et al., 2014). Due to the great economic and environmental importance of these fishing activities, most of the studies on FAD-associated species have focused on tunas (GOVINDEN et al., 2013; MATSUMOTO et al., 2014; HALLIER & FONTENEAU, 2015).

Many other species, such as dolphinfish (*Coryphaena hippurus*, Linnaeus, 1758), wahoos (*Acanthocybrium solandri*, (Cuvier, 1832), *Scomberomorus* spp.), rainbow runners (*Elagatis bipinnulata*, (Quoy & Gaimard, 1825)) and jacks (*Caranx* spp.), however, are found and captured around these structures (CASTRO et al., 2002). These species have been important in increasing fish production and consumption in local communities (ALBERT et al., 2014), and are commonly captured as bycatch, mainly by industrial purse seiners targeting tunas (DAGORN et al., 2013). Despite the environmental, economic and social importance of the other pelagic associated species, limited research have focused on the characterization of these fish communities (TAQUET et al., 2008; OAKES et al., 2009; SINOPOLI et al., 2011).

The studies made in coastal and oceanic FADs using visual census (ADDIS et al., 2006;GAERTNER et al., 2008; TAQUET et al., 2008) have shown, in general, both oceanic and coastal FADs present juveniles and adults of economically important species, mainly Carangidae, such as rainbow runners, amberjacks (*Seriola* spp.) and jacks. Most times it is also possible to observe dolphinfish around both FAD types. Nevertheless, only in oceanic FADs it is common to observe big fish schools, mainly from the Scombridae family, such as tunas, wahoos and billfishes (Istiophoridae). Other schools of small species may also be observed, such as triggerfish (*Balistes* spp.) and chubs (*Kyphosus* spp.), besides the occurrence of vulnerable species, such as silky sharks (*Carcharhinus falciformes,* (Müller & Henle, 1839)) and oceanic white-tip sharks (*Carcharhinus longimanus,* (Poey, 1861)). Coastal FADs, on the other hand, aggregate mostly young individuals that tend to be distributed closer to the structures. Although they are also visited, in less frequency and quantities, by top predators, such as tunas, the occurrence of sharks is much rarer.

Physical factors, such as FAD characteristics, environmental and oceanographic conditions have been demonstrated to influence the presence, abundance and biomass of fish around FADs (DEMPSTER, 2005, CAPELLO et al., 2013, LOPEZ et al., 2017). Biotic factors, such as the presence of predators, preys, or fish schools, nonetheless, continue to be considered the main drivers for such associations (GOODING e MAGNUSORN, 1967; HUNTER e MITCHELL, 1968; FRÉON e DAGORN, 2000).

In Brazil, artisanal tuna fishing around oil rigs or even anchored oceanographic buoys has grown significantly in the past decade (SOUZA et al, 2013; SILVA et al. 2013). However, up to date, no study has been yet conducted on the description of fish communities around these structures using independent fishery methods. This study provides the first characterization of pelagic fish communities associated to an experimental coastal FAD array located in the continental shelf-break off Northeaster, Brazil, including the species composition, abundance and behavior of the recorded fish. The influence of physical, abiotic and biotic factors on pelagic fishes around these FADs was also investigated.

MATERIALS AND METHODS

STUDY SITE AND FAD ARRAY CHARACTERIZATION

This study was part of a bigger project entitled “Projeto de Implantação de Atratores de Tunídeos e Afins em Meia Água na Plataforma Externa do Litoral de Pernambuco-ATUNA” which aimed at anchoring 5 fish aggregating devices in the shelf-break of Pernambuco State, in order to evaluate the aggregation of pelagic species in their vicinity. The study area was located 20 miles from the Port of Recife, where the FADs were anchored at 50 and 200m depth (Fig. 1). All FADs consisted of a single 1.2m diameter float, a monitoring buoy, a stainless still chain, a positively buoyant rope and four concrete block anchors (1300 kg total) (Fig 2). Two buoys, one at 50 m and one at 200 m depth, also had an underwater aggregative structure consisting of pvc tubes, plastic nets and pieces of ropes (Figs 2 and 3). A buoy from the “Programa Nacional de Boias” (PNBOIA), anchored by the Brazilian Navy

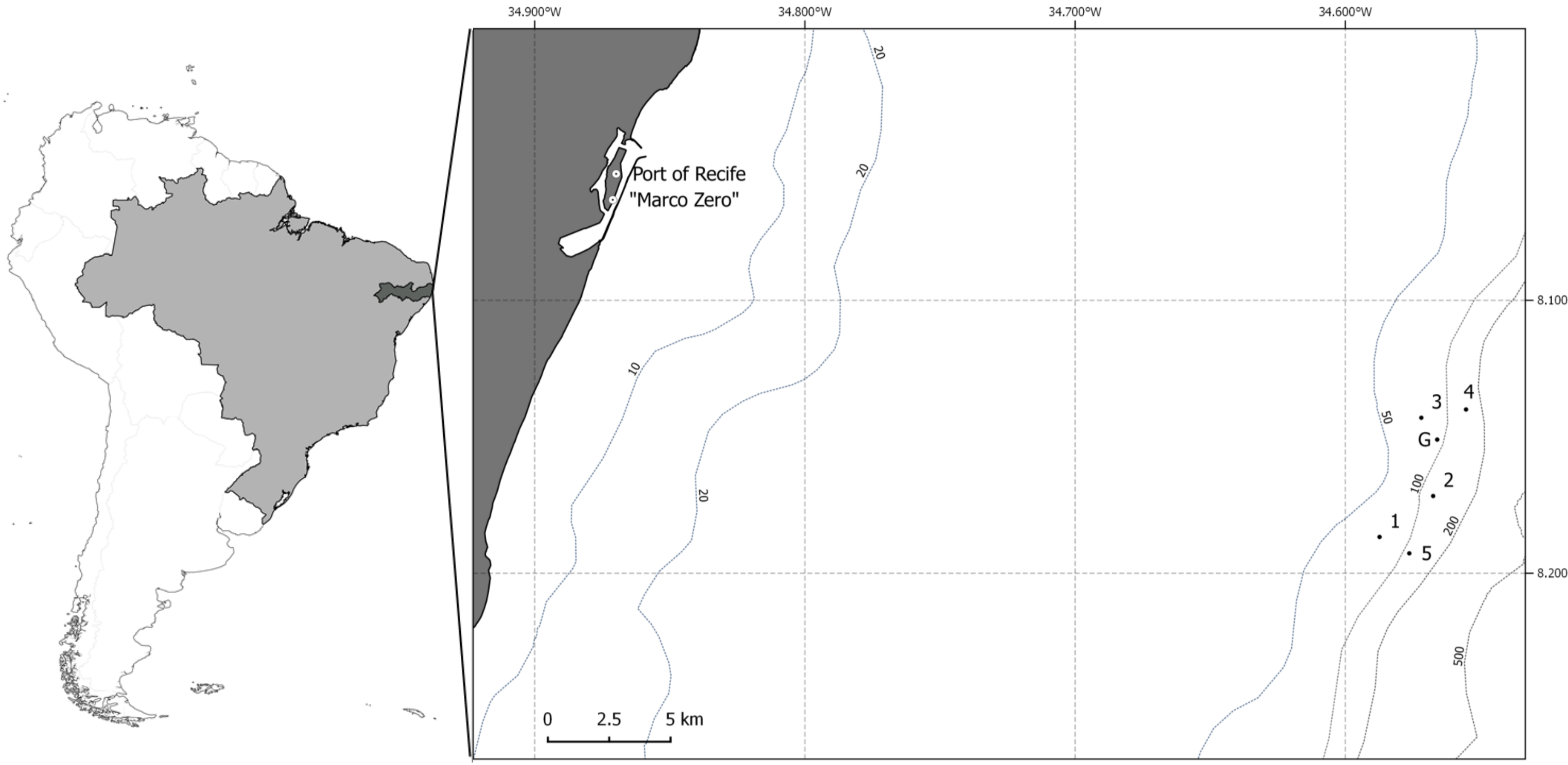

Figure 1. FAD locations. Black dots indicate FAD positions. The gray lines represent the isobaths.   .

and The Global Ocean Observing System- Brasil (GOOS-Brasil) to collect oceanographic data, was already implemented in the study area, during the time of the experiment. It also consisted of a single float (3.4 m diameter), a stainless still chain, a positively buoyant rope and four concrete block anchors (GOOS-Brasil, 2016).

VISUAL CENSUS

Dives were carried out by two divers, in all six FADs, including both equipped FADs (FADs 1 and 2) and the PNBOIA, from September 5th 2015 to September 29th 2016, in order to record the species and abundance of fish located around the buoys (~15 m radius). The data collection methodology was based on Taquet et al. (2008), in which two experienced and trained divers used the visual census technique for 30 min to observe and record the local fish community using underwater cameras for pictures and videos and PVC clipboards for notes. Besides the species and abundance, the size of the fish was also estimated. When individual estimation measurements were not possible due to the large amount of fish, such as in fish schools, the maximum and minimum sizes were estimated for each species. A biomass dive index was calculated for each species using the formula (CINCO, 1982):

$$B_i = a_i * L_i^{b_i} * N_i$$

Where B_i is the biomass index for each species, in grams, a_i and b_i are the length-weight relationship parameters, obtained from available literature (Table 4), L_i is the mean size of each species in each dive and N_i is the total abundance of each species in each dive.

Using the biomass index for each species, a total biomass index (b) was calculated for each dive (TAQUET et al., 2008), as well as the species richness (z) and the total abundance (n). Frequency of occurrence (fo), relative abundance (ra), relative biomass (rb), total abundance (n) and total biomass index (b) were calculated for each recorded species.

Table 1. Position and description of the 4 Fish Aggregating Devices implemented in Pernambuco and the PNBOIA, Brazil, including FAD number, FAD position, FAD anchor depth in meters, presence of aggregative structure:present(P), or absent(A), installation date, and date of removal or loss.

FAD #	**Position**	**Depth ~ (m)**	**Agreg. structure**	**Inst.date**	**Ps.**
1	Lat 8 11´12"S Long 34 35´14.4"W	50	A	07.07.2015	
2	Lat 8 10´18"S **Long 34 34´3''W**	200	A	11.05.2015	Lost in 02.16.16

3	Lat 8 08´34.8"S Long 34 34´18.8"W	50	P	28.11.2015	
4	Lat 8 08´23.9"S Long 34 33´19.2"W	200	P	28.11.2015	Lost in 05.16.16
5	Lat 8 11´33.6"S Long 34 34´34.8"W	200	A	21.01.2016	Lost in 05.16.16
PNBoia(G)	Lat 8 09´3.6"S Long 34 33´57.6"W	200	A	11.07.2012	Removed in 04.08.16

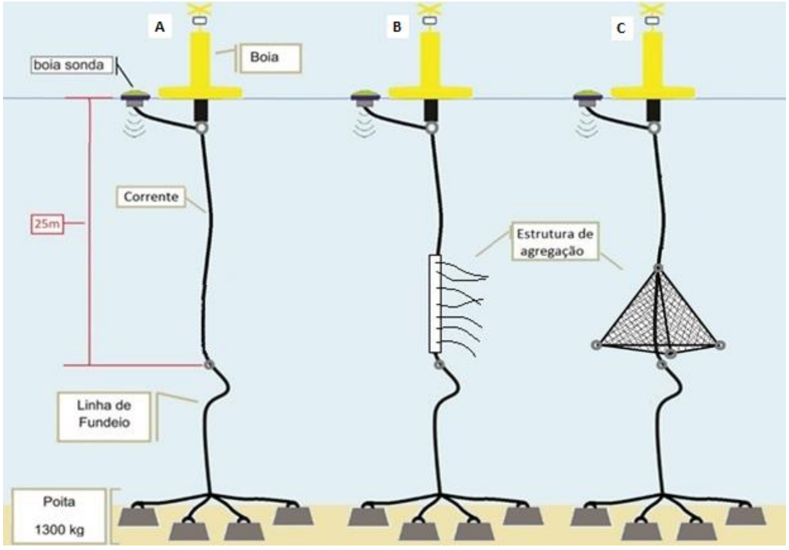

Figure 2. Schematic representation of the components of the implemented FADs, including FADs a) without an underwater aggregative structure (ASA) and, b) and c) with an underwater aggregative structure (ASP).

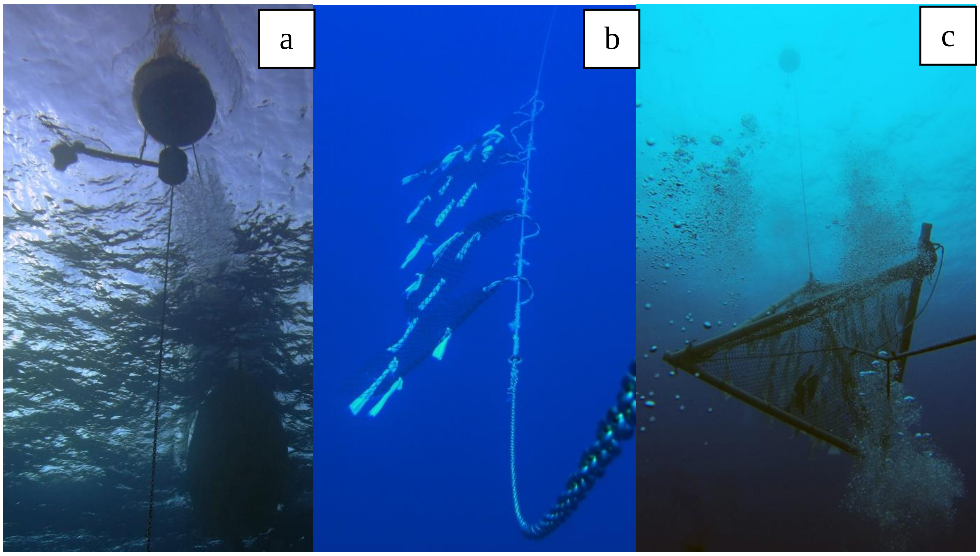

Figure 3. Underwater view from the two types of aggregative structures used: a) absent (ASA); b) and c) present (ASP).

Total fish counts and total fish biomass per species were compared between Diver 1 and Diver 2 to check for significant statistical differences using Mann-Whitney U tests. A linear regression between Diver 1 and Diver 2 counts of all dives was also done to check for correlations between them. No significant statistical differences in fish counts and/or fish biomass were found between divers (*Mann Whitney* test, $p>0.05$) and a strong correlation was found among counts for divers 1 and 2 ($F_{1,33}$, $p<0.01$, $r^2=0.98$). A rarefaction curve was also drafted to check if the sampling effort was enough to obtain a representative sample of the community in the study area (SANDERS, 1968).

A total of eleven data-collection trips were carried out, totalizing 35 dives and 70 visual censuses. Due to oceanographic conditions and logistical problems, it was not possible to perform the same amount of dives in each of the FADs, with a total of 10 dives and 20 visual censuses at FAD1, 7 dives and 14 visual censuses at FAD2, 5 dives and 10 visual censuses at FAD3, 4 dives and 8 visual censuses at FAD4, 2 dives and 4 visual censuses at FAD5, and 7 dives and 14 visual censuses at the PNBOIA (Table 2). All dives were made between 11:00 and 16:00.

