UNIVERSIDADE FEDERAL DE PERNAMBUCO CENTRO DE TECNOLOGIA E GEOCIÊNCIAS DEPARTAMENTO DE OCEANOGRAFIA

Relações ecológicas entre *Stegastes fuscus* e outros peixes associados ao coral-de-fogo *Millepora alcicornis* utilizando diferentes métodos.

Isabela Carolina Silva Leal

Recife – PE
Março de 2014

UNIVERSIDADE FEDERAL DE PERNAMBUCO CENTRO DE TECNOLOGIA E GEOCIÊNCIAS DEPARTAMENTO DE OCEANOGRAFIA

Relações ecológicas entre *Stegastes fuscus* e outros peixes associados ao coral-de-fogo *Millepora alcicornis* utilizando diferentes métodos.

Isabela Carolina Silva Leal

Orientadora: Profa. Dra. Maria Elisabeth de Araújo

Dissertação apresentada à Coordenação do Programa de pós-graduação em Oceanografia da Universidade Federal de Pernambuco para obtenção do grau de Mestre em Oceanografia Biológica.

Recife - PE

Março de 2014.

UNIVERSIDADE FEDERAL DE PERNAMBUCO

CENTRO DE TECNOLOGIA E GEOCIÊNCIAS

DEPARTAMENTO DE OCEANOGRAFIA

Data da aprovação: 27/03/2014

_____

Dra. Maria Elisabeth de Araújo (Orientadora)
Universidade Federal de Pernambuco – UFPE

_____

Dra. Beatrice Padovani Ferreira (Membro Interno)
Universidade Federal de Pernambuco – UFPE

_____

Dra. Caroline Vieira Feitosa (Membro Externo)
Universidade Federal do Ceará-UFC

_____

Dr. Antônio Souto (Suplente Interno)
Universidade Federal de Pernambuco - UFPE

_____

Dr. Antônio da Silva Souto (Suplente Externo)
Universidade Federal de Pernambuco - UFPE

Recife, março de 2014.

Dedico esta pesquisa a minha avó Margarida.
A mais bela de todas as flores.

Agradecimentos

A minha orientadora, Maria Elisabeth de Araújo. Beth eu te agradeço muito pela orientação em todos esses anos, tenho aprendido muito com você. Além de uma orientadora comprometida e sempre disposta a ajudar conquistei também uma amiga. É muito bom saber que além do lado profissional existe também o carinho, amor e atenção que você sempre nos transmite.

A Pedro, meu Co-orientador. Queria te agradecer por todo o aprendizado e ideias compartilhadas desde minha graduação. Mesmo distante você sempre esteve disposto a me ajudar e me incentivar no meu trabalho.

A Bea e a Carol pela presença na minha banca. Tenho certeza que vocês irão contribuir muito com o meu trabalho. Carol, pra você tenho uns dizeres a mais...ter te conhecido melhor foi massa, gosto demais de você. Você é você e pronto.

Aos professores José Souto e Antônio Souto, pelo aceite em contribuir com o meu trabalho.

A UFPE e a Capes, o órgão financiador desta pesquisa. Em especial a Myrna pela grande ajuda burocrática.

Aos meus pais, por serem pessoas tão especiais e estarem ao meu lado em todos os momentos. Agradeço ao apoio incondicional de vocês com os meus objetivos e por me fazerem enxergar todo dia a simplicidade nas coisas. Obrigada por tudo!

Aos meus irmãos: Léo, André, Rogério e Gito. Aos meus sobrinhos: Rafael, Leozinho, Camila, Clara grande, Clara pequena, Dudinha, Carol, Pedrinho e Lívia que estar por vir, e João, meu "enteado" que amo como se fosse da família.

Ao Laboratório mais animado, unido (apesar dos pesares) e eficiente do mundo. Vocês são especiais demais. Agradeço a cada um pela ajuda, risadas e implicâncias do dia a dia. Amo vocês!

A Tonho pescador, por desde pequena me levar pra passear no mar e por me ajudar nas idas de campo.

A minhas amigas da natureza Nica, Mari e Bel. Pelos momentos de alegria compartilhados e por todo amor que sempre me deram. Pelos ensinamentos da biologia, tanto na terra quanto no mar.

A minhas amigas do colégio, "trio parada dura", Deborah e Raisa. Por tudo que vivemos juntas, por tantos momentos de risadas. Vocês sempre estarão no meu coração.

Ao mar de Tamandaré. Por ser tão azul, calmo e lindo. Com destaque para as *Milleporas* e os peixinhos.

Em especial, a Luiz. Meu companheiro de todos os momentos. Obrigado por todos os incentivos e confiança que você deposita em mim a cada dia. Aprendo muito ao teu lado.

A natureza, em especial ao mar onde pude descobrir outro mundo, cheio de vida, amor e paz.

E por último, porém não menos importante, eu agradeço a Deus. Primeiramente pela vida e por ter colocado a biologia no meu caminho.

Sumário

Introdução Geral 11

Capítulo 1 15

Effects of coral colony size and competition by *Stegastes fuscus* on the reef fish community associated with the fire-coral *Millepora alcicornis.*

Capítulo 2 42

Remote video *versus* diver observation analysing reef fish community in association with *Millepora alcicornis* coral colonies.