Table 2. Dive characteristics, including: dive number, FAD number, FAD depth, FAD latitude, FAD longitude, dive date, dive time, and FAD immersion time in months

Dive	**FAD#**	**Depth**	**Lat.**	**Long.**	**Date**	**Time**	**Imm. Time (mths)**
D1	1	50	8 10,29´S	34 34,06´W	05.09.15	12:50	4
D2					24.10.15	14:40	5
D3					30.10.15	11:25	5
D4					07.11.15	15:01	6
D5					20.11.15	12:02	6
D6					12.12.15	12:10	7
D7					29.02.16	12:27	9
D8					19.03.16	13:10	10
D9					16.06.16	13:06	13
D10					29.09.16	11:00	16
D11	2	200	8 10,31´S	34 34,05´W	05.09.15	14:25	2
D12					24.10.15	13:18	3
D13					30.10.15	12:31	3
D14					07.11.15	15:46	4
D15					20.11.15	11:20	4
D16					05.12.15	12:58	5
D17					12.12.15	13:01	5
D18	3	50	8 09,37´S	34 34,14´W	30.10.15	14:26	0

D19					29.02.16	14:39	4
D20					19.03.16	15:12	5
D21					16.06.16	11:52	8
D22					29.09.16	12:30	11
D23	4	200	8 08,65´S	34 34,28´W	30.10.15	13:56	0
D24					05.12.15	12:03	2
D25					29.02.16	15:12	4
D26					19.03.16	14:50	5
D27	5	200	8 10,29´S	34 34,06´W	29.02.16	13:36	1
D28					19.03.16	13:46	2
D29	P	200	8 09,15´ S	34 33,48´W	24.10.15	15:31	39
D30					30.10.15	13:23	39
D31					07.11.15	16:27	40
D32					05.12.15	13:55	41
D33					12.12.15	14:33	41
D34					29.02.16	15:40	43
D35					19.03.16	15:54	44

ABIOTIC/PHYSICAL/TEMPORAL VARIABLES

In order to evaluate the influence of abiotic/physical/temporal factors on fish biomass around FADs, the following data were used; abiotic: sea surface temperature (SST), moon phase (M), current velocity (CV) and direction (CD) (from 11 to 13.5 m depth), dive visibility (V); physical: FAD location depth (D), presence of underwater aggregative structure (AS), buoy diameter size (S), distance from the PNBOIA (PN); and temporal: soaking time (ST). Sea surface temperature was obtained from NOAA website (www.class.ngdc.noaa.gov). The other oceanographic data were obtained from online available PNBOIA information (http://www.goosbrasil.org/pnboia/).

Since the implemented FADs were relatively close to the PNBOIA (1.1 to 4.77km), the current data were considered to be similar for all the FADs. FAD depths were measured by an echo-sounder. The visibility was estimated and categorized in each dive using a wrist depth gauge and the FAD anchor chain, which connects to the FAD sinking rope at 20m depth. When the divers, from the surface, could see the connection between the chain and the rope, the visibility was considered as “Good”: G (≥20m); when the connection was observed by the divers from a depth up to 10 m, the visibility was considered as “Regular”: R (20m>visib≥10m); and when the connection was only observed from a depth higher than 10m, the visibility was considered as “Bad”: B (<10m).

GENERALIZED LINEAR MODELS (GLMS)/ GENERALIZED ADDITIVE MODELS (GAMS)

The relationship among the variables and fish biomass was tested using Generalized Linear Models- GLMs (MCCULLAGH & NELDER, 1989) and Generalized Additive Models- GAMs (HASTIE & TIBSHIRANI, 1990). The total fish biomass (TB) and the biomass of the most representative species (accounting for 95% of TB) were tested. A previous exploratory analysis of the covariates and the dependent variables was done in order to decide the error distribution family to be used, if variables should be used in qualitative or quantitative form and to check for correlations among covariates. Pearson´s rank correlations were used to test for collinearity. As adopted by Lopez et al. (2017) and Hassrick et al. (2016), the covariate pairs which correlation values were > 0.7 and < −0.7, could not be tested together in the variables selection and ordering process. The selection and ordering process (MCCULLAGH & NELDER, 1989) consisted on the following steps: First, univariate GLMs were done for each of the covariates. The covariate which model residual deviance was the lowest was defined as the first variable. Each of the remaining covariates were then individually added to the model and tested similarly to the first one. Once the second variable was defined, the models with 1 and 2 variables were tested between them using an χ^2-test to check for statistical differences. If statistically different, the second variable was maintained. The third variable was then added to the model, tested and the process continued until there were no statistical differences between models with higher and lower covariate number. Based on the parsimony concept, the latter was then defined as the final model. To confirm the inclusion of the selected variables, a stepwise elimination was performed. If the AIC score increased when the term was added, the covariate was then deleted from the model. The final models were then also tested as Generalized Additive Models. The final models with higher r^2 were chosen. The model diagnosis for all final models was evaluated to ensure all statistical assumptions were met.

Based on the exploratory analysis, a Gaussian error distribution and an identity link were used to model fish biomass around FADs. Fish biomass values were discrepant among counts, therefore, in order to diminish the weight of outliers, the natural logarithm (log(fish biomass)) was used as the dependent variable. No variables presented a correlation value lower than -0.7 or higher than 0.7. M (New – N, Crescent – C, Full – F and Waning – W), D (50 and 200m), AS (FADs 1, 2, 4 and PNBOIA - Absence – A, FADs 3 and 5 - Present – P), V (< 20m – Bad or Regular - BD, ≥20m – Good - G), S (FADs 1, 2, 3, 4 and 6 – 1.2m, PNBOIA – 3.4m) and PN (0km, 0km<PN≤1.5km, <1.5km) were tested as factors. SST in Celsius, CV in mm.s^{-1}, CD and ST in months were tested as numeric variables.

RESULTS

SPECIES COMPOSITION **(FOTOS ANEXO 1)**

From September 2015 to September 2016, in all 70 visual census performed by both divers over 11 days, a total of 16,690 specimens from 14 species belonging to 9 families were recorded in the FADs immediate vicinity (maximum of 15 m from the FADs) (Table 3). The rarefaction curve stabilized towards asymptotic values close to the 50th visual census (Fig.4). This result is important to show the number of samples was sufficient to satisfactorily estimate the species richness of the studied zone. The Carangidae family was the most representative family, with five species observed, followed by the Balistidae family with two species. All other families had one species only. Although large schools were not observed in all dives, FADs always presented fish closely associated to them. Buoys at 200 m depth presented a slightly higher average number of species per count (*n*= 3.1±1.1) than buoys at 50 m depth (*n*= 2.3±1.1) (*Mann-Whitney* test, *p*<0.01) (Fig. 5a).

Fish composition was similar between FAD depths, with all species recorded at 50 m also seen at 200 m depth and only two species (*C. hyppurus* and *Aluterus monocerus*, (Linnaeus, 1758)) exclusively registered at 200 m deep FADs (Table 3). Their frequencies of occurrence, however, differed considerably between depths (Table 4). Deeper buoys had *E. bipinnulata* as the most common species (43%), followed by *Caranx crysos* (Mitchill, 1815) (31%), *Carangoides bartholomaei* (Cuvier, 1833) (17%), *Seriola rivoliana* Valenciennes, 1833 (17%) and *A. monocerus* (17%). Shallower buoys had *E. bipinnulata* (26%) and *C. bartholomaei* (26%) as the most common species, followed by *Decapterus macarellus* (Cuvier, 1833) (9%) and *Lobotes surinamensis* (Bloch, 1790) (9%). Larger predatory species were not commonly observed. *C. hippurus* was only registered at 200 m FADs, with a frequency of occurrence (fo) of 11%. *A. solandri* was observed at both depths with 4% fo at 50 m and 6% fo at 200 m depth. Small juvenile individuals from the Carangidae family (*C. bartholomaei*, *E. bipinnulata*, *C.crysos*, *D. macarelus*) (<10 cm) were observed in almost 46% of the census (29% fo in deeper FADs and 17% in shallower ones).

Most of the registered taxa were mainly represented by adults (~86%), with 4 species presenting both adult and juvenile life phases (*E. bipinnulata*, *C. crysos*, *D. macarelus* and *Psenes cyanophrys* Valenciennes, 1833). All *C. bartholomaei* and *Canthidermis maculata* (Bloch, 1786) were juvenile. Larger individuals of the same species were observed at deeper buoys (*Mann-Whitney* test, *p*=0.02) (Table 3).

Table 3. Fish species recorded around moored Fish Aggregating Devices in the outer continental shelf of Pernambuco Brazil, from visual census performed from September 2015 to September 2016, including the maximum and minimum fish sizes observed in all dives and FADs, the life stage of each species (J-Juvenile, A-Adult) in each FAD depth, the mean fish size for each FAD depth, a and b length parameters per species, and the literature consulted to obtain fish information. (-) indicates the species absence in all dives at the specific depth (50 or 200 m).

Family	**Species**	**Size(cm)**		**Mean size (cm)**		**Life stage**				**Length x Weight parameters**		**Consulted literature**
						50 m		**200 m**				
		Min	**Max**	**50 m**	**200 m**	**J**	**A**	**J**	**A**	**A**	**b**	
Exocoetidae	*Cheilopogon* sp.	30	35	32.5	30.0		X		X	0.012	3.01	Oxenford et al., 1993
Coryphaenidae	*Coryphaena hippurus*	80	100	-	90.7	-	-		X	0.020	2.80	Frota et al., 2004
Echeneidae	*Echeneis naucrates*	40	60	48.3	55.0		X		X	0.001	3.36	Kulbicki et al., 2005
Carangidae	*Elagatis bipinnulata*	5	80	38.4	62.8	X		X	X	0.013	2.92	Schroeder, 1982
	Carangoides bartholomaei	1.5	15	7.2	8.7	X		X		0.072	2.66	Ferreira et al., 1998
	Caranx crysos	10	45	33.2	36.5	X	X		X	0.032	2.95	Ferreira et al., 1998
	Seriola rivoliana	30	50	37.5	37.3		X		X	0.012	2.96	Frota et al., 2004
	Decapterus macarellus	2	15	5.0	5.3	X	X	X	X	0.008	3.14	Magnúson & Magnúson,1987
Lobotidae	*Lobotes surinamensis*	30	60	40.0	55.0		X		X	0.054	2.87	Gumanao et al., 2016
Scombridae	*Acanthocybium solandri*	100	150	106.0	128.3		X		X	0.002	3.27	Frota et al., 2004
Nomeidae	*Psenes cyanophrys*	4	12	9.7	7.0	X	X	X		0.012	2.95	Madeireira & Rossi-Wongtschowski, 2005
Balistidae	*Canthidermis maculata*	10	17	12.5	12.9	X		X		0.018	3.05	Bohnsack & Harper, 1988
	Canthidermis sufflamen	25	50	37.5	45	X	X		X	0.018	3.05	Bohnsack & Harper, 1988
Monacanthidae	*Aluterus monóceros*	35	55	-	42.9	-	-		X	0.019	2.96	Garcia et al., 1998

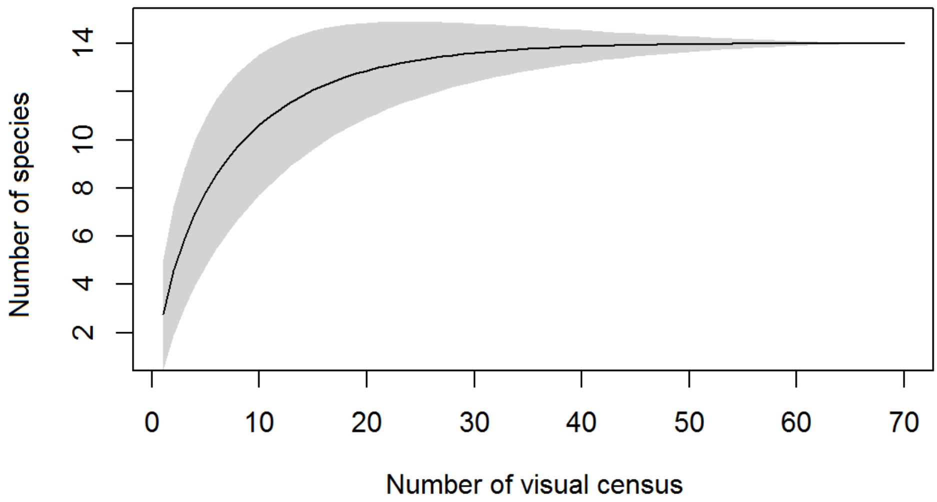

Figure 4. Species rarefaction curve for the 70 visual censuses performed in the experimental FAD array implemented on the continental shelf brake of Pernambuco - Brazil.

FISH ABUNDANCE AND BIOMASS

Fish abundance was highly variable among counts (min.:2, max.:1,300), but at 50m deep FADs the variability in abundance was considerably lower (min.: 5, max.: 131) (Table 5). In general, the four most abundant taxa were *E. bippinulata* (~50%), *C. crysos* (~37%), *D. macarelus* (~5%) and *A. monocerus* (~3%), accounting for approximately 94% of all recorded fish (Table 4). All the other observed species represented less than 1% of all fish counted. The average number of aggregated fish per count was much higher at 200 m deep buoys (388.1 ± 453.3), than at 50 m deep buoys (36.1 ± 34.4) (Fig. 5b). Buoys at 200 m depth presented similar abundances when compared to total abundance values, with *E. bippinulata* (~51%), *C. crysos* (~39%), *D. macarelus* (~5%) and *A. monocerus* (~3%) as the most abundant species, differently from 50 m deep FADs, which presented *C. bartholomaei* (~45%), *E. bippinulata* (~36%) and *D. macarelus* (~11%) as the most representative families, accounting for approximately 92% of all fish.

In terms of biomass, the variability among counts was even higher (min.:0.1 kg, max.:1,560.7 kg), specially at deeper FADs .The average estimated biomass per count differed between FAD depths (50m: 7.4 ± 9.5, and 200m: 379.0 ± 519.6) with deeper FADs accounting for approximately 98% of the total estimated biomass (Fig. 5c) (Table 4). *E. bippinulata* accounted for more than half of the total biomass estimated (~61%), followed by *C. crysos* (~33%) and *A. monocerus* (~4%), similarly to the estimated biomass at 200 m deep FADs. *E. bipinnulata* was also the biggest contributor to the biomass estimated at 50 m buoys (~54%), followed by *A. solandri* (~19%) and *C. crysos* (~9%), summing about 72% of the total biomass calculated at these buoys.

Table 4. Fish species recorded around moored Fish Aggregating Devices in the continental shelf-brake of Pernambuco, Brazil, from visual census performed from September 2015 to September 2016, including: the total number of counts in which the species was recorded (a), approximate frequency of occurrence at 50 and 200 m depth (~fo), the total abundance (n), the biomass index (b) in kilograms, the approximate relative abundance (~ra) at 50, 200 m depth and in total, and relative biomass at 50, 200 m depth and in total.

Family	**Species**	***a***	***~fo* (%)**		***n***	***b* (Kg)**	***~ra*(%)**			***~rb* (%)**		
			50	**200**			**50**	**200**	**Tot**	**50**	**200**	**Tot**
Exocoetidae	*Cheilopogon* sp.	3	3	1	13	5.2	2	0	0	4	0	0
Coryphaenidae	*Coryphaena hippurus*	8	-	11	7	42.7	-	0	0	-	0	1
Echeneidae	*Echeneis naucrates*	8	6	6	5	2.3	1	0	0	1	0	0
Carangidae	*Elagatis bipinnulata*	48	26	43	4164	4667.6	36	51	50	54	61	61
	Carangoides bartholomaei	30	26	17	395	8.4	45	2	5	4	0	0
	Caranx crysos	26	6	31	3077.5	2581.6	2	39	37	9	34	33
	Seriola rivoliana	14	3	17	12	9.6	0	0	0	1	0	0
	Decapterus macarellus	12	9	9	405.5	0.7	11	5	5	0	0	0
Lobotidae	*Lobotus surinamensis*	8	9	3	4	8.4	1	0	0	4	0	0
Scombridae	*Acanthocybium solandri*	7	4	6	5.5	68.9	0	0	0	19	1	1
Nomeidae	*Psenes cyanophrys*	5	4	3	3.5	0.0	0	0	0	0	0	0
Balistidae	*Canthidermis maculata*	8	3	9	11	0.6	1	0	0	0	0	0
	Canthidermis sufflamen	4	3	3	4	6.3	1	0	0	4	0	0
Monacanthidae	*Aluterus monóceros*	12	-	17	212.5	290.0	-	3	3	-	4	4

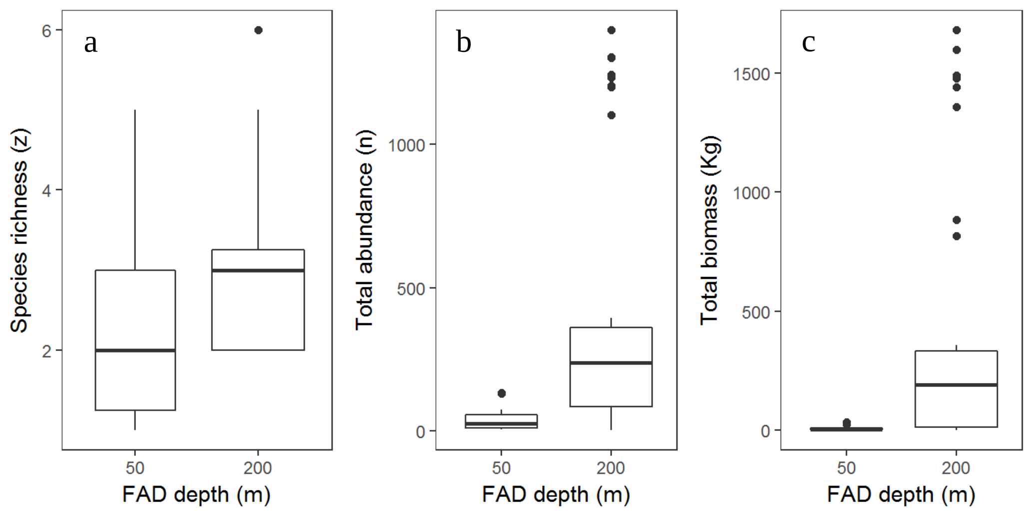

Figure 5. a)Specie richness, b)abundance, and c)estimated biomass per count at both FAD depths (50 and 200 m).

Table 5. Species richness (z), total abundance recorded by Diver 1 (*n*D1), total abundance recorded by Diver 2 (*n*D2), mean total abundance, biomass index for Diver 1 (*b*D1) in kilograms, biomass index for Diver 2 (*b*D2) in kilograms and mean biomass index, for each of the 35 dives performed.

Dive	FAD#	Depth	*z*	*n*D1	*n*D2	Mean *n* + s.d.	*b*D1 (kg)	*b*D2(kg)	Mean *b* (kg) + s.d.
D1	1	50	2	59	60	59.5 + 0.7	1.4	1.2	1.3 + 0.2
D2			1	18	18	18 + 0.0	4.2	4.2	4.2 + 0.0
D3			4	26	26	26 + 0.0	23.8	23.8	23.8 + 0.0
D4			3	28	28	28 + 0.0	4.5	4.5	4.5 + 0.0
D5			1	40	50	45 + 7.1	9.2	11.5	10.4 + 1.6
D6			2	9	9	9 + 0.0	2.2	2.2	2.2 + 0.0
D7			3	5	5	5 + 0.0	5.6	5.6	5.6 + 0.0
D8			4	10	11	10.5 + 0.7	3.7	13.1	8.4 + 6.7
D9			2	14	14	14 + 0.0	2.3	2.3	2.3 + 0.0
D10			1	130	132	131 + 1.4	1.1	1.1	1.1 + 0.0
D11	2	200	3	197	197	197 + 0.0	4.0	4.0	4.0 + 0.0
D12			4	322	312	317 + 7.1	280.7	270.8	275.8 + 7.0
D13			3	358	358	358 + 0.0	316.4	316.4	316.4 + 0.0
D14			3	370	395	382.5 + 17.7	334.1	356.7	345.4 + 16.0
D15			4	1306	1206	1256 + 70.7	883.0	815.7	849.4 + 47.6
D16			3	35	35	35 + 0.0	54.7	54.7	54.7 + 0.0
D17			2	6	6	6 + 0.0	1.7	1.7	1.7 + 0.0
D18	3	50	2	9	9	9+ 0.0	0.0	0.0	0.0 + 0.0
D19			5	35	34	34.5 + 0.7	8.8	8.8	8.8 + 0.0
D20			4	73	75	74 + 1.4	2.4	2.4	2.4 + 0.0
D21			3	73	67	70 + 4.2	35.4	33.8	34.6 + 1.1
D22			1	8	8	8 + 0.0	1.8	1.8	1.8 + 0.0
D23	4	200	3	309	259	284 + 35.4	0.2	0.2	0.2 + 0.0
D24			2	2	2	2 + 0.0	16.9	16.9	16.9 + 0.0
D25			2	5	5	5 + 0.0	1.0	1.0	1.0 + 0.0
D26			3	9	9	9 + 0.0	0.1	0.1	0.1 + 0.0
D27	5	200	5	213	245	229 + 22.6	98.8	127.2	113.0 + 20.1
D28			5	277	232	254.5 + 31.8	291.1	256.7	273.9 + 24.3
D29	P	200	3	1102	1302	1202 + 141.4	1357.5	1597.6	1477.6 + 169.8
D30			2	1200	1400	1300 + 141.4	1440.7	1680.8	1560.7 + 169.8
D31			6	1233	1243	1238 + 7.1	1479.2	1489.9	1484.5 + 7.6
D32			2	101	101	101 + 0.0	154.8	154.8	154.8 + 0.0
D33			3	210	160	185 + 35.4	330.3	248.4	289.4 + 57.8
D34			2	290	260	275 + 21.2	213.0	191.5	202.2 + 15.2
D35			3	102	152	127 + 35.4	128.9	189.9	159.4 + 43.1

FISH BEHAVIOR

All juvenile fish (≤20 cm) (*C. bartholomaei, D. macarelus, E. bipinnulata, C. crysos, P. cyanophrys* and *C. maculata*) and *L. surinamensis* were closely associated to the surface float or to the underwater aggregative structures, hiding behind them when a diver approached or at any sign of danger. Even though the small individuals of *E. bipinnulata* (8 cm maximum) would also protect themselves when divers came near the FADs, they were more often seen attacking the smaller *C. bartholomaei* around them, showing strong predation behavior even at early life stages. Small juvenile fish, especially from the Carangidae family were pretty much only observed when bigger predator fish (*E. bipinnulata, C. hippurus, A. solandri, S. rivoliana, C. crysos*) were not present or were in low numbers (Fig 6).

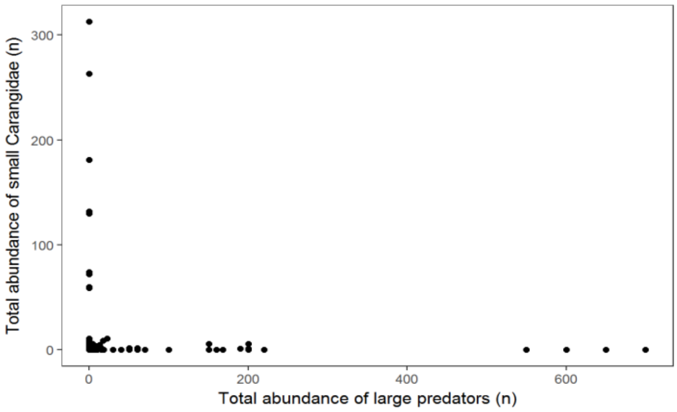

Figure 6. Total abundance per census of juvenile individuals (*C. bartholomaei, D. macarelus, E. bipinnulata, C. crysos, P. cyanophrys*), and total abundance per census of large predator individuals (*E.bipinnulata, C. hippurus, A. solandri, S. rivoliana, C. crysos*).

Adult *E. bipinnulata, C. crysos* and *A. monocerus* were always observed as fish schools. When divers entered the water *E. bipinnulata* and *C. crysos* would usually come to the surface close to the divers, and then return to the vicinity of the FADs. They usually remained from 5 to 25 m depth, but would sometimes swim to deeper waters, out of the visual range of the divers (>35 m deep). In days when currents were stronger, these species would remain at deeper waters, coming, sometimes, closer to the divers at lower depths.

Some individuals of *E. bipinulata* were also seen chafing their sides on the underwater aggregative structures. *C. crysos* were only observed associated to *E. bipinnulata* fish schools, but always presenting similar or lower abundance. Both species were usually seen going up and down the water column, feeding near the surface. They did not demonstrate any clear protective behavior, even when large *A. solandri* were seen near the fish schools.

A. monocerus schools were always seen at higher depths (~25 m). This species never remained at the vicinity of the FAD for the whole duration of a census. It would already be close to the buoy when the divers started the count, or would get close to the FAD when the divers were already there, but always left the FAD before the census was finished. Such behavior might indicate they associate to the FADs but with higher association distances, or are behaving as visitors, remaining associated to the structures for some minutes and then leaving.

S. rivoliana was also only recorded when *E.bipinnulata* schools were present. This species was usually seen in pairs or alone and remained mostly in the surface layer (10-15 m), close to the divers, but would sometimes swim to higher depths following the mooring rope and disappear from the divers' view. *E. naucrates* would appear during the census, in pairs or alone, and follow the divers in whatever depth they were at, until the end of the dive. *Cheilopogon* sp. was seen in small groups, swimming closer to the support boat than to the FAD.

L. surinamensis was always observed alone, hiding under the surface float. *C. suflamen* was also seen alone, hiding under the floating device or in small groups swimming farther from the FAD and quickly disappearing from the diver's visual range. *C. maculata* was only recorded in one diving day in four out of the five FADs visited. Current intensity in that day was pretty intense and the individuals were observed actively swimming in order to remain under the surface float.

A. solandri and *C. hippurus* presented distinct behavior from the other species. When divers entered the water, those fish would come closer to the divers but remaining at a safe distance from them and from the FADs (around 20 m), not allowing any approximation. They would remain in the diver´s visual range for some minutes, frequently disappearing and returning, indicating they were in the FAD area but at further distances. *C. hippurus* was only seen in days when current intensity was markedly strong.

GENERALIZED LINEAR/ADDITIVE MODELS

Since biomass of *E. bippinulata, C. crysos* and *A. monocerus* accounted for approximately 98% of the total biomass, in addition to the model for total fish biomass, biomass models were carried out for only these 3 species, as well. With the exception of the model for *A. monocerus* biomass, the GAMs presented better r^2 than the corresponding GLMs, being thus chosen as the final models (Table 6). Similarly, the GAMs usually presented better AIC scores than equivalent GLMs.

The GAM for the total fish biomass explained 69.6% of the deviance with an r^2 of 0.661. Three covariates were selected following the criteria explained in the Methods section, presented in order of significance: depth of FAD location, distance of the PNBOIA and sea surface temperature (Fig 7a). Higher fish biomass was associated with deeper FADs (200 m), and at the PNBoia. The biomass decreased at a higher rate at the FADs closer to the PNBOIA

(0 km<PN≤1.5 km) than in the ones farther from it (>1.5 km). Fish biomass, on the other hand, decreased at higher (<28.75ºC) and intermediate values (27ºC<SST<27.8ºC) of SST. The GAM for *E. bipinnulata* biomass explained 73.1% of the deviance, with an r^2 of 0.698. The influence of the covariates found at this model were almost identical to the one explained above (Fig. 7b), probably because this species accounted for more than half of the total estimated fish biomass.

The GAM for *C. crysos* biomass had a deviance explained by 66.7%, with an r^2 of 0.628. Three covariates were also selected for this model: FAD depth, Current velocity and Soaking Time (Fig. 7c). Higher *C. crysos* biomass was also associated to deeper FADs. An increase in biomass was also recorded for decreasing current velocities, and for soaking times from 9 to 43 months. Nonetheless, almost no observations with soaking times among these values were obtained, and thus, the results should be interpreted with caution.

Finally, the GLM for *A. monocerus* biomass presented the lowest r^2 value, of 0.256. Two covariates were representative for this model: FAD depth and Current velocity. As in the previous 3 models, higher biomass values were associated with deeper FADs. For this species, specifically, such association was evident since *A. monocerus* were only observed at 200 m deep FADs. An increase in biomass was also recorded with decreasing current intensities.

Table 6. Selected GLM or GAM models for the total fish biomass and the biomass for the 3 most abundant species recorded. Bold r^2 values represent the selected final models. [SST: sea surface temperature; MN:new moon; MC: crescent moon, MF: full moon; MW: waning moon; CV: current velocity; CD: current direction; D50: 50 m FAD depth; D200: 200 m FAD depth; ASA: aggregative structure absent; ASP: aggregative structure present; S1.2: 1.2 m buoy diameter; S3.4: 3.4 m buoy diameter; VBR: bad or regular dive visibility; VG: good dive visibility; PN0: 0 km distance from the PNBOIA; 0<PN≤1.5: distances from the PNBOIA higher to 0km or lower or equal to 1.5 km; PN>1.5: distances higher than 1.5 km from the PNBOIA; ST: Soaking Time; - not selected].

Parameter	**Total Fish Biomass**		***E.bip.* Biomass**		***C.cry.* Biomass**		***A.mon.* Biomass**	
	GLM	**GAM**	**GLM**	**GAM**	**GLM**	**GAM**	**GLM**	**GAM**
r^2	0.648	**0.661**	0.672	**0.698**	0.530	**0.628**	**0.256**	0.227
Dev.explain.(%)	-	69.6	-	73.1	-	66.7	--	-
AIC score	-	225.49	-	225.97	-	232.41	180.88	-
Covariates	**Cov.#**	***P***	**Cov.#**	***P***	**Cov.#**	***p***	**Cov.#**	***P***
SST	3	<0.01	3	<0.01	-	-	-	-
M N	-	-	-	-	-	-	-	-
C	-	-	-	-	-	-	-	-
F	-	-	-	-	-	-	-	-
W	-	-	-	-	-	-	-	-
CV	-	-	-	-	2	<0.01	2	<0.01
CD	-	-	-	-	-	-	-	-
D 50	1	<0.01	1	<0.01	1	<0.01	1	<0.01

	200		<0.01		<0.01		<0.01		<0.01
AS	A	-	-	-	-	-	-	-	-
	P	-	-	-	-	-	-	-	-
S	1.2	-	-	-	-	-	-	-	-
	3.4	-	-	-	-	-	-	-	-
V	BR	-	-	-	-	-	-	-	-
	G	-	-	-	-	-	-	-	-
PN	0		<0.01		<0.01	-	-	-	-
	0<PN≤1.5	2	<0.01	2	<0.01	-	-	-	-
	>1.5		<0.01		<0.01	-	-	-	-
ST		-	-	-	-	3	<0.01	-	-

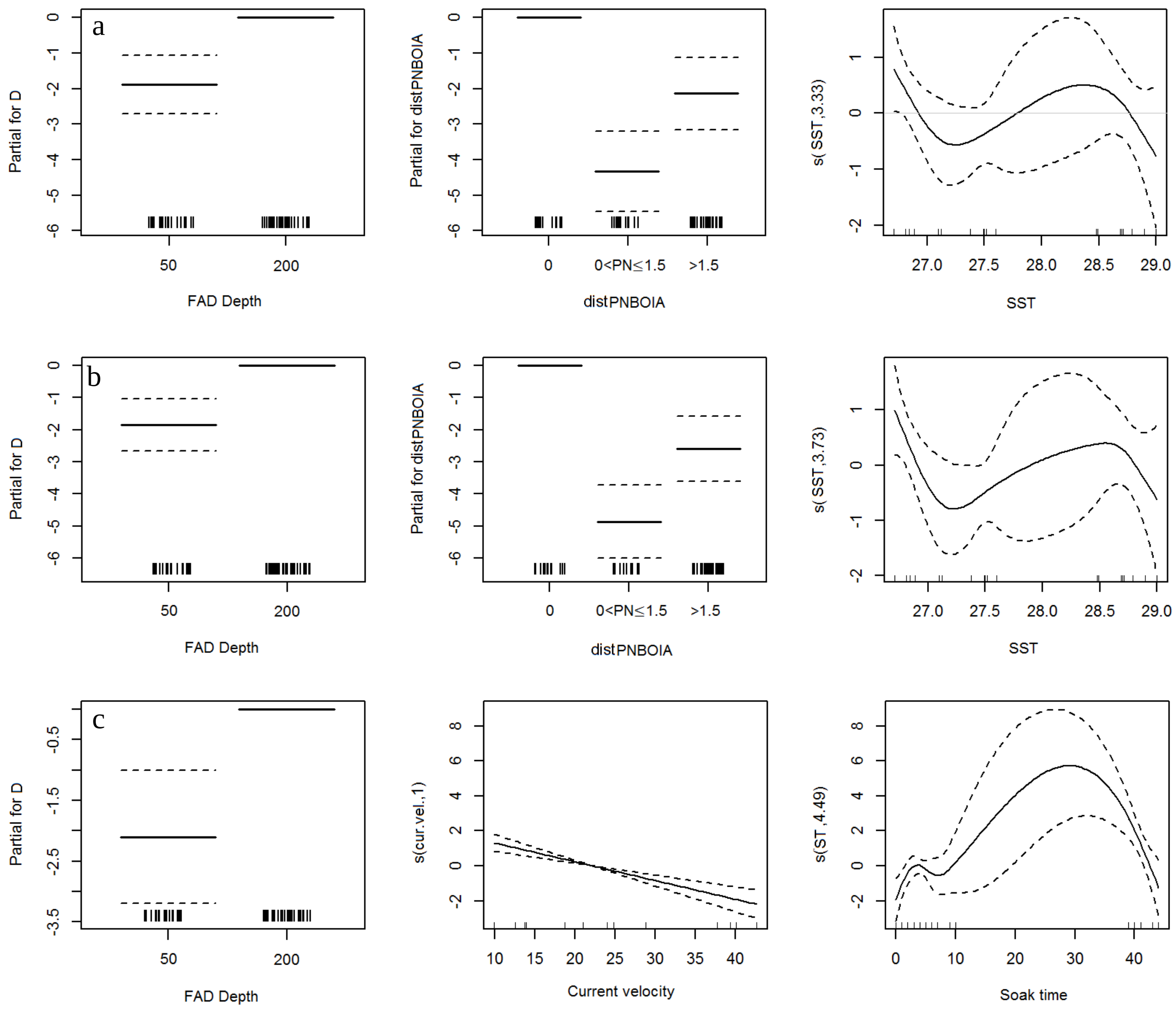

Figure 7. Covariate fits and smoothed fits for: a) total estimated fish biomass (kg), b) *E. bippinulata* estimated biomass (kg), and c) *C.cysos* estimated biomass (kg). The small "tick" lines on the bottom of the graphics shows the distribution of the registered values for each variable. The y-axis represents the centered smooth term contribution to the model on the scale of the linear predictor. Dashed lines represent the approximate 95% confidence interval.