Considerações finais 59

Referências Gerais 61

Lista de Tabelas

Capítulo 1

Table 1: List of the fish species and respective families that associated with *Millepora alcicornis* colonies and corresponding trophic guilds, decreasing in order of the total number of individuals and relative frequencies of occurrence. TERH = Territorial herbivores; OMN = Omnivores; ROVH = Roving herbivores; MIF = Mobile invertebrate feeders; CARN = Carnivores and SIF = Sessile invertebrate feeders 23

Table 2: List of the fish species and respective families that *Stegastes fuscus* performed agonistic behavior, classified in decreasing order of the total numbers of individuals encountered and percentage of individuals registered as well as corresponding trophic guilds 26

Capítulo 2

Table 1 – Reef fish species and number of individuals recorded in association with *Millepora alcicornis* coral colonies using the two different methods. 49

Table 2 – Review of techniques for reef fish data collection, with advantages and disadvantages according previous researchers and the present study data. 51

Lista de Figuras

Capítulo 1

Fig.1. Map of the study volume, "Ilha do Norte" reef in Tamandaré municipality – Northeast Brazil, indicating the 20 sampled *Millepora alcicnornis* colonies. 20

Fig. 2. Linear regressions between *Millepora alcicornis* coral colony volume (m^2) and the total abundance and richness of associated fishes. 24

Fig. 3. Ontogenetic changes on the behavior patterns (protective posture, sheltered on the base, sheltered coral branches, feeding coral, feeding algae and agonistic) of *Stegastes fuscus* associated with *Millepora alcicornis.* 25

Fig. 4. Electivity (Invlev index) of the proportion of abundance and agonistic interactions performed by *Stegastes fuscus* individuals for the different trophic guilds. 27

Fig. 5. Behaviors patterns of *S. fuscus* **(**protective posture, sheltered on the base, sheltered coral branches, feeding coral, feeding algae and agonistic**)** associated with the size categories: S= small, M=medium, L= large and VL= very large *Millepora alcicornis.* coral colonies. 28

Capítulo 2

Fig.1. Map of the study volume, "Ilha do Norte" reef in Tamandaré municipality – Northeast Brazil, indicating the *Millepora alcicnornis* colonies. 47

Fig.2. Video camera Go Pro Hero 2 fixed in a weight tripod in front of the *Millepora alcicnornis* colonies.

48

Resumo

Hidrocorais ramificados do gênero *Millepora* desempenham importantes papéis ecológicos nos recifes de corais do Atlântico Sul. De acordo com estudos anteriores uma grande proporção de espécies de peixes recifais usam as ramificações das colônias como abrigo, reprodução e / ou fonte de alimento. No entanto, pouca atenção tem sido dada à importância ecológica do coral-de-fogo em relação à ecologia da comunidade de peixes que vivem a eles associados e na competição intra / inter-específica de algumas espécies que ocorrem dentro do coral. O estudo foi divido em dois capítulos, sendo o primeiro com o objetivo de analisar como o volume das colônias de *M. alcicornis* e a competição exercida pelos indivíduos de *Stegastes fuscus* pode afetar a comunidade de peixes associadas ao hidrocoral. O segundo capítulo teve como objetivo comparar a eficiência do uso de diferentes metodologias (censo visual e câmera de vídeo) na observação da abundância e riqueza da comunidade de peixes associadas ao coral-de-fogo *M. alcicornis*. Para análises do primeiro capítulo, o presente estudo analisou a influência do tamanho das colônias do coral (volume - m^3) e a presença competitiva da espécie *Stegastes fuscus* na comunidade de peixes recifais associados às ramificações dos corais-de-fogo. De setembro de 2012 a abril 2013 estudos foram realizados no recife "Ilha do Norte" localizado no litoral de Tamandaré-PE. 20 colônias do corais-de-fogo *M. alcicornis* foram marcadas e medidas, buscando assim relacionar o volume da colônia com abundância e a riqueza das espécies associadas. Os resultados mostraram que a abundância e a riqueza dos peixes foram diretamente correlacionadas com volume colônias. Dentre as espécies associadas, *Stegastes fuscus* foi a mais abundante. Essa espécie mostrou visíveis mudanças de comportamento, quando associadas às colônias, a depender do tamanho do corpo. Por exemplo, indivíduos menores de 6 cm foram vistos com maior frequência abrigando-se e alimentando-se de corais e indivíduos maiores de 6 cm realizando interações agonísticas, alimentando-se de algas e nadando ao redor do coral. Herbívoros errantes, onívoros e comedores de invertebrados sésseis foram as guildas tróficas que os indivíduos de *S. fuscus* preferiram manter interações agonísticas, provavelmente devido à sobreposição alimentar. Colônias muito grandes mostraram ser importantes locais de abrigo para os indivíduos de *S. fuscus* de menores que 6 cm. O comportamento agonístico foi mais frequente em colônias categorizadas como muito grandes. Os demais padrões também variaram a depender do volume da colônia. O presente estudo forneceu a primeira evidência de que através da competição, a presença *S.fuscus* pode afetar na comunidade de peixes associadas com as colônias de *M. alcicornis*. Os resultados também indicam que os indivíduos de *S. fuscus* usam as colônias de corais-de-fogo como parte de seu território, abrigo e recurso alimentar. Para análises do segundo capítulo, observações foram realizadas a partir de setembro de 2012 a abril de 2013, também no recife "Ilha do Norte". Nove colônias de *M. alcicornis* de diferentes tamanhos foram escolhidas para análise e os dois tipos de metodologias (censo visual e câmera de vídeo) foram utilizadas. Três réplicas de cada método de análise foram utilizadas em cada colônia estudada. A fim de evitar possíveis erros metodológicos, os dois tipos de metodologias foram realizadas sob as mesmas condições de maré, hora do dia e época do ano. A riqueza e abundância dos peixes recifais associados às colônias do coral-de-fogo foram analisadas tanto pelo censo visual quanto pelo uso de câmera de vídeo. Os resultados indicam que ambas as metodologias registraram números semelhantes de abundância e riqueza de espécies em cada colônia, não havendo assim diferença significativa a depender do método utilizado. Contudo, pequenas diferenças relacionadas com a capacidade do uso de cada método foram observadas. Pode-se afirmar que os dois tipos de metodologias utilizadas foram eficazes na observação dos peixes associados às colônias de *M. alcicornis*.