DISCUSSION

Even though visual census around FADs have already been carried out in many parts of the world (DORAY et al; 2007; GAERTNER et al., 2008; SINOPOLI et al., 2012), the present study was the first to assess pelagic fauna around Fish Aggregating Devices in Brazil using fisheries independent methods. Up to date, the only work done in the characterization of FAD associated fish in the country was Silva (2013), who, in one chapter of his thesis, identified and weighed fish caught around an oceanic moored FAD (an oceanographic buoy) in the northeast region of the country.

OBSERVATIONS ON THE SAMPLING EFFORT (VISUAL CENSUS)

It is important to mention the FAD array was not designed especially for this study, precluding a more adequate sampling design to better fit the statistic tests. The sampling design was also affected by environmental and oceanographic conditions, such as big waves and strong currents and winds, causing the premature release of some buoys and also preventing dives at certain places and/or periods. Fishery-independent data in open ocean environments are always harder to obtain than in fishery-dependent/coastal environments, due to the cost and logistic difficulties to access the areas of interest (GAERTNER et al., 2008, MORENO et al., 2015). Such effort, especially at Fish Aggregating Devices, however, is extremely important to obtain information on the ecology of less common species as well as to determine species and life phases of fish hardly sampled by more conventional methods (DEMPSTER & TAQUET, 2004).

Other constraint from the use of visual census was the maximum area covered by them (15 m horizontal radius from the FADs, approximate depth of 40 m), precluding the divers from sampling not only species further from the FADs, but also at greater depths than the ones reached in the dives. The visual censuses were also limited to morning hours, with the possibility of different abundance patterns or new species showing up at night due to diel movement patterns (HELFMAN, 1986). Gooding and Magnuson (1967), in one of the first papers about icthyofauna around FADs, made diurnal and nocturnal census from an observation chamber and estimated population changes in resident species between day and night. Resident fish abundance was always higher during the day than during nighttime.

Besides the restrictions of this census technique, the observation of species not captured by fisherman, especially juvenile individuals, besides the fish behavior and distribution information provided by the visual census, would not be possible with any fishing method, neither with acoustic techniques, emphasizing the need of multiple census methods, including both fishing-independent and dependent methods, for a more complete assessment of FAD communities and impacts (DEMPSTER & TAQUET, 2004; MORENO et al. 2015).

The total amount of samples (35 dives and 70 visual censuses) was much lower than other studies with visual census around FADs at more accessible locations and with simpler designs (ADDIS, 2006; OAKES et al., 2009; SINOPOLI et al.; 2011). The asymptotic values reached at the rarefaction curve, yet, showed the sample effort was adequate to estimate the species richness of the study area (15 m horizontal radius from the FADs, approximate depth of 40 m). Since the oceanic environment is a dynamic place, with extremely mobile species, the asymptotic curve does not suggest the ictiofauna was exhaustively sampled and no new species are expected to occur. An increasing number of samples would eventually result in the appearance of new species, but at low numbers.

According to Taquet et al. (2008), 30 min was recommended as the minimum duration of a visual census around drifting devices to exhaustively identify and count fish around FADs. Each dive in the present study did last for about 30 min, but, in general, a maximum of 20 min was sufficient to determine and count the fish present. Oceanic FADs usually attract a greater number of species than coastal ones with much higher biomass (TAQUET et al. 2013). For shallower coastal moored FADs, as the ones explored in the present study, we considered 20 min an adequate period of survey, with some dives possibly lasting longer due to a higher number of species or individuals.

SPECIES COMPOSITION

In this work, in the 35 dives performed in a 12 months period, 14 species belonging to 9 families were recorded. Other studies using visual censuses in moored FADs in other parts of the world (NELSON, 2003; DEMPSTER, 2005, ADDIS et al., 2006) obtained, in general, close results to the ones found here, especially the number of families recorded. Addis et al. (2006) found 14 species from 9 families in 18 sampling months. Dempster (2005) found 18 species distributed in 9 families over a period of 36 months. In Nelson (2003), from the 26 species observed belonging to 16 families, only 9 species, belonging to 4 families, were pelagic, recorded in 9 sampling days. Even with the high variability in the sampling periods, the differences among species richness registered in the present study and in the other studies mentioned are not discrepant, with a small increase of species with an increasing sampling period, also corroborating with the rarefaction curve.

The species observed around the buoys are known to associate with floating structures (CASTRO et al., 2002) and some of them, such as *A. solandri*, *E. bippinulata*, *C. hippurus*, are commonly found associated to other coastal and oceanic FADs around the world (SILVA et al., 2013; DAGORN et al., 2013; FORGET et al., 2015). In the present study, the Carangidae family was the most observed family. The same result is seen in the vast majority of studies around FADs (CASTRO et al., 2002; ADDIS et al., 2006; TAQUET et al., 2008). Nonetheless, differently from what is usually recorded for coastal moored FADs (CASTRO et al., 1999; NELSON, 2003; DEMPSTER, 2005), most of the observed individuals in the present study were adults, maybe due to the proximity of the FADs to the continental shelf-break, a region known to aggregate pelagic fish (INNISS et al., 2016), including a higher number of adults.

Even though tuna and tuna like species, such as *K. pelamis*, *T. albacares*, and *T. atlanticus*, were usually caught by artisanal and sport fishing in the area[1], they were not observed in any of the dives. Complementary fishing census techniques or the use of echo sounder data would be necessary to estimate the abundance of circumnatant species around the FADs.

FISH BEHAVIOR AND BIOLOGICAL INFLUENCES OF FAD-SPECIES

Based on the observations made, search for food supply (GOODING e MAGNUSORN, 1967) was probably the most important reason for the aggregative behavior seen around the FADs.

Even though juvenile individuals were regularly observed hiding behind the surface float or the underwater aggregative structures as a way to avoid danger (GOODING e MAGNUSORN, 1967; HUNTER e MITCHELL, 1968; ROUNTREE,1989), most of the times they were not recorded when larger fish were present. Whether they were preyed or left the area it is not possible to state, but in either case the FADs were not acting as a good protection site for the fish, probably because there were not enough areas were they could find shelter. Dempster (2005) also only observed *Trachurus* sp. schools when *Seriola lalandi* Valenciennes, 1833 or *C. hippurus* were not present, also demonstrating the presence of predators probably affected the presence of prey. Castro et al. (1999) found much higher zooplankton biomass under anchored FADs than in the surrounding area. Most likely, the juvenile fish associated to the FADs mainly due to greater available food concentrations, also using them as a protection, when possible. *E. bipinnulata* and *C. crysos* when adults were only seen as fish schools presenting similar behavior and distribution around the FADs, often observed going up and down the water column, feeding near the surface. In contrast, single

[1] Travassos, P. E. (Universidade Federal Rural de Pernambuco. Personal communication, 2016)

juvenile individuals of both species were observed mixed to *C. bartholomaei* schools. These species are known to feed on small teleost, crustaceans and mollusks mainly found as micronekton and larger zooplankton (RANDALL, 1996; SLEY et al., 2009; JUNIOR et al., 2017), and are naturally found inhabiting areas near oceanographic features or floating objects due to higher food availability around these places (HOLLAND et al., 1999; CASTRO, 2002).

Junior et al. (2017) found *E. bippinulata* from São Pedro e São Paulo Archipelago (SPSPA) to be mainly micronekton predators, eating specially Euphausiaceae, Brachyura megalopae and *Cavolinia* sp. pteropods, but also opportunistic predating on periodically available abundant prey, such as the case of flying fish at night. The diet of *C. crysos* has been investigated around petroleum platforms in the Gulf of Mexico and similar patterns to *E. bippinulata* were found. The diet consisted mainly of zooplankton during the day but shifted to more visible micronekton and zooplankton during the night (KEENAN et al., 2003), probably due to reduced light intensities (BROWN et al., 2010).

Local sport spear fisherman who captured *E. bippinulata* in the vicinity of the studied FADs informed the research divers that when treating the fish, many small juveniles from the Carangidae family were removed from their stomachs[2]. Even the only recorded juvenile individual of *E. bipinnulata* was seen actively attacking the smaller Carangidae fish present.

It is possible that *E. bippinulata* and *C. crysos* schools remain associated to the FADs strategically feeding on the micronekton and zooplankton present in the area and predating on small juvenile fish when they were available, especially at night.

A. monocerus schools were only observed at higher depths of FADs moored at 200 m and even though they were never seen for the whole duration of a census, they were probably not only quickly passing near the FADs. This species is known to associate under floating objects and to present benthopelagic behavior (KUITER & TONOZUKA, 2001; MUNDY, 2005). They were also commonly and easily captured near the bottom of the FAD vicinities by local artisanal fishers[3]. The fish schools observed in many of the dives probably remained in the FAD area, at higher depths, even thought they were not in the visual range of the divers. *Cheilopogon* sp. and *E. naucrates,* on the other hand, seemed to behave as visitors. Both species are known to live free-swimming and shortly associate to floating objects, especially when younger (OXENFORD et al., 1993; O´TOOLE , 2002). *E. naucrates* is known to rely on hitch-hiking behavior and follow and attach to a wide variety of hosts

[2] Drausio Pinheiro Véras, Yuri de Oliveira Marins(Universidade Federal Rural de Pernambuco., Personal communication. 2016)

[3] Gleidson Tavares(Associação de Pescadores de Brasília Teimosa. Personal Communication. 2016)

(BRUNNSCHWEILER & SAZIMA, 2008), including divers (ANDRADE, 2007). They were probably quickly passing near the FADs and stopped there due to the presence of the divers (*E. naucrates*) or the floating structures (*Cheilopogon* sp.).

L. surinamensis and *C. suflamen* were only seen a few times during the census and were mostly hiding beneath the surface float. For these species, the main driving factors for the observed aggregative behavior were possibly the use of FADs as resting areas (BATALYANTS, 1993) and as refugee sites (ROUNTREE, 1989)

ABIOTIC/PHYSICAL/TEMPORAL INFLUENCES ON FAD-SPECIES

Among all variables evaluated in the present study, the depth in which FADs were anchored was by far the most important physical variable to influence FAD associated fish. It was possible to observe species that were exclusively seen at 200 m deep FADs (*A. monocerus* and *C. hippurus*), as well as higher species richness, bigger fish size of same taxa and higher abundances. Looking at the variables tested in the GAMs/ GLMs, FAD depth was also chosen as the variable of more significance in all 4 biomass models.

Castro et al. (1999) also tested the influence of anchorage depth (50-100, 120-160, and >300 m) in the fish community structure around moored FADs in the Canary Islands. They also found higher species richness and total biomass at deeper FADs. Agenbag et al. (2003), studying environmental preferences of South African pelagic species, found captures of a herring species to strongly increase with water depth, reaching its maximum near the shelf edge. Lopez et al. (2017) using GAMMs to evaluate environmental preferences of fish associated to drifting FADs (dFADs) in the Atlantic Ocean, encountered opposite biomass trends, with lower biomass values at higher depths Probably because drifting FADs are generally located in much higher depths than moored ones (BUSH & MOL, 2014).

Smith and Brown (2002) studied the diversity patterns of pelagic species along a gradient of depth and found a general pattern of steep decrease in fish diversity with increasing depth, but with a diversity peak observed between 100 to 200m, with species richness in this area slightly greater than the shallowest interval (0 to 100 m). The authors discuss this peak could be a result from adequate environmental conditions in the area, but it may also be due to sampling error. Our results support the hypothesis of favorable conditions to pelagic species around 100-200 m depth. Most likely, such pattern could be explained by the fact the shelf-break is usually located within this depth interval, and, as explained before, these areas aggregate a greater number of pelagic species (HOLLAND & GRUBBS, 2007; DUBROCA et al., 2013; INNISS et al., 2016). Some other possible explaining factors could be difficulties in adapting to higher temperatures in shallower waters (MATSUMOTO et al., 2013) and a better visibility at 100-200m than in waters less than 100 m deep, due to the lower amount of sediments from continent,probablyresulting in a more intense feeding activity in these regions.

Current velocity has also influenced the distribution and biomass (which implies abundance) of some species. This variable was the second in significance for *C. crysos* and *A. monocerus* biomass models, with biomass decreasing with increasing current strengths. *C. hippurus* were also only observed around the FADs when current intensities were stronger.

Kakuma (2000) registered higher catches of yellowfin tuna around moored FADs when currents were weak, suggesting tuna abundance to be possibly lower in stronger currents. Our results also corroborate with Dempster (2005), who found the abundance of *A. monocerus* to decrease at higher current intensities, while the abundance of dolphinfish increased with increasing current strength. Capello et al. (2013) found not the abundances but the position of a bigeye scad aggregation (*Selar crumenophthalmus* (Block, 1793)) to be shifted upstream and at increasing distances from a moored FAD with increasing currents.

As observed in the present study as in the other studies mentioned above, the abundance and distribution of smaller species such as *C. crysos*, and *A. monocerus* were affected by stronger currents, possibly due to lower swimming capabilities and higher energy costs in order to remain associated to the FADs (DEMPSTER, 2005).As observed for *E. bippinulata* and *C. crysos*, the species may also have moved to deeper waters where currents were lower, staying out of the diver´s visual range. *C. hippurus*, possibly in order to save energy and using the buoys as a reference point (HUNTER & MITCHELL, 1967; HOLLAND et al, 1990), may have preferred to stay closer associated to the FADs when currents were stronger.

Distance from the PNBOIA was also significant for the total and *E. bippinulata* biomass, being chosen in the GAMs as the second variable of the model. A steep decrease in biomass was observed at FADs closer to the Navy buoy (biomass around 5 times lower than at the PNBOIA), and a significant biomass increase at buoys further from the PNBOIA (biomass approximately double when compared to closer buoys). A possible explanation is the pre-existing Navy buoy was probably holding the fish in its vicinity instead of being a fish source to other areas. Biomass at the PNBOIA was mainly composed by *E. bippinulata* and *C. crysos.* If these fish were already associated to the PNBOIA before the FADs were implemented, they might have preferred to remain there or to go back to a previously chosen location than switch to a new FAD. New fish could also prefer the PNBOIA than the newest FADs because a pre-existing ecosystem could be more attractive to them.

Sea Surface Temperature was the third selected variable for Total and *E. bippinulata* abundance models. In both models fish biomass generally decreased from lower to higher values of SST. Sea surface temperatures in the study area present a general annual variation from 26.1 to 29.7ºC with temperatures above the average (27.8ºC) from December to June (GOOS-Brasil). In the study area, temperatures above the average coincide with dry months, of lower wind and sea currents values (GOOS-Brasil, 2016). These periods are marked as the fishing season, when larger pelagic fish such as tunas, billfishes and other larger pelagic predators are more abundant[4]. Negative correlations of SST and non-tuna species abundance and positive correlations for tuna species were also found by Lopez et al. (2017) around drifting FADs in the Atlantic Ocean. Higher numbers of possible predators is a possible explanation for lower abundances of smaller species around FADs.

Whereas soaking time was chosen as the third variable of the *A. monocerus* biomass model, with an increase in biomass approximately from 10 to 40 months of soaking time, observations during this period were almost inexistent and thus the results should be taken with caution. Castro et al. (1999) found an increased number of species with soaking time, but a stable fish biomass. Looking at the other areas of the graph for this covariate fit, it is possible to see there´s no clear positive correlation from *A. monocerus* biomass and soaking time, which could indicate a complex colonization process (LOPEZ et al., 2017).

The results presented in this study provide unprecedented information on the composition, abundance and behavior of pelagic species associated with DAPs in the country and may be used as a first data base for researchers and even decision makers. These data are also of particular scientific and ecological relevance due to the great knowledge scarcity regarding oceanic pelagic fish species, mainly due to the nektonic behavior of these animals and the difficulty in accessing oceanic environments for regular data collections (GAERTNER et al., 2008).

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COMPETING INTERESTS

The authors declare no conflicts of interest.

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- *Report or Bulletin*
  Chippendale, G. M., and Wolf, L. (1981). The natural distribution of *Eucalyptus* in Australia. Australian National Parks and Wildlife Service, Special Publication No. 6, Canberra.

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  Goudet, J. (2001). ´FSTAT, a Program to Estimate and Test Gene Diversities and Fixation Indices (Version 2.9.3).´ Available at http://www2.unil.ch/popgen/softwares/fstat.htm [accessed 15 November 2007].

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Effective data analysis seeks to summarise and clarify results, enhancing the objectivity with which they are presented and interpreted. If an analysis fails to achieve this, it is probably unsuitable. No matter what analysis is used, the reader must be provided with enough information to independently assess whether the method is appropriate. Therefore, assumptions and models underlying unusual statistical analyses must be clearly stated, usually with supporting references. Even when conventional parametric statistics are used, the reader must be assured that the data satisfied assumptions of normality as well as other specific requirements (e.g. homogeneity of variances). Bayesian and other non-frequentist approaches are welcomed but their application and assumptions must be explained and justified in sufficient detail.

Describing data. Full details of sampling, survey and experimental designs, protocols for collecting data (with references where appropriate), precision of measurements, sampling or experimental units, and sample sizes must be given. Typically, reported values should include the sample size and some measure of precision (e.g. standard errors or specified confidence intervals) of estimates. Presenting data as graphs is invaluable, helping demonstrate trends and illustrate where data might violate statistical assumptions. Tables are useful when specific values are to be presented or the data do not lend themselves readily to graphical presentation. See recent issues of the Journal for examples of effective figures and tables.

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4. Artigo científico II

FIRST TELEMETRY EXPERIMENT ON PELAGIC FISH BEHAVIOR AROUND MOORED FADS OFF NORTHEASTERN BRAZIL

Artigo científico a ser encaminhado a Revista
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FIRST TELEMETRY EXPERIMENT ON PELAGIC FISH BEHAVIOR AROUND MOORED FADS OFF NORTHEASTERN BRAZIL

ABSTRACT

In Brazil, FAD fishing has been carried out at least since the mid-1980, but, up to date, no study was conducted on the behavior of pelagic fish species around these structures in order to assess their site fidelity. This study investigated the associative behavior of acoustically-tagged fish within a coastal FAD array off Northeastern Brazil using passive acoustic telemetry. From the 13 tagged fish belonging to 4 species (*Thunnus atlanticus, Coryphaena hyppurus, Acanthocybium solandri* and *Caranx crysos*), 2 *T. atlanticus* and 6 *C. crysos* were detected. Both species presented a preference for a specific FAD but distinct associative patterns were observed; strong site fidelity was recorded for *C. crysos*, different from what was registered for *T. atlanticus.* Faster excursions far from the FADs during the day and smaller number of longer excursions during the night were recorded for *C. crysos*. Higher numbers of detections during nighttime were also observed for this species. The observed general pattern of independent *C. crysos* departures, plus the observation of a certain synchronicity in departure events of some individuals, suggests the existence of small fish schools rather than just a bigger one. We discussed the correlations between biological (food availability, presence of predators, natural behavior, and stress) and physical factors (FAD depth of anchorage, visibility, current speed and direction, and proximity to the continental shelf-break) and the associative behavior patterns recorded.

Key words: acoustic tagging, pelagic fish, coastal FADs, associative behavior.

INTRODUCTION

Fish Aggregating Devices (FADs) have been used by fishermen since ancient times in order to enhance their fisheries due to the natural behavior of many pelagic fish species to aggregate around floating objects (MORALES-NIN et al., 2000). At first, FADs consisted of floating debris such as trunks and palm leaves, naturally found in the ocean (JONES, 1772). More recently, besides the use of these naturally found FADs, fishermen also started to construct them, primarily of bamboos and palm leaves (MORALES-NIN et al., 2000). Since the 1960s, modern FADs, produced with manmade materials, have been released or anchored in oceanic and coastal regions (TAQUET et al., 2013), reaching, nowadays, tens of thousands of FADs disseminated across all five oceans (BASKE et al., 2012).

Coastal and oceanic anchored FADs are mainly used by artisanal and sport fisherman, targeting tuna and other pelagic species (TAQUET et al., 2013), being also used by semi industrial tuna fishers in the Maldives (ADAM et al., 2015). Oceanic drifting FADs are primarily used by industrial purse seiners, having tunas as their target species (TAQUET et al., 2013). Purse seine fishing around FADs has been currently responsible for more than 50% of the tuna catches worldwide (PARKER et al., 2014). Due to the great economic and environmental importance of these activities, most of the studies dedicated to the behavior of FAD-associated species, and the relationship between the fish and the devices have focused on tuna (GOVINDEN et al., 2013; MATSUMOTO et al., 2014; HALLIER & FONTENEAU, 2015).

The other species found and captured around FADs, including fish of economic importance, especially to artisanal fisheries (ALBERT et al., 2014), such as dolphinfish (*Coryphaena hippurus*, Linnaeus, 1758), wahoos (*Acanthocybrium* *solandri*, (Cuvier, 1832), *Scomberomorus* spp.), rainbow runners (*Elagatis bipinnulata*, (Quoy & Gaimard, 1825)) and jacks (*Caranx* spp.), are most of times captured as bycatch (DAGORN et al., 2013), further increasing the concern about the impact of this type of fishing on these pelagic environments (MORENO et al., 2015). From 17.4 to 89.3 tons of bycatch are captured by 1000 tons of tunas landed, varying from ocean to ocean (DAGORN et al., 2013). These numbers are 2.8 to 6.7 times higher than bycatch on free swimming tuna schools (DAGORN et al., 2013). The Atlantic Ocean presents the highest catches of unwanted species, representing 3 times more bycatch than on free swimming tuna schools (DAGORN et al., 2013). Catches of pelagic species associated to FADs, others than tunas, have also been discussed regarding their value to sport fishing and food security in coastal communities (HOLLAND et al., 2000; ALBERT et al., 2014; BELL et al., 2015).

Despite the environmental, economic and social importance of these species, and the development of the ecosystem-based approach to fisheries management (PIKITCH, 2004), limited research have focused on the associative behavior of these species (CAPELLO et al., 2012; FORGET et al., 2015), leaving, still, a great lack of information on the ecology and health status of their populations (TAQUET et al., 2008; MORENO et al., 2015).

In Brazil, tuna fishing associated with oil rigs or even anchored oceanographic buoys have already demonstrated their use in artisanal fisheries (SOUZA et al, 2013; SILVA et al. 2013). However, no study was conducted on the behavior of pelagic fish species around these anchored structures in order to assess their site fidelity. In this study, we investigated the associative behavior of acoustically-tagged fish within a coastal FAD array located offshore the city of Recife, Pernambuco (Brazil). These are the first data ever collected about the behavior of pelagic species associated with FADs in Brazil.

MATERIALS AND METHODS

Study site and FAD array instrumentation (FOTOS ANEXO 2)

The study area is located 20 miles from the Port of Recife, Pernambuco, Brazil, where 4 FADs were anchored, two at 50 m and two at 200 m depth (Fig. 1). All FADs consisted of a single float, all of same size, a monitoring buoy, a stainless still chain, a positively buoyant rope and four concrete block anchors. A buoy from the “Programa Nacional de Boias” (PNBOIA), anchored by the Brazilian Navy and The Global Ocean Observing System – Brasil (GOOS-Brasil) to collect oceanographic data, was already implemented in the study area during the time of the experiment.

When the tagging operations were carried out, only 2 FADs were already deployed (FADs 1 and 2 in Fig. 1). at 50 and 200m depth, respectively (Table 1). Each FAD was equipped with a Vemco VR2 acoustic receiver (VEMCO, a division of Amarix Ltd., Canada). The receivers were attached.at 15m depth, from 3rd of November 2015 until 29th of February 2016, and continuously recorded the presence of tagged fish Due to financial and logistical difficulties, it was not possible to conduct a detection range test with the transmitters, but using the range calculator from Vemco´s website (www.vemco.com), it was possible to estimate the ranges for the V13 tags from 406 m to 551 m(for winds 11 to 16 knots) and for the V9 tags from 363 m to 501 m (for winds 11 to 16 knots).

Table 1. Position and description of the 4 Fish Aggregating Devices implemented in Pernambuco and the PNBOIA, Brazil. FADs 1 and 2 were instrumented with acoustic receivers.

FAD #	Position	Depth ~ (m)	Inst.date
1	Lat 8 11´12''S Long 34 35´14.4''W	50	07.07.2015
2	Lat 8 10´18''S Long 34 34´3''W	200	11.05.2015

3	Lat 8 08´34.8"S Long 34 34´18.8"W	50	28.11.2015
4	Lat 8 08´23.9"S Long 34 33´19.2"W	200	28.11.2015
PNBOIA(G)	Lat 8 09´3.6"S Long 34 33´57.6"W	200	11.07.2012

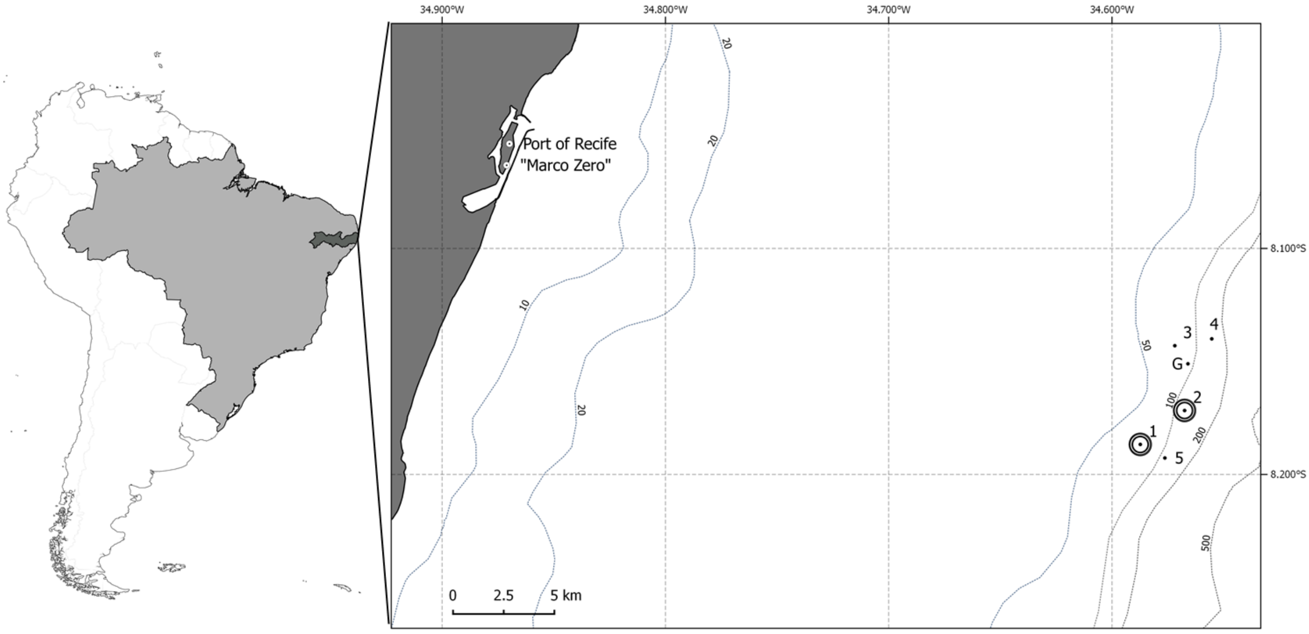

Figure 1. Map of FAD locations. Black dots indicate FAD positions. Black dots surrounded by open circles indicate FADs instrumented with VR2 receivers. Open circles represent the detection range of the receivers. The gray lines represent the isobaths.

Tagging procedures (FOTOS ANEXO 3)

Two acoustic tagging cruises were held around the instrumented FADs, one in November 3rd and the other one in November 6th 2015. The fish were captured using different techniques, trolling, rod and reels or hand lines, with the use of hooks without barbs to diminish fish injuries. In order to capture large pelagic predator fish associated to the FADs, trolling was carried out with the boat navigating from one FAD to the other; for smaller fish which are usually closely associated to the devices, the boat was positioned right next the buoy and trolling was switched to pole and line fishing.

When hooked, fish were carefully transferred to a V format table, where its eyes were covered with a wet towel to calm them, and a rose was allocated towards the mouth of the fish in order to supply oxygen to the gills. Only apparently healthy fish were measured (Fork Length – FL) and then tagged with coded Vemco V9 and V13 - 69kHz acoustic transmitters. The transmitters were surgically implanted according to insertion techniques previously adopted (MEYER et al., 2000; SORIA et al., 2009, GOVINDEN et al., 2013). After the tagging, the fish were immediately released back to the water and the GPS position was registered. Aiming the fast recovery of the fish, the total duration of the tagging procedure did not exceed 2 minutes, which also implies that the capture position was very similar to the release position.

A total of 13 fish of 4 different species, 4 *Thunnus atlanticus* (Lesson, 1831), *2 Acanthocybium solandri*, *1 Coryphaena hippurus* and 6 *Caranx crysos* (Mitchill, 1815), were tagged in both cruises (Table 2). The size of the *T. atlanticus* ranged from 39 to 43 cm fork length, *A. solandri* from 95 to 100 cm, *C. hyppurus* had a 70 cm fork length and the *C. crysos* ranged from 28 to 33cm fork length (Table 2). All tagged fish were captured and released closer to FAD2 than FAD1 (Fig 2).

Table 2. Acoustically tagged fish summary: date of capture, fish species, fish size (Fork Length), type of tag, release position, distance of release position to FAD1 and distance of release position to FAD 2.