Palavras chaves: Estrutura de habitat; Associação peixe e coral; Pomacentridae; Brasil

Abstract

Branching hydrocorals from the genus *Millepora* play important ecological roles in South Atlantic reefs, where branching scleractinians are absent. According to previous studies, a high proportion of reef fish species use branching fire-coral colonies as shelter, breeding and/or feeding sites. Nevertheless, little attention has been given to the ecological importance of branching fire-corals in regards to determinants of fish association and intra/interspecific competition. The study was divided into two chapters, the first being with the aim of examining how the volume of colonies of *M. alcicornis* and the competition performed by the individuals *Stegastes fuscus* can affect the fish community associated with hydrocoral. The second chapter aimed to compare the efficiency of using different methodologies (visual census and video camera) on the observation of abundance and richness of the fish community associated with the fire coral *M alcicornis*. The first chapter analyzed the influence of coral colony size (colonies volume - m^3) and presence of a high-competitive and extremely aggressive damselfish (Brazilian endemic *Stegastes fuscus*) on the reef fish community associated with branching fire-corals *M. alcicornis*. From September 2012 to April 2013 surveys were conducted on tagged fire-coral colonies at Tamandaré Reefs, Northeast Brazil. The abundance and richness of coral-associated fish was directly correlated with *M. alcicornis* coral colonies volume. *S. fuscus* was the most abundant species associated with colonies showing noticeable behavioral ontogenetic shifts according to body size (*e.g.* individuals smaller than 6 cm sheltering and feeding on corals and individuals larger than 6 cm performing agonistic interactions, feeding on algae and swimming around the coral). Roving herbivores, omnivores and sessile invertebrate feeders were the trophic guilds that suffered the most with agonistic interactions, probably due food overlap. Very large colonies show to be important places of refuge for individuals of *S. fuscus* smaller than 6 cm. The agonistic behaviors were more frequent in proportion to the volume of the colonies increased. The other behavior patterns also showed variation depending on the volume of the colony. The present study provided the first evidence that through competition, *S.fuscus* presence may affect reef fish associated with *M. alcicornis*. The results also indicate that *S. fuscus* individuals use *M. alcicornis* coral colonies as part of their territory for shelter and foraging. For analysis of the second chapter, the richness and abundance of associated reef fishes presented non-significant difference depending on the used methodology. The present study represented the first one investigating the use of different methodologies and their influence in the abundance and richness species associated with coral colonies.

Key-words: Habitat structure, Coral-fish association, Pomacentridae, Brasil

Introdução Geral

O gênero *Millepora* (Família Milleporidae, Classe Hydrozoa, Filo Cnidaria), é considerado o segundo mais importante formador de recifes, (Lewis, 2006) e produz colônias em recifes de corais rasos por todo o mundo (Boschma, 1948; Weerdt, 1984). Possui distribuição circumtropical, com até 17 espécies reconhecidas. Oito no Oceano Índico, nove no Oceano Pacífico e seis no Oceano Atlântico (Cairns et al. 1999). No Brasil, espécies de corais do gênero *Millepora* podem ser facilmente encontradas em recifes de corais, rochas e outros habitats semelhantes. Este gênero é um componente importante nos recifes brasileiros e muitas vezes ocorrem em colônias extensas com até dois metros de diâmetro, especialmente na região nordeste (Amaral et al. 2008). Suas ramificações podem alcançar entre 30 a 60 cm de altura (Lewis, 1969) e possuem geralmente coloração amarela ou marrom (Edmunds, 1998). Quatro espécies do gênero *Millepora* foram identificadas ao longo da costa brasileira até o presente momento: *Millepora alcicornis* (Linnaeus 1758), *M. brasiliensis* (Verrill 1868), *M. nitida* (Verrill 1868) e *M. laboreli* (Amaral *et al.*. 2008), sendo a primeira espécie a mais abundante(Amaral et al.. 2008).

Espécimes do gênero *Millepora* possuem pólipos numerosos e altamente tóxicos e, por este motivo, são muitas vezes chamados ''corais urticantes'' ou ''corais de fogo'' (Hyman, 1940; Boschma, 1948). A toxicidade destes pólipos é usada principalmente para captura de presas e defesa contra predadores. Colônias de *Millepora s*pp. formam complexos sistemas físicos e biológicos, que possibilitam mutualismo e refúgios contra predadores, aumentando a produtividade e, consequentemente, a diversidade das espécies (Oliveira et al.. 2008). As pequenas falhas, fendas e os buracos localizados dentro das colônias providenciam abrigo para recrutas de invertebrados e peixes recifais, que eventualmente utilizam dessas áreas para escapar de predadores maiores que não conseguem ter acesso a este microambiente (Leão & Dominguez, 2000). Relações positivas entre a complexidade estrutural do coral e abundância dos peixes sugerem que a complexidade é um fator chave para estruturação da assembleia de peixes (Hixon & Beets, 1993, Graham & Nash, 2012).

Além da complexidade estrutural desses hidrozoários, o tamanho da colônia é outra variável importante e determinante na qualidade do habitat. Em geral, a abundância e riqueza de espécies de peixes variam de acordo com tamanho da colônia do coral

(Lomolino, 2001 Holbrook et al. 2002a , 2002b , Schiemer et al. 2009). Colônias maiores são muitas vezes um recurso preferencial para peixes de recife possivelmente devido a maior quantidade de espaço entre as ramificações (Hobbs & Munday , 2004).

Além da estrutura física do ambiente recifal, a distribuição dos peixes recifais também podem ser influenciada por processos de concorrência (Almany, 2003, Munday et al. 2001 , Geange et al. 2013) e também por meio de interações predador-presa (Eklöv & Diehl, 1994, Almany, 2004). Peixes da espécie *Stegastes fuscus s*ão frequentemente encontrados em grande abundância associados com as colônias do coral-de-fogo *Millepora* spp. Estes indivíduos usam as colônias como parte de seu território e fonte de alimento. (Coni et al. 2012, Pereira et al. 2012, Leal et al. 2013). O gênero *Stegastes* é conhecido por formar territórios relativamente pequenos e por serem altamente agressivos contra membros da mesma espécie, por exemplo, os herbívoros que invadem seus territórios (Robertson et al. 1976 , Johnson et al. 2011, Souza et al. 2011, Leal et al. 2013). Além do território, indivíduos desse gênero foram registrados mordendo os pólipos de corais, matando o tecido vivo dos mesmos e com isso favorecendo o crescimento de alga (Ceccarelli et al. 2001, Potts, 1977). Outra hipótese pressupõe que os peixes associados podem aumentar o crescimento coral pelo aporte de nutrientes (Holbrook et al. 2008) e também por remoção de algas tóxicas (Dixson & Hay 2012).