Species	ID	Date	FL (cm)	Tag type	Release position	Distance to FAD 1 (km) -	Distance to FAD2 (km) -
T. atlanticus	TATL1	03.11.15	43	V13	8 10,48'7 S 34 34,39'1 W	1.894	0.855
	TATL2	03.11.15	42	V13	8 10,58'7 S 34 34,53'1 W	1.577	1.171
	TATL3	03.11.15	39	V13	8 10,49'5 S 34 34,53'1 W	1.722	1.042
.	TATL4	06.11.15	40	V13	8 10,51'2 S 34 34, 41'4 W	1.855	0.903
A. solandri	ASOL1	03.11.15	95	V13	8 10,32'8 S 34 34,27'8 W	2.066	0.708
	ASOL2	06.11.15	100	V13	8 10,29'6 S 34 34,28'6 W	2.178	0.628
C. hippurus	CHIP1	06.11.15	70	V13	8 10,16'6 S 43 43,00 W	2.865	0.118
C. crysos	CCRY1	06.11.15	29	V9	8 10,17'4 S 34 34,05'8 W	2.635	0.271

CCRY2	06.11.15	30	V13	8 10,19'4 S 34 34,02'4 W	2.744	0.105
CCRY3	06.11.15	28	V13	8 10,18'9 S 34 34,03'4 W	2.645	0.102
CCRY4	06.11.15	32	V13	8 10,17'6 S 34 34,03'4 W	2.715	0.102
CCRY5	06.11.15	33	V13	8 10,17'7 S 34 34,02'0 W	2.806	0.060
CCRY6	06.11.15	31	V13	8 10,18'9 S 34 34,04'5 W	2.607	0.145

Data Analysis

In order to investigate the site fidelity and behavior of the tagged fish, the amount of visits and time spent by the fish around the FADs was obtained using Total Residence Times (TRTs), defined as the total time detected by the acoustic receivers, spent by the fish in the FAD array (ROBERT et al., 2012), and Continuous Residence Times (CRTs), defined as the total detection time of a tagged fish by an acoustic receiver without absences of predetermined time intervals, known as Maximum Blanking Periods (MBP) (CAPELLO et al., 2015). In this study, due to the difference in the behavior of the 4 species investigated, two distinct MBPs were utilized; for a smaller and a larger timescales. For the larger timescale, the MBP used was a 24h interval, also called as “day-scale absence”, usually used in studies which focus tuna and other large pelagic fish (DAGORN et al., 2007; TAQUET et al., 2007; GOVINDEN et al., 2013), especially because of their long excursions far from the FADs, mainly for feeding purposes (HOLLAND et al., 1990; GIRARD et al., 2007). The second MBP, for the smaller timescale, was used to analyze the fine-scale behavior of the tagged fish (SORIA et al., 2009; CAPELLO et al., 2012 and 2013), mainly *C.crysos*, known to stay closer associated to the FADs than the other 3 species. The smaller MBP was calculated based on Capello et al. (2015) who developed a methodological framework to estimate the optimal Maximum Blanking Period to be used in passive acoustic data analysis, which are free of bias from external noise, ideal to study fine-scale behavior data. The method is based on survival curve analysis of CRTs with incremental values of MBPs. In the present study, the optimal MBP found was 20 min.

The total number of detections per hour, also known as presence rate, was analyzed for all the *C. crysos* which stayed associated to the FAD for more than a day, using a Mann Whitney U test (FORGET et al., 2015), in order to investigate day-night differences in the presence rate of the species. Sunrise and sunset in Recife during summer time, season when the fish were tagged, is around 5am and 5pm, respectively (CPTEC, 2016). Thus, day was considered from 5am to 4:59pm and night from 5pm to 4:59am. The departure times of the *C.crysos* at the fine-scale CRTs were also analyzed to investigate day-night departure differences and to determine if some fish could have left the FAD simultaneously. For this purpose, the time interval at which the last fish detections were considered to be simultaneous departures was identified choosing the largest value between the time period obtained through the collision calculator from Vemco website (www.vemco.com), and the lowest MBP calculated through Capello et al. (2015) method. The time period calculated at Vemco website is based on the transmission interval of the acoustic tags and possible collisions of acoustic signals emitted at the same time. The lowest MBP from Capello et al. (2015) is the minimum time period obtained free from noise uncertainties. The largest value chosen between both time periods was, then, free from noise and collision bias. The transmission interval, also known as “delay”, for V9 and V13 tags is 90s, and the minimum time period to detect all 13 tagged fish if they were all in the detection range of the receiver at the same time was 5 min, however the lowest MBP found through Capello et al. (2015) method was also 20 min. Thus, fish leaving the FADs within 20 min interval were considered to leave simultaneously.

Finally, the total time of an excursion far from the FAD, also called as Continuous Absence Time (CAT) was obtained and then the maximum distance of an excursion (MED) from a fish which departed and returned to the same FAD less than 24 hr later was calculated considering a linear movement at a mean speed (1 body length per second, CAPELLO et al., 2012). The maximum excursion distance *D(t)* was defined as:

$$D(t) = FLt_i \frac{1}{2}$$

where FL is the fork length of the fish in meters, and t is the total absence time of the fish at the FAD in seconds.

Current velocity and direction data were plotted against associated and non-associated periods in order to check for current influence. Current direction data were categorized into 8 direction classes: North-N (0o-22.4o and 337.5o -360.0o), Northeast-NE (22.5o -67.4o), East-E (67.5o -112.4o), Southeast-SE (112.5o -157.4o), South-S (157.5o -202.4o), Southwest-SW (202.5o -247.4o), West-W (247.5o -292.4o), and Northwest-NW (292.5o -337.4o). Current intensities were tested for significant statistic differences (Kruskal-Wallis Test) among the 8 direction categories.

RESULTS

Acoustic tagging procedures

From the 13 tagged fish, 2 *T. atlaticus* (TALT3, TATL4), 2 *A. solandri* (ASOL1, ASOL2) and the *C. hippururs* (CHIP1) were never detected while 1 *C.crysos* (CCRY6) was detected only twice, being excluded from the analysis. A total of 7 detected fish were then analyzed, 2 *T.atlanticus* and 5 *C.crysos*. Except by one of the *C.crysos* (CCRY3), which visited both FADs, the other six fish were just detected at the FAD closer to their release position, FAD 2 (Table 2).

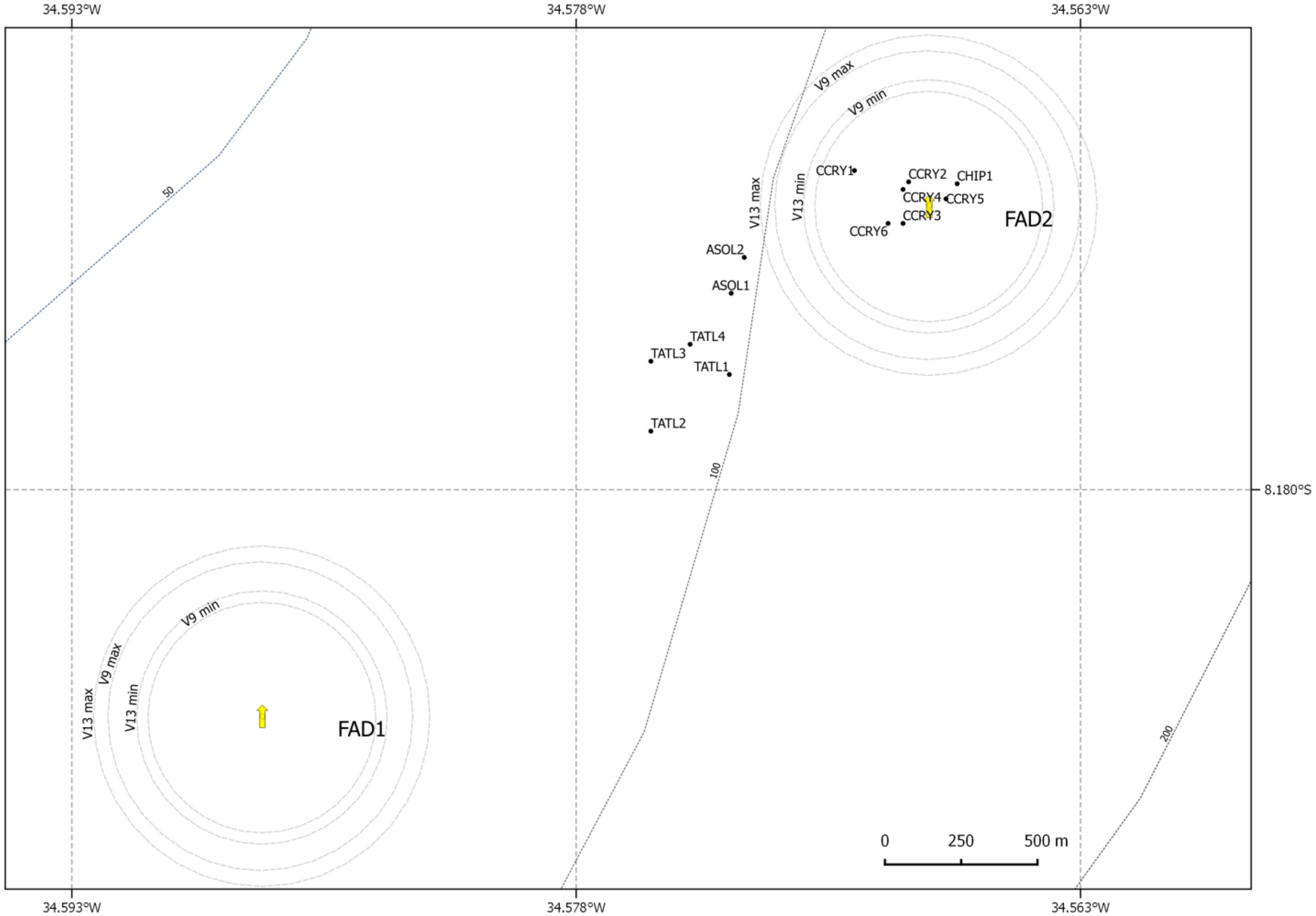

Figure 2. Release position of the 13 acoustically tagged fish. Arrows represent FAD positions. Black dots indicate the release position of the fish. Open circles represent the maximum and minimum detection range of the receivers for V9 and V13 tags. Gray lines represent the isobaths.

Continuous residence times

Total residence time (TRT)

Clear differences in the Total Residence Time were observed between both detected species (Table 3). The *T. atlanticus* were just detected during the first two days after the tagging, with an average TRT of 0.71 d (±0.53 S.D.). The *C. crysos* presented, in general, longer TRTs, most of them close to or higher than 15 days, with a mean of 16.83 d (±11.70 S.D.). The interval between the release and detection time was also different between both species, mainly because the 2 *T. atlanticus* were released out of the detection range of the receiver, while all *C. crysos* were released inside the detection range. The mean interval detection time for *T. atlanticus* was 9.44 hr (±11.87 S.D.) and for *C. crysos* was 0.17 hr (±0.03 S.D.).

Table 3. Total Residence Time description: Fish ID, FAD number, total number of detections, start date and time, end date and time, total TRT duration in days and interval between release and detection time in hours.

	Fish ID	**FAD#**	**Release time**	**Total # of detections**	**Start**	**End**	**Total TRT (days)**	**Interval Release/ detection time (hr)**
1	TATL1	FAD2	13:25	8	03/11/2015 14:28	04/11/2015 16:32	1.09	1.05
2	TATL2	FAD2	13:50	38	04/11/2015 07:40	04/11/2015 15:35	0.33	17.83
3	CCRY1	FAD2	08:20	167	06/11/2015 08:31	06/11/2015 16:19	0.32	0.18
4	CCRY2	FAD2	09:00	10358	06/11/2015 09:08	21/11/2015 02:30	14.72	0.13
5	CCRY3	FAD1&2	14:23	9706	06/11/2015 14:32	07/12/2015 16:22	32.08	0.15
6	CCRY4	FAD2	14:50	10423	06/11/2015 15:01	21/11/2015 02:26	14.48	0.18
7	CCRY5	FAD2	15:00	9916	06/11/2015 15:12	29/11/2015 04:38	22.56	0.2

Day-scale absence (24hr-MBP)

A total of 10 CRTs was obtained using a MBP of 24 hr, with a maximum of 2 CRTs per fish (Table 4). All seven detected specimens revealed a preference for FAD2, with 92% of visits (total number of CRTs) (Fig 3a). The *T. atlanticus* presented residence times of less than one day*.* TATL1 presented *2* CRTs, both at FAD2, one in the same day of the tagging and the second one on the next day. Both CRTs were of short duration with a maximum of 16.32 min. TATL2 presented 1 CRT, also at FAD2, with a total duration of 7.93 hr.

The 5 *C. crysos* in general were detected for much longer periods than the *T. atlanticus*. CCRY1 was only detected on the first day after the tagging, at FAD2, with a residence time of 7.8 hr. CCRY2 and CCRY4 from the time of their release stayed associated to FAD2 for 15 consecutive days, leaving the FAD both in the same day and within 20min interval, which means they were considered to leave the FAD simultaneously. CCRY3 and CCRY5 were also associated to FAD2 since the time of their release, but they left the FAD, also both in the same day, but not simultaneously, after 16 days of association. CCRY5*,* however, returned to FAD2 almost 7 days later and remained associated to the FAD for 7.09 hr. CCRY3 was the only fish to make an excursion between both FADs, being detected at FAD1 15 days after its last detection at FAD2, with a residence time of 10.17 hr.

Table 4. 24hr interval CRTs description: Fish ID, FAD number, CRT number, total number of detections, start date and time, end date and time, total CRT duration in days, CAT duration in hours.

	Fish ID	FAD#	CRT#	Total # of detections	Start	End	Total CRT (days)	CAT (days)
1	TATL1	FAD2	1	5	03/11/2015 14:28	03/11/2015 14:35	0.005	
2	TATL2	FAD2	1	38	04/11/2015 07:40	04/11/2015 15:35	0.33	
3	TATL1	FAD2	2	3	04/11/2015	04/11/2015	0.01	1.07

					16:16	16:32		
4	CCRY1	FAD2	1	167	06/11/2015 08:31	06/11/2015 16:19	0.32	
5	CCRY2	FAD2	1	10358	06/11/2015 09:08	21/11/2015 02:30	14.72	
6	CCRY3	FAD2	1	9700	06/11/2015 14:32	22/11/2015 01:05	15.44	
7	CCRY4	FAD2	1	10423	06/11/2015 15:01	21/11/2015 02:26	14.48	
8	CCRY5	FAD2	1	9911	06/11/2015 15:12	22/11/2015 02:15	15.46	
9	CCRY5	FAD2	2	5	28/11/2015 21:33	29/11/2015 04:38	0.29	6.80
10	CCRY3	FAD1	2	6	07/12/2015 12:20	07/12/2015 16:22	0.17	15.47

20 min absence (20min-MBP)

Using a MBP of 20 min, 18 CRTs were obtained, with a maximum of 5 CRTs for Fish ID CCRY3 and a mean of 2.6 ± 1.8 S.D. (Table 5). Besides the differences in the number of CRTs, the trends observed at both MBPs were similar, with almost all visits (94%) and longer periods of retainment of the fish occurring at FAD2, and *C. crysos* presenting the CRTs of longer duration (Fig 3b). With the utilization of a 20 min MBP, however, it was possible to observe finer scale movements of the fish.

The *T. atlanticus* presented only diurnal CRTs of short duration (29.2 min ± 17.7 S.D.). CATs also only occurred during the day, with a mean duration of 10.5hr ± 13.1 S.D., and maximum excursion distances of 2.225.8 ± 459.1 S.D. Besides CCRY1 and CCRY4, the other 3 *C. crysos* presented higher numbers of CRTs when compared to the 24hr MBP. Differently from the 24hr-interval CCRY3 and CCRY5 also left FAD2 simultaneously with CCRY2 and CCRY4, both returning on the next day for a short period, of 10.8 min maximum. As observed in the 24 hr MBP, CCRY5 returned to FAD2 after 6 days, but in the 20 min MBP the fish showed 2 short excursions around FAD2, of 12.5 min maximum.

All *C. crysos* showed similar behavior of excursions of less than an hour far from the FAD (CATs) (0.5 hr ±0.1 S.D.) during the day, and longer nocturnal CATs, varying from 6.8 to 372.0 hr, which were more frequent than diurnal excursions (63%). The total number of detections per hour, for the 4 *C. crysos* with a Total Residence Time of more than a day, was higher during the night than during the day (Mann-Whitney *U*; P<0.01), indicating the fish were more closely associated to the FAD during nighttime. The maximum distances which could have been travelled during the dayscale diurnal excursions had a mean of 267.2 m ± 68.3 S.D., while the dayscale nocturnal excursions had a mean of 10.3 km ± 5.5 S.D..

Table 5. 20min absence CRTs description: Fish ID, FAD number, CRT number, total number of detections, start date and time, end date and time, total CRT duration in days, and CAT in days.