Para realizar um estudo de identificação, quantificação e comportamento da ictiofauna alguns tipos de metodologias são conhecidas e utilizadas pelos pesquisadores. A técnica conhecida como censo visual é o método mais popular para o estudo da distribuição de peixes tropicais e estudos ecológicos, e foi usada pela primeira vez por Brock (1954). Censos visuais subaquáticos são comumente usados para estimar a densidade populacional e diversidade de peixes de recife de coral (Edgar et al. 2004;. Kulbicki et al. 2007; Samoilys & Carlos, 2000) Essa técnica tem a vantagem de permitir fácil identificação de espécies crípticas e a possibilidade de observar o comportamento dos peixes. Além disso, é considerado, um método não destrutivo (Bonhnsack & Bannerot, 1986). Esta metodologia possui algumas desvantagens quando, por exemplo, a presença do mergulhador afasta ou aproxima algumas espécies de peixes, resultando em estimativas equivocadas de abundância das espécies estudadas (Watson et al. 2010). Outras técnicas de observação também são utilizadas, isoladamente ou complementar à técnica de censo visual; é o caso do uso de câmeras de vídeo (Dunlap & Pawlik 1996;

Bellwood & Fulton 2008; Burkepile & Hay 2011). Para muitos autores as principais vantagens dos métodos de vídeo é a possibilidade de observar as imagens quantas vezes forem necessárias. A câmera também pode também registrar espécies que se sintam intimidadas quando na presença do mergulhador (Willis e Babcock 2000; Willis et al. 2000).

O objetivo geral do presente estudo foi analisar como o volume das colônias de *Millepora alcicornis* e a presença competitiva da espécie *Stegastes fuscus* podem influenciar na comunidade de peixes associada ao coral-de-fogo. Além disso, buscou-se testar a eficiência de dois diferentes tipos de metodologias (câmera de vídeo e censo visual) no registro da abundância e riqueza das espécies associadas às colônias de *M. alcicornis*.

Hipóteses a serem testadas foram: 1)O volume da colônia influência na abundância e riqueza das espécies. 2)A presença competitiva da espécie *S. fuscus* dentro das colônias de *M. alcicornis* afastam algumas espécies e as impedem de manterem associação com o hidrocoral. 3)A observação da riqueza e abundância das espécies de peixes associadas às colônias de *M. alcicornis* diferem a depender do tipo de metodologia utilizada.

Capítulo 1

Coral colony size and competitive behavior of *Stegastes fuscus* affects the reef fish community associated with *Millepora alcicornis*

Isabela Carolina Silva Leal

Departamento de Oceanografia, CTG, Universidade Federal de Pernambuco (UFPE)

Av. Arquitetura, s/n, Cidade Universitária, Recife, PE, 50670-901, Brazil.

Autor Correspondente - Isabela Carolina Silva Leal

Departamento de Oceanografia, CTG, Universidade Federal de Pernambuco (UFPE)

Av. Arquitetura, s/n, Cidade Universitária, Recife, PE, 50670-901, Brazil.

Telefone: (081) 2126-7221

E-mail: leal.ics@gmail.com

Abstract

Branching hydrocorals from the genus *Millepora* play important ecological roles in South Atlantic reefs, where branching scleractinians are absent. According to previous studies, a high proportion of reef fish species use branching fire coral colonies as shelter, breeding, and feeding sites. Nevertheless, the ecological importance of branching fire corals in determining the fish that associate with the corals and their intra- or interspecific competition has received little attention. The present study examined the influence of a coral colony's volume and the presence of a highly competitive and aggressive damselfish (Brazilian endemic *Stegastes fuscus*) on the reef fish community associated with the branching fire corals *Millepora alcicornis*. Tagged fire coral colonies at Tamandaré Reefs in Northeast Brazil were surveyed from September 2012 to April 2013. The abundance and richness of coral-associated fish were directly correlated with *M. alcicornis* coral colony volume. *S. fuscus* was the most abundant species associated with the colonies and showed noticeable behavioral ontogenetic shifts according to their body size (e.g., individuals smaller than 6 cm sheltering and feeding on corals vs. individuals larger than 6 cm performing agonistic interactions, feeding on algae, and swimming around the coral). Roving herbivores, omnivores, and sessile invertebrate feeders were the trophic guilds that suffered the most with agonistic interactions, which was probably due to overlapping food sources. Very large colonies were important places of refuge for individuals of *S. fuscus* that were smaller than 6 cm. The agonistic behaviors became more frequent as the volume of the colonies increased. Other behavior patterns also varied with the colony volume. The present study provides the first evidence that through competition, the presence of *S. fuscus* may affect the reef fish associated with *M. alcicornis*. The findings also indicate that *S. fuscus* use *M. alcicornis* coral colonies as part of their territory for shelter and foraging.

Key-words: Habitat structure, Coral-fish association, Pomacentridae, South Atlantic reefs.

Introduction

Habitat structure complexity has critical relevance in marine ecosystems such as seagrass beds, mangroves, kelp forests, and coral reefs (Syms & Jones 2000; MacNeil et al. 2009). Coral reefs are an example of structurally complex habitats that play key roles in the life cycles of many associated species, including crustaceans (Brown & Edmunds 2013) and fish (Johnson et al. 2011, Graham & Nash 2012). With their complex structure of holes and open volumes, branching corals (e.g., *Acropora* spp. and *Millepora* spp.) host a great diversity of organisms and provide suitable volumes for shelter, feeding, and reproduction (Holbrook et al. 2002a, 2002b, Brooks et al. 2007, Coni et al. 2012, Leal et al. 2013).

Variables including the abundance, diversity, settlement patterns, predation rates, and competitive interactions among fish seem to be connected to the habitat complexity (Garpe et al. 2006, Grober-Dunsmore et al. 2007, Cabaitan et al. 2008). Positive relationships between coral complexity and fish abundance suggest that coral complexity is a key factor for structuring fish communities (Hixon & Beets 1993, Graham & Nash 2012). Coral colony size and volume are other important variables that determine a habitat's quality, which generally varies with fish abundance and species richness (Lomolino 2001, Holbrook et al. 2002a, 2002b, Schiemer et al. 2009). Larger colonies are often a preferred resource for reef fish because of the space between their branches (Hobbs & Munday 2004) that allow the presence of larger species and provide superior shelter volumes (Eggleston et al. 1997). The available shelter that branching corals provide, as well as other physical attributes (e.g., surface volume), are strong predictors of fish growth, survival, and reproductive outcomes (Jones 1988, Holbrook et al. 2000, 2002a; Brooker et al. 2013). Coni et al. (2012) first suggested that fire coral colonies from the genus *Millepora* spp. could affect fish abundance and species richness in the Abrolhos Bank coral reefs (East Brazil).

The distribution of reef fish also can be influenced by competition (Sale 1977, Almany 2003, Munday et al. 2001, Geange et al. 2013) and predator-prey interactions (Eklöv & Diehl 1994, Almany 2004). *Stegastes fuscus, a* Brazilian endemic damselfish, forms relatively small territories and is highly aggressive against conspecifics and other fish species, especially when they are herbivores and invade their territories

(Robertson et al. 1976, Johnson et al. 2011, Souza et al. 2011, Leal et al. 2013). According to Shulman, (1984) the aggressive behavior of territorial *Stegastes* spp. in the Caribbean can reduce the recruitment of other fish families, such as Acanthuridae and Chaetodontida. The genus *Stegastes* is often found in high abundance with *Acropora* spp. coral colonies and defending filamentous algae turfs on their territories (Mahoney 1981, Robertson 1984, Hata & Kato 2004, Precht et al. 2010). On Brazilian coral reefs, *S. fuscus* is found in high abundance with hydrocoral colonies of the genus *Millepora* (Coni et al. 2012, Leal et al. 2013), which may create competition for food and territorial resources (Leal et al. 2013). Furthermore, Pereira et al. (2012) suggested that juveniles of *S. fuscus* could establish feeding relationships with *Millepora* spp. coral colonies, with feeding rates up to 1.35 ± 0.93 bites/min.

Hydrocorals from the genus *Millepora* are found in coastal reefs worldwide and are considered the second most important reef builders, behind only the scleractinian corals (Boschma 1948; Lewis 1989). The fire coral *Millepora* spp. of the Southwestern Atlantic reefs are the only species with conspicuous branching forms. *Millepora alcicornis* and *Millepora braziliensis*, which form colonies that can be more than 2 m in diameter, are considered the most abundant species along the Brazilian coast. The habitat of these hydrozoans in Brazilian reefs is comparable to those of the *Acropora palmata* and *Acropora cervicornis* species in the Caribbean (Coni et al. 2012, Leal et al. 2013). *Millepora* spp. is an important resource for associated organisms (Lewis 1989, 2006, Coni et al. 2012, Leal et al. 2013, Brown & Edmunds 2013). For example, a wide variety of fish and invertebrates use them as food or shelter (Lewis 1989, 2006, Garcia et al. 2008, Pereira et al. 2012, Coni et al. 2012, Leal et al. 2013).

The present study examined whether the coral colony size or competition with aggressive damselfish *S. fuscus* in a reef fish community were associated with the fire coral *M. alcicornis*. Therefore, the following aims were investigated: (1) examine whether coral colony volume of *M. alcicornis* influences species abundance or richness; (2) analyze ontogenetic changes in *S. fuscus* behavior patterns associated with *M. alcicornis;* (3) examine agonistic interactions between *S. fuscus* and other trophic guilds associated with the fire coral *M. alcicornis*; and (4) investigate whether the volume of a *M. alcicornis* colony affects *S. fuscus* size distribution or behavior.

Materials and methods

Study area

This study was conducted in the coastal reefs located in the municipality of Tamandaré (88°44'54''S and 35°86'14''W). Tamandaré is located 110 km from Recife, the capital of Pernambuco State, and has a climate that includes 2 distinct seasons. The rainy season occurs from September to April and has average air and sea temperatures of 20°C and 22°C, respectively. The dry season occurs from August to April and has average air and sea temperatures of 28°C and 27°C, respectively. The reef complex examined in the present study is located within the "Area de Preservação Ambiental Costa dos Corais" (Coral Coast MPA), which includes over 135 km of coastline from Tamandaré in the southern state of Pernambuco, to Paripueira in the northern state of Alagoas. The coordinates for this region are within the limits of the 8^{th} 42'16"S and 35°04'40"W; 8^{th} 47'44"S and 34°47'20"W; 9^{th} 46'30"S and 35°25'00"W; and 9^{th} 32'51"S and 35°36'59"W.

This study focused on the "Ilha do Norte" reef (Fig. 1), which is located 300 to 600 m from the shoreline and has an average depth of 0.5 m. The reef is covered by macroalgae species, hermatypic corals (*Favia gravida*, *Montastrea cavernosa*, *Mussismilia* spp., and *Porites astreoides*) (Lamarck, 1816), and the hydrocoral colonies *M. alcicornis* and *M. braziliensis*, (Ferreira & Maida, 2006) with *M. alcicornis* being the most abundant.