	Fish ID	**FAD#**	**CRT#**	**Total # of Detections**	**Start**	**End**	**Total CRT (d)**	**Total CAT (d)**	**Maximum excursion distante (m)**
1	TATL1	FAD2	1	5	03/11/2015 14:28	03/11/2015 14:35	0.01	-	-
2	TATL2	FAD2	1	5	04/11/2015 07:40	04/11/2015 08:09	0.02	-	-
3	TATL2	FAD2	2	19	04/11/2015 10:40	04/11/2015 11:28	0.03	0.10	1901.13
4	TATL2	FAD2	3	13	04/11/2015 14:50	04/11/2015 15:35	0.03	0.14	2550.45
5	TATL1	FAD2	2	3	04/11/2015 16:16	04/11/2015 16:32	0.01	1.07	-
6	CCRY1	FAD2	1	167	06/11/2015 08:31	06/11/2015 16:19	0.33	-	-
7	CCRY2	FAD2	1	717	06/11/2015 09:08	07/11/2015 08:42	0.98	-	-
8	CCRY3	FAD2	1	4440	06/11/2015 14:32	13/11/2015 08:11	6.74	-	-
9	CCRY4	FAD2	1	10423	06/11/2015 15:01	21/11/2015 02:26	14.48	-	-
10	CCRY5	FAD2	1	9905	06/11/2015 15:12	21/11/2015 02:04	14.45	-	-
11	CCRY2	FAD2	2	9641	07/11/2015 09:05	21/11/2015 02:30	13.73	0.02	207.9
12	CCRY3	FAD2	2	4851	13/11/2015 08:38	20/11/2015 10:55	7.10	0.02	251.875
13	CCRY3	FAD2	3	406	20/11/2015 11:32	21/11/2015 02:20	0.62	0.03	341.93
14	CCRY3	FAD2	4	3	22/11/2015 01:01	22/11/2015 01:05	0.00	0.95	12656.84
15	CCRY5	FAD2	2	5	22/11/2015 02:04	22/11/2015 02:15	0.01	1.00	14255.67
16	CCRY5	FAD2	3	2	28/11/2015 21:33	28/11/2015 21:35	0.00	6.80	-
17	CCRY5	FAD2	4	3	29/11/2015 04:25	29/11/2015 04:38	0.01	0.29	4063.95
18	CCRY3	FAD1	5	4	07/12/2015 13:06	07/12/2015 13:11	0.00	15.50	-

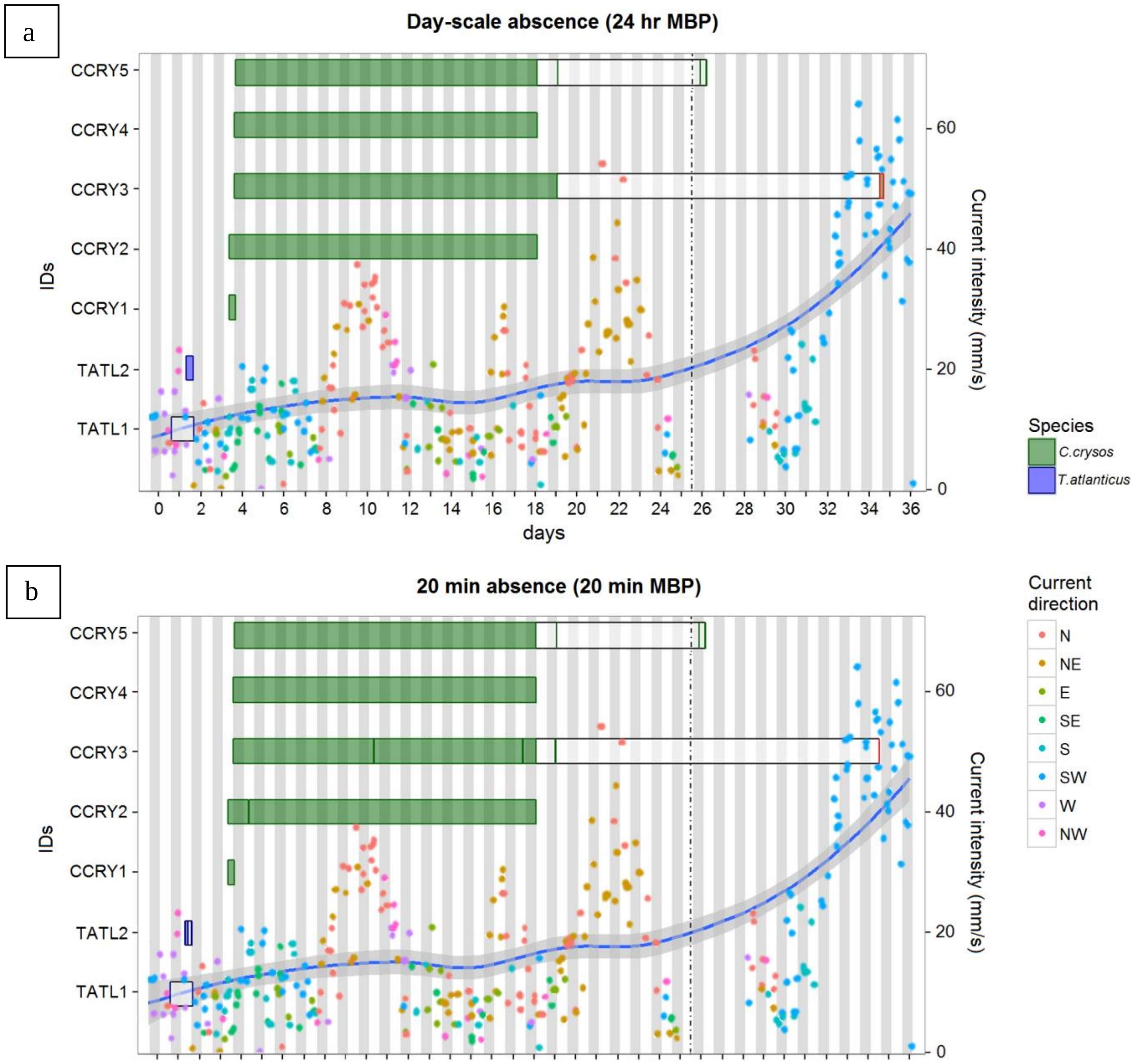

Figure 3. Continuous Residence Times (CRTs) by species, for “24hr MBP” and, “20 min MBP”, and current intensity ($mm.s^{-1}$) and direction (North-N, Northeast-NE, East-E, Southeast-SE, South-S, Southwest-SW, West-W and Northwest-NW. The white bars represent the Continuous Absence Times (CATs). The light grey areas indicate nighttime. Red lines indicate detections at FAD1. The vertical dashed lines represent the moment in which the FAD array increased from 2 to 4 FADs. Colored points represent current intensities. The blue line is the current velocity smooth conditional mean and the gray shaded area around it, the standard error bounds.

Current measurements

Current intensities ranged from 0.003 to 0.068 $m.s^{-1}$ during the study period, with a mean of 0.018 $m.s^{-1}$ ± 0.015 SD. It was possible to observe three major current intensity peaks in the 35 days measured, but, in general, the mean current strength increased with time (Fig. 3). It was also possible to observe there was not a predominant current direction when current speeds were below 0.02 $m.s^{-1}$. Currents intensities higher than 0.02 $m.s^{-1}$, however, were exclusively from North and Northeast direction until the 30^{th} day of the experiment, and from Southeast direction from day 32 until the end of the experiment.

Current strengths were significantly different among current directions (Kruskal-Wallis Test, p= 2.2e-16), with the segregation of three different groups: (1) N, NE and NW; (2) E, SW, S and W, and (3) SW (Fig.4). There seems to be no clear correlation between arrival/departure of the fish and current direction and intensity. However, it was possible to observe a stronger current speed (0.035$m.s^{-1}$) 20 min before CCRY3 left FAD2 for more than 20 min (20 min MBP). Also, all *C. crysos* left FAD2 right before the mean current intensity started to increase at a higher rate, with some fish being detected later, but for a couple of minutes only (Fig. 4b). CCRY3 showed up at FAD1, on the 34^{th} experiment day, during a predominant Southwest current which was present since day 30 and which strength had been increasing with time, reaching the highest values recorded for the study period (Fig. 4).

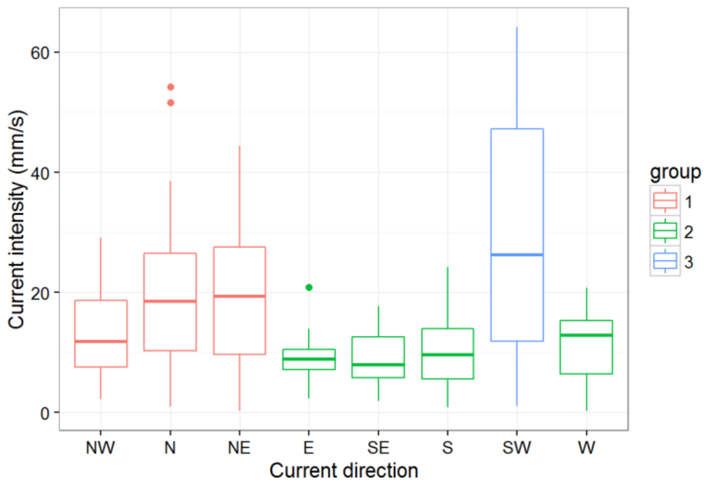

Figure 4. Current intensities in $mm.s^{-1}$, from 11 to 13.5 m depth, at each of the eight current direction categories: North (N), Northeast (NE), East (E), Southeast (SE), South (S), Southwest (SW), West (W) and Northwest (NW).

DISCUSSION

Passive acoustic tagging has been used to investigate fidelity, movements and residence times of FAD associated species in different oceans for many years (KLIMLEY & HOLLOWAY, 1996; VOEGELI et al., 2001). Nonetheless, this is the first time acoustic tagging is used to investigate the behavior of pelagic species associated with FADs in Brazil. The species tagged around the buoys are commonly found associated to other coastal and oceanic FADs around the world (FORGET et al., 2015, MUIR et al., 2012; DAGORN et al., 2013). These species have also been captured by artisanal and recreational fishing nearby the continental shelf-break of Recife and could be aggregating around the buoys implemented there. Based in the acoustic tagging data, however, it was only possible to observe site fidelity behavior for *C.crysos.*

From the 13 tagged fish, 2 blackfin tunas (*T. atlanticus*), the wahoo (*A. solandri*) and the dolphinfish (*C. hippurus*) were never detected. Up to date there is no available information on the behavior of *T. atlanticus* around FADs, but studies related to other tropical tuna species, specially yellowfin (*Thunnus albacares* (Bonnaterre, 1788)) and bigeye (*Thunnus obesus* (Lowe, 1839)), have found the estimated detection distance of a FAD by these fish to be around 7 to 13 km (HOLLAND ET AL., 1990; MARSAC & CAYRE, 1998). The radius of association, however, has been estimated to be much narrower than that (1.6 km, WENG et al., 2013; 1.8 km, MARSAC & CAYRÉ, 1998; 2 km, GIRARD et al., 2004). The non-detected fish, thus, could still be attracted by the FADs, but swimming at distances higher than the detection range of the receivers (0.5 km max.).

Studies with ultrasonic transmitters in moored and drifting FADs, however, have shown that even if fish were associated to the FADs at longer distances or for short periods, at some point they would swim to the vicinity of the FAD (HOLLAND, 1990; WENG et al.,2013; MATSUMOTO et al., 2014), where they could be detected by the receiver, if present. The likelihood of distant associations for both non-detected *T. atlanticus*, then, remains low, suggesting they probably left the area right after the release due to natural migrating behavior (MAGUIRE et al., 2006), or to tagging stress (TAQUET et al., 2007).

Information on the associative behavior of *A. solandri* is also scarce (SEPULVEDA et al., 2011). Wahoos are regularly captured as bycatch in the purse-seine tuna fisheries around drifting aggregating devices in many parts of the world (DAGORN et al., 2013). In Brazil, they have been recorded as valuable bycatch in the tuna fisheries in “associated school”, around a moored oceanic PIRATA buoy 323 nm distant from Areia Branca (RN) (SILVA et al., 2013). There is no existing information, however, on their association distance from FADs. Visual censuses carried out in the study area, before, during and after the acoustic tagging experiment period, have detected the presence of *A. solandri* at short distances from the FADs (<20 m) (VÉRAS et al., *in prep.)*. Since they were not detected by any of the VR2s, even though they were released at a close distance (only 77 and 159 m) from the detection range of FAD2 receiver, both non-detected individuals have likely also left the area after the release (TAQUET et al., 2007), probably due to tagging stress (TAQUET et al., 2007).

The dolphinfish on the other hand, was not detected even though it was released inside of the VR2 detection range. This species is known to aggregate around FADs and is regularly seen by divers in the vicinity of anchored devices (<20 m) (DEMPSTER, 2004, 2005; ADDIS et al., 2006). In the visual census observations made at the study area, different from what is usually observed in the other studies mentioned, *C. hippurus* was only recorded a few times, more specifically when currents were stronger and visibility was regular (VÉRAS et al., *in prep)*. Since the tagged specimen was not detected, it might have been injured or negatively stressed (TAQUET et al., 2007), especially because of its aggressive behavior when captured, swimming far from the detection range of FAD2 before it could be detected. Technical problems with the tag are also possible (CHATEAU & WANTIEZ., 2007).

Looking at the 24hr MBP it was possible to observe all detected fish had a preference for FAD2 (200 m deep). This result was already expected since the fish were released closer to FAD2 than FAD1, but even the catch distribution (all fish were captured closer to FAD2 than FAD1) already suggested fish were more concentrated in deeper areas. The considered detectable distance of a FAD by tunas (7 to 13 km, HOLLAND ET AL., 1990; MARSAC & CAYRE, 1998) is much higher than the distance between both FADs (less than 3 km), but all *T. atlanticus* were still captured closer to the 200m deep FAD and no visits were recorded at the shallower one, suggesting other factors were related to the preference for deeper areas.

Véras et al. (*in prep)* also found higher fish abundance, biomass and size at deeper FADs in the study area. Smith and Brown (2002) found a peak in pelagic fish diversity from 100 to 200 m depth. The tagging data from the present study support their results. The continental shelf-break break is known to aggregate greater abundance and biomass of pelagic species (DUBROCA et al., 2013; INNISS et al., 2016) being usually located within this depth interval. In the present study the buoys were purposely anchored near this region which may explain the fish preference for FAD2. They may also prefer higher depths due to difficulties in adapting to higher temperatures in shallower waters (MATSUMOTO et al., 2013) and/or due to a better visibility at 200 m, where the amount of sediments from the continent is lower.

The residence times obtained for *C. crysos,* with TRTs of more than a month and 20min-MBPs of more than 14 consecutive days demonstrated a strong site fidelity to the FADs. Brown et al. (2010) studied the movement patterns and home range of *C. crysos* around an array of oil platforms in the Gulf of Mexico. Their results also demonstrated a strong site fidelity behavior, with a mean core daily home range (circular area where the blue runner spent 50% of the day) from 373 to 2,202 m^2 and a 95% daily range from 3,082 to 14,333 m^2. Faster excursions far from the FADs during the day and smaller number of longer excursions during the night were recorded for *C. crysos* using the 20min-MPB. Higher numbers of detections during nighttime were also observed for this species. The daily excursions may be used to explore and feed with the FAD acting as a reference point (GOODING AND MAGNUSON, 1967).

Looking at the maximum diurnal excursion distances found for *C. crysos* (267.2 m ± 68.3 S.D.), it was possible to observe they did not move very far from the FAD area, and could not have visited other FADs during CAT periods. At night, the excursions were less common, with fish staying closer to the FADs possibly because the reference point could not be used with the same efficacy during the night. It may also be due to a shift in feeding strategy because of lower visibility (KEENAN et al., 2003), or even to use the FADs for protection (HUNTER & MITCHEL, 1968). Nonetheless, when there were excursions at night, the maximum calculated nocturnal excursion distances were much higher during this period (10.3 km ± 5.5 S.D), in which fish could have swam to much further areas, including the other FADs, and returned. Most likely, the low visibility may have hampered the fish return to the FAD (CASTRO et al., 2000).

Forget et al. (2015) also observed a higher number of detections during nighttime for rainbow-runner and oceanic triggerfish around drifting FADs in the Indian Ocean, while tunas and silky sharks (*Carcharhinus falciformes*, (Müller & Henle, 1839)) exhibited opposite behavior. The behavior of possible predators, such as sharks and bigger fish as tunas, away from the FAD at night, maybe for feeding purposes, emphasizing the use of FADs by smaller species, such as the blue runner (*C. crysos*), as protection (HUNTER & MITCHEL, 1968; CASTRO et al., 2000). Brown et al. (2010), in contrast, recorded more detections during the day for *C. crysos* around oil platforms in the Gulf of Mexico. The authors, nevertheless, suggested the differences may rise from movements of the fish at night to areas bellow the thermocline, which could make detections by the receivers more challenging.