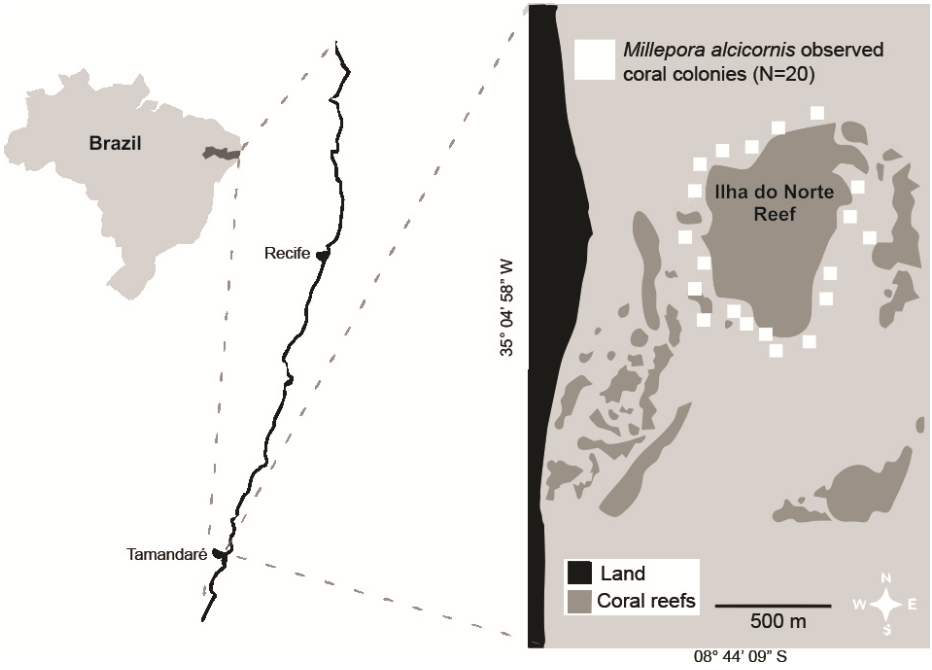

Fig. 1. Map of the study area, "Ilha do Norte" reef in Tamandaré municipality, Northeast Brazil, indicating the 20 sampled *M. alcicornis* colonies.

Underwater census and behavioral observations

Underwater observations were conducted between September 2012 and April 2013, which was during the dry season and at low tide. Using snorkeling to conduct the underwater observations, the investigators collected data amounting to a total of 40 hours of direct observation. A total of 20 *M. alcicornis* colonies were selected, tagged, and measured (diameter and height); their volumes (m^3) were calculated using the formula for a cylinder (base area × colony height) (Holbrook et al. 2000; Coni et al. 2012). The base area was calculated from the average diameter of the colony. The colony height was measured from where the colony attached to the substratum of its highest branch.

To evaluate the influence of coral colony size on fish richness and abundance, the numbers of fish in each colony were counted at each sampling date. To detect ontogenetic changes in behavior according to body size, individuals of *S. fuscus* were classified as having a total length (TL) that was either less than or greater than 6.0 cm.

S. fuscus behavior associated with the coral colonies were observed with focal animal sampling (Altmann 1974). Direct behavioral observation of individuals was

standardized to 5 min, and *S. fuscus* colony behaviors were categorized with 6 behavioral categories. These 6 categories were as follows: *feeding on corals*, individuals bit the polyps of *M. alcicornis* colonies; *feeding on algae*, individuals ate algae present on *M. alcicornis*; *agonistic,* individuals maintained aggressive behavior against other fish that approached or roved close to *M. alcicornis* colonies; *protective posturing*, individuals swam around the colonies with a protective posture and maintained a maximum distance of 20 cm from the hydrocoral; *sheltered on the coral branches*, individuals sheltered in the crevices and hollows of the coral; *sheltered on the base*, individuals sheltered in the coral base. Behaviors matching any of these categories were recorded throughout the 5-min observation period.

Instances in which *S. fuscus* individuals behaved aggressively against fish that swam close to *M. alcicornis* colonies were counted to determine the agonistic interactions between *S. fuscus* and the trophic guilds associated with the coral. Individuals showing these aggressive behaviors were classified according to their trophic categories (Ferreira et al. 2004): mobile invertebrate feeders, sessile invertebrate feeders, omnivores, territorial herbivores, roving herbivores carnivores, and planktivore.

To investigate whether the volume of an *M. alcicornis* colony affected the distribution of *S. fuscus* sizes or behaviors, the colonies were categorized as small (S), medium (M), large (L), or very large (VL). The number of *S. fuscus* in each colony volume matching each size class and behavioral category was counted.

Data analysis

Linear regression analyses were performed to determine whether *M. alcicornis* volumes and the presence of *S. fuscus* competitors affected the abundance and richness of the associated species. A chi-square test was performed to investigate ontogenetic changes in *S. fuscus* behavior and to compare the number of individuals performing each behavior between the 2 size classes (TL = < or > 6 cm). Ivlev's index of electivity (Ivlev 1961) was calculated to examine agonistic interactions between *S. fuscus* and the trophic guilds associated with the coral. The index was calculated with the following equation:

$$E_i = \frac{r_i - p_i}{r_i + p_i}$$

where electivity for the trophic guild *i*(E_i) was considered the percentage of the trophic guild *i* associated with fire coral colonies (r_i) and the percentage of agonistic interactions performed against the trophic guild *i*(p_i). The *E* values vary from −1.0 to +1.0, with positive values indicating a preference and negative values indicating avoidance; values equal to 0 indicated no agonistic interactions.

Chi-square tests also were performed to determine whether the categories of *M. alcicornis* colony volume affected the *S. fuscus* size distribution. The same approach was used to compare behavioral differences among the volume categories.

Results

A total of 1051 reef fish from 24 species were associated with the *M. alcicornis* coral colonies (Table 1). Among them, *S. fuscus* was the most abundant species, representing 56.8% of the total community (n = 598). The most represented family was Pomacentridae, which represented 64% of the fish community.

Table 1: List of fish species and their respective families associated with *Millepora alcicornis* colonies and corresponding trophic guilds, listed in decreasing order of the total number of individuals and relative frequency of occurrence. TERH = territorial herbivores; OMN = omnivores; ROVH = roving herbivores; MIF = mobile invertebrate feeders; SIF = sessile invertebrate feeders; CARN = carnivores; PLANK = planktivore.

Family	Species	Trophic Guilds	Individuals (N)	Rel. Freq. Occur. (%)
Pomacentridae	*Stegastes fuscus* (Curvier, 1830)	TERH	598	56.8
Holocentridae	*Holocentrus adscensionis* (Osbeck, 1765)	MIF	111	10.5
Pomacentridae	*Abudefduf saxatilis* (Linnaeus, 1758)	OMN	73	6.9
Epinephilidae	*Ephinephelus adscensionis* (Osbeck, 1765)	CARN	46	4.3
Acanthuridae	*Acanthurus coeruleus* Bloch & Schneider, 1801	ROVH	42	4
Holocentridae	*Myripristis jacobus* Curvier, 1829	PLANK	34	3.2
Labrisomidae	*Labrisomus nuchipinnis* (Quoy & Gaimard, 1824)	CARN	31	3
Epinephelidae	*Cephalopholis fulva* (Linnaeus, 1758)	CARN	21	2
Labridae	*Sparisoma axillare* (Steindachner, 1878)	ROVH	17	1.6
Blenniidae	*Ophioblenius trinitatis* (Miranda Ribeiro, 1919)	TERH	15	1.4
Scianidae	*Pareques acuminatus* (Bloch & Schneider, 1801)	MIF	10	0.9
Chaetodontidae	*Chaetodon striatus* Linnaeus, 1758	SIF	9	0.8
Haemulidae	*Anisotremus virginicus* (Linnaeus, 1758)	MIF	8	0.7
Labridae	*Scarus zelindae* Moura, Figueiredo & Sazima, 2001	ROVH	8	0.7
Haemulidae	*Haemulon squamipinna* (Desmarest, 1823)	MIF	7	0.6
Labridae	*Halichoeres brasiliensis* (Bloch, 1791)	MIF	6	0.5
Lutjanidae	*Lutjanus spp.* (Bloch, 1787)	CARN	3	0.2
Pomacentridae	*Chromis multilineata* (Guichenot, 1853)	PLANK	3	0.2
Labrisomidae	*Labrisomus kalisherae* (Jordan, 1904)	CARN	3	0.2
Lutjanidae	*Ocyurus chysurus* (Bloch, 1791)	CARN	2	0.2
Labridae	*Halichoeres poyei* (Steindachner, 1867)	ROVH	1	0.09
Pomacentridae	*Microspathodon chrysurus* (Curvier, 1830)	TERH	1	0.09
Monacanthidae	*Aluterus scriptus* (Osbeck, 1765)	OMN	1	0.09
Muraenidae	*Muraena pavonina* Richardson, 1845	CAR	1	0.09

Each category of coral colony volume showed large variability in richness and abundance (Fig. 2a,b), except for those smaller than 1.4 m^3. When only colonies with volumes greater than 1.4 m^3 were included in the analysis, the volume of *M. alcicornis* could partially explain the variability ($r^2 = 0.49$; $p < 0.05$) in richness ($r^2 = 0.49$; $p < 0.05$) and abundance ($r^2 = 0.63$; $p < 0.05$).

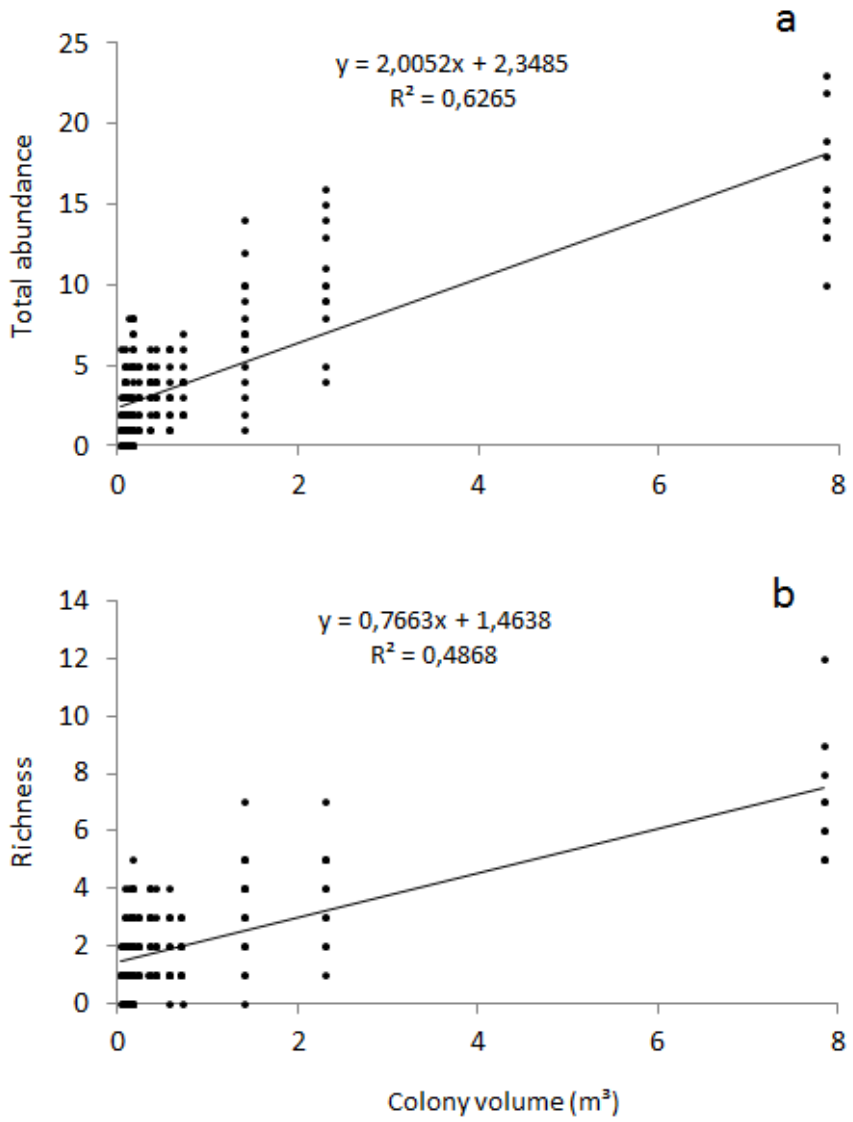

Fig. 2. Linear regression between *M. alcicornis* coral colony volume (m^2) and the total abundance (a) and richness (b) of associated fish.