The observed general pattern of independent *C. crysos* departures, plus the observation of a certain synchronicity in departure events of some individuals, suggests the existence of small fish schools rather than just a bigger one, with small groups leaving the buoy within short time intervals and others remaining associated to the FAD (DAGORN et al., 2007). The only simultaneous departure event, however, does not guarantee individuals have exited the FAD physically together. Similar patterns of small fish schools around FADs have also been observed for yellowfin tuna (*T. albacares*), bigeye tuna (*T.obesus*) and skypkack tuna (*Katsuwonus pelamis* (Linnaeus, 1758)) (DAGORN et al., 2007, GOVINDEN et al., 2013).

The results may also suggest a possible link between arrival/departure of *C. crysos* at FAD2 and current intensity, with the detected fish leaving the FAD area when the mean current strength started to increase at a higher rate. CCRY3 was also observed to move from FAD2 during a strong Southwest current, showing up at FAD1 (located southwest of FAD2) a couple days later. This fish could have swum with the current towards FAD1. Véras et al. (*in prep*), also found current strength to influence fish biomass and distribution in the study area, which was possibly explained by lower swimming capabilities of smaller fish such as *C. crysos* and higher energy expenditures in order to remain associated to the FADs (DEMPSTER, 2005). Véras et al. (*in prep)* also proposed fish may not have left the FAD but have moved to deeper areas, out of the diver´s visual range. Even dough Brown et al. (2010) proposed lower *C.crysos* detections to be due to fish moving to deeper areas, the detections absence observed at the present study suggests the tagged fish may have left the area.

Both *T. atlanticus* detected did not present site fidelity. The 20 min MBP showed they stayed around the FADs for short time intervals (maximum of 48 min), and for a maximum Total Resident Time of only 2 days. Even though studies have not been carried out with this species, residence times of tunas around FADs have been extensively studied and varying significantly among study sites, tuna species, size classes and even intra-individually (GOVINDEN et al., 2013; CAPELLO et al., 2016; RODRIGUEZ-TRESS et al., 2017).

Robert et al. (2013) categorized tuna behavior around FADs in three groups, briefly passing near a FAD, short association or long association. Briefly passing near a FAD is generally an association of a couple of minutes, as observed in the present study. This species is a small epipelagic tuna known to feed on fish, crustaceans and cephalopods, mainly on crustaceans when juveniles and on fish when adults (HEADLEY et al., 2009). The calculated length at 50% maturity for *T. atlanticus* in the Northeast Brazil was 49.8 cm FL for females and 52.1 cm FL for males (FREIRE et al., 2005). All tagged blackfin tunas were then juvenile individuals with the diet probably mainly based on crustaceans. No information is currently available on the abundance and distribution of this type of prey around FADs in the area, but it is possible that those coastal and shallower devices were not attractive enough in terms of prey availability or even in terms of location and FAD characteristics in order to keep the fish associated for longer periods (DEMPSTER, 2005). It is important to note that only two individuals were detected and, therefore, the short association pattern may also be due to the low number of tagged fish.

The non-detection of the tagged *A. solandri* and *C. hippurus* added to the non-site-fidelity of the *T. atlanticus*, diverge from results found in other studies around the world (TAQUET et al., 2007; MUIT et al., 2013; FORGET et al., 2015). All five Fish Aggregating Devices installed in Pernambuco were anchored near the Continental Shelf Break. Such habitats are known to present increased diversity due to enhanced productivity and consequently food availability (INNISS et al., 2016). Large pelagic fish then take advantage of these rich feeding areas, besides reproductive benefits and navigational use (HOLLAND & GRUBBS, 2007; DUBROCA et al., 2013, INNISS et al., 2013). The Continental Shelf-break of Pernambuco may be acting, therefore, as a “distraction” for the fish that would normally aggregate around FADs, if they were located in more oceanic areas.

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COMPETING INTERESTS

The authors declare no conflicts of interest.

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5. CONSIDERAÇÕES FINAIS

Apesar de no Brasil não haver qualquer tipo de monitoramento da pesca no entorno de atratores flutuantes artificiais, tal atividade já vem sendo realizada no país pelo menos desde meados da década de 80, com o registro da implementação de DAPs ancorados, focados na pesca do bonito listrado (SCOTT, 1985). Mesmo sabendo-se da importância econômica, social e ambiental desta modalidade de pesca, praticamente nenhum estudo relacionado à ictiofauna no entorno de DAPs foi realizado no país (SCOTT, 1985; SILVA et al., 2013). Sabe-se também da necessidade de geração de conhecimentos a respeito de espécies pelágicas oceânicas, devido à grande escassez de dados ainda existente (GAERTNER et al., 2008).

Os resultados do presente trabalho trazem informações inéditas acerca da composição, abundância e comportamento de espécies pelágicas associadas à DAPs no Brasil. Tais informações, além de aprofundarem o conhecimento sobre a fauna pelágica de maneira geral, trazem novos dados para o país sobre a utilização de DAPs costeiros ancorados por espécies alvo da pesca. . A expectativa, portanto, é de que os resultados obtidos possam servir como uma primeira base de informação tanto para pesquisadores quanto para gestores, podendo, inclusive, contribuir para a avaliação deste tipo de pescaria na plataforma continental do país.

Os resultados apresentados, apesar de registrarem a presença de peixes de importância comercial no entorno dos atratores como cavalas, dourados, peixes rei, arabaianas e atuns, em sua maioria como indivíduos adultos, demonstraram, em geral, uma baixa abundância dessas espécies. Foi possível observar também, para a maioria delas, um comportamento de não fidelidade aos DAPs. A profundidade de ancoragem dos DAPs foi a variável mais significativa, com maior riqueza, abundância, biomassa e tamanho de indivíduos sendo registrados em atratores com maior profundidade. É possível que para o local de estudo, regiões mais rasas da Plataforma, ou talvez até a Plataforma Continental como um todo não sejam as áreas mais adequadas para a instalação de Dispositivos Agregadores de Peixes voltados para a pesca. Áreas mais profundas e distantes da costa (longe de feições submarinas como a quebra da plataforma continental), por serem regiões mais inóspitas, onde os DAPs provavelmente atuariam como a principal referência para os peixes, possivelmente agregariam um maior número de indivíduos.

É importante salientar que mesmo gerando informações relevantes e inéditas acerca da ictiofauna associada à atratores na costa do Brasil e da eficiência de tais dispositivos na Plataforma Continental, o conhecimento da comunidade associada a estas boias ainda precisa ser substancialmente aprofundado. Sendo assim, sugere-se a continuidade do monitoramento visual da ictiofauna, durante todos os períodos do ano, além da realização de mais experimentos de telemetria, visando à marcação de um maior número de exemplares, e a utilização de outras espécies. O acompanhamento das capturas no entorno dos atratores também seria de grande importância, tanto na avaliação dos reais impactos na atividade pesqueira local, quanto devido à impossibilidade do monitoramento visual de espécies extranatantes, como os atuns.

6. ANEXO 1

Figura 1. Jovens da família Carangidae se protegendo próximos ao DAP 2, sem a presença de indivíduos maiores. Foto do dia 05.09.15.

Figura 2. Foto de grande grupo de *E. bipinnulata*, no entorno do DAP 2, no dia 24.10.15. Um mês após a foto anterior não haviam mais indivíduos jovens da família Carangidae.

Figura 3. Juvenis de *D. macarellus* se protegendo entre as telas das estruturas de agregação do DAP 4, no dia 30.10.15.

Figura 4. Indivíduos de *E. bipinnulata* próximos ao DAP 1, dia 24.10.15.

Figuras 5 e 6. Grande cardume de *E. bipinnulata* no entorno do DAP 2, no dia 30.10.15.

Figuras 7 e 8. Cardumes de *E.bipinnulata* e *C. crysos*, próximos a boia da Marinha e DAP 2.

Figura 9. Cardume de *A. monóceros* no entorno do DAP 2, no dia 07.11.15.

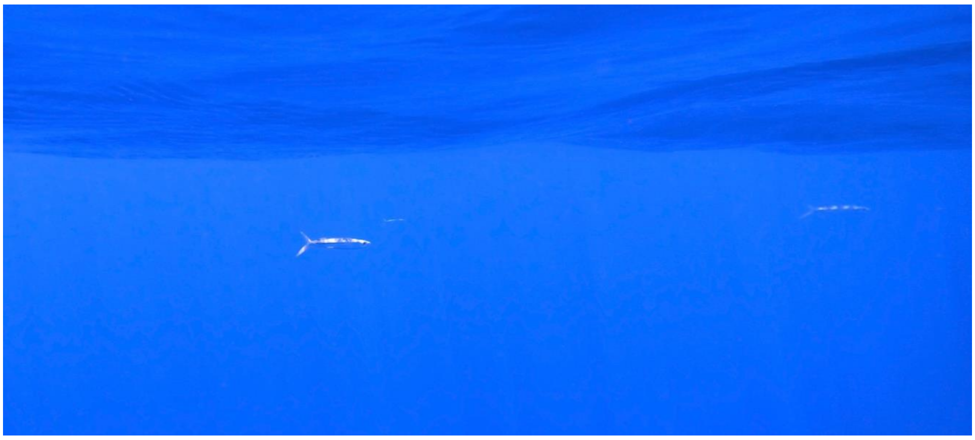


Figura 10. Espécimens da família Exocoetidae no entorno do DAP 1, no dia 30.10.15.

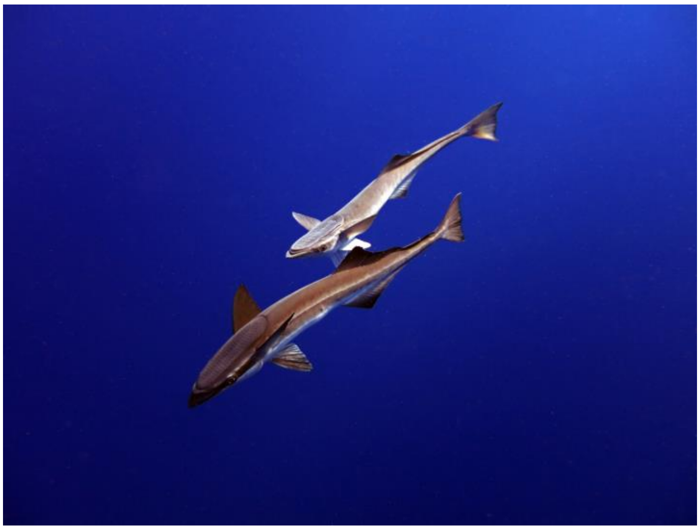


Figura 11. Indivíduos da espécie *E. naucrates*, no entorno do DAP 1, no dia 07.11.15.

Figura 12. Indivíduo da espécie *L.surinamensis*, utilizando a boia da Marinha como refúgio, no dia 07.11.15.

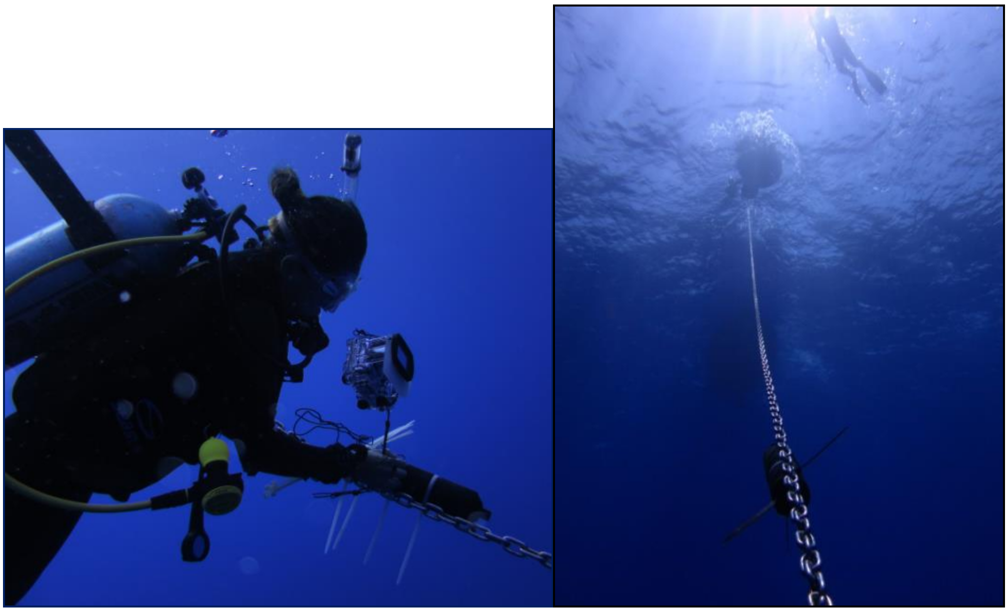
Figura 13. Indivíduo da espécie *C.suflamen*, utilizando a boia da Marinha como refúgio, no dia 07.11.15.

Figura 14. Indivíduos da espécie *D.macarellus*, se refugiando próximo ao DAP 2, no dia 05.09.15.

Figura 15. Indivíduo de *A.solandri*, no meio de um cardume misto de *C. crysos* e *E. bipinnulata* no entorno da boia da Marinha, no dia 24.10.15.

7. ANEXO 2

Figuras 1. Receptor passivo VR2W da Vemco, utilizado no presente estudo.



Figuras 2 e 3. Instalação dos receptores acústicos nas correntes de fundeio dos DAPs.

8. ANEXO 3

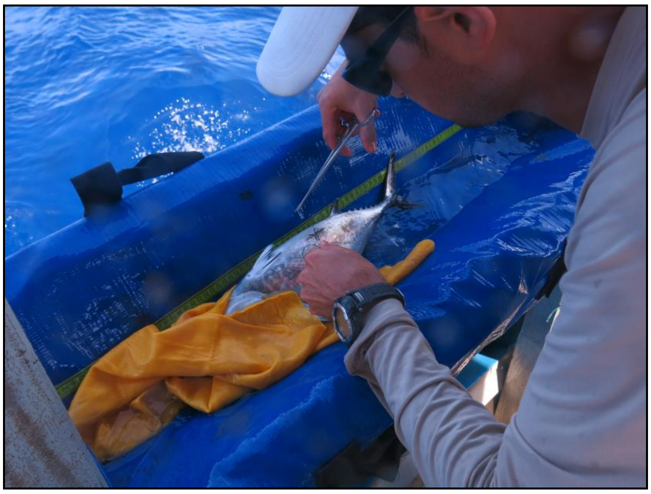


Figura 1. Indivíduo de *T. atlanticus* em procedimento de sutura ao final da marcação acústica

Figura 2. Indivíduo de *A. solandri* pronto para ser liberado ao mar após marcação acústica.

Figura 3. Indivíduo de *C. hippurus* pronto para o procedimento de marcação acústica.

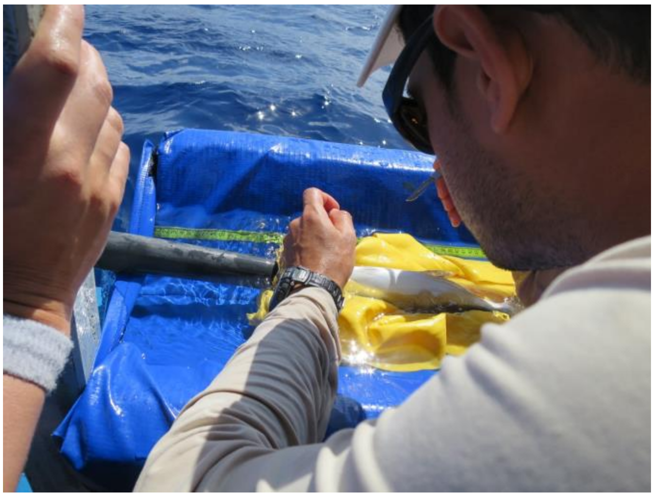


Figura 4. Espécime de *C. crysos* pronto para incisão no procedimento de marcação acústica.