S. fuscus associated with *M. alcicornis* colonies presented evident ontogenetic changes in behavior, (Fig. 3). Smaller fish (<6.0 cm) mainly showed 2 behaviors: sheltering on coral branches (55%) and feeding on corals (23%). Larger fish (>6.0 cm) showed greater equitability among the behavioral categories, with the most frequent behaviors being protective posturing (29%), agonistic (26%), and feeding on algae (24%). The most common behaviors demonstrated by smaller fish were rarely demonstrated by larger fish.

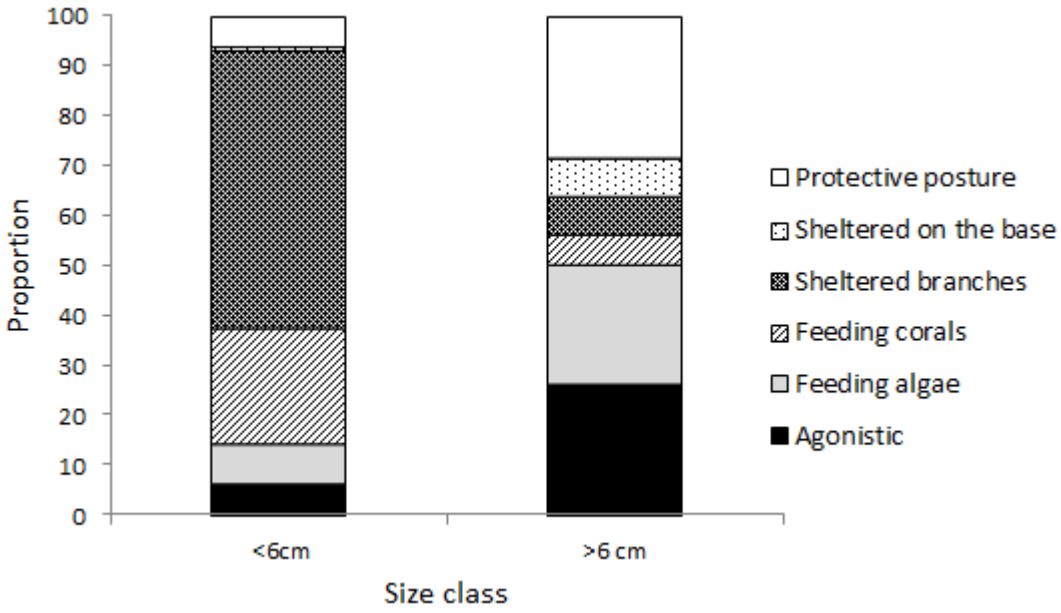

Fig. 3. Ontogenetic changes in the behavior (swimming around the coral colonies, sheltered on the base, sheltered coral branches, feeding coral, feeding algae, and agonistic) demonstrated by individuals of *Stegastes fuscus* < 6 cm and > 6 cm that were associated with *M. alcicornis.*

S. fuscus performed 111 agonistic interactions against 13 other reef fish species, including intraspecific agonistic interactions. Of these, the territorial herbivores (mainly *S. fuscus*) were the dominant trophic guild (Table 2).

Table 2: List of fish species and their respective families that *Stegastes fuscus* targeted with agonistic behavior, listed in decreasing order of the total number of individuals encountered, the percentage of individuals registered, and the corresponding trophic guilds.

Species	Family	Individuals (N)	Percentage (%)	Trophic Guilds
Stegastes fuscus	Pomacentridae	33	30	Territorial herbivores
Abudefduf saxatilis	Pomacentridae	29	26	Omnivores
Acanthurus coeruleus	Acanthuridae	18	16	Roving Herbivores
Halichoeres brasiliensis	Labridae	10	9	Mobile Invertebrate Feeders
Scarus zelindae	Labridae	6	5	Roving Herbivores
Sparisoma axillare	Labridae	4	4	Roving Herbivores
Lutjanus spp.	Lutjanidae	3	3	Carnivores
Chaetodon striatus	Chaetodontidae	2	2	Sessile Invertebrate Feeders
Holocentrus adscensionis	Holocentridae	1	0.9	Mobile Invertebrate Feeders
Microspathodon chrysurus	Pomacentridae	1	0.9	Territorial herbivores
Aluterus scriptus	Monacanthidae	1	0.9	Omnivores
Ophioblennius trinitatis	Blenniidae	1	0.9	Territorial herbivores
Myripristis jacobus	Holocentridae	1	0.9	Planktivore
Chromis multilineata	Pomacentridae	1	0.9	Planktivore

The absolute abundance of interactions with this guild was expected once it was the most frequently observed on the coral colonies (Table 1). Nevertheless, based on the electivity Ivlev's index (Fig. 4), the trophic guilds positively selected by *S. fuscus* for agonistic interactions, as compared to their total abundance, were roving herbivores (0.59), omnivores (0.58), and sessile invertebrate feeders (0.35). In contrast, other trophic guilds, such as carnivores (−0.58), territorial herbivores (−0.30), planktivore (−0.34), and mobile invertebrates feeders (−0.11), were negatively selected and received a proportionally low number of agonistic interactions, as compared to their total abundance (Fig. 4).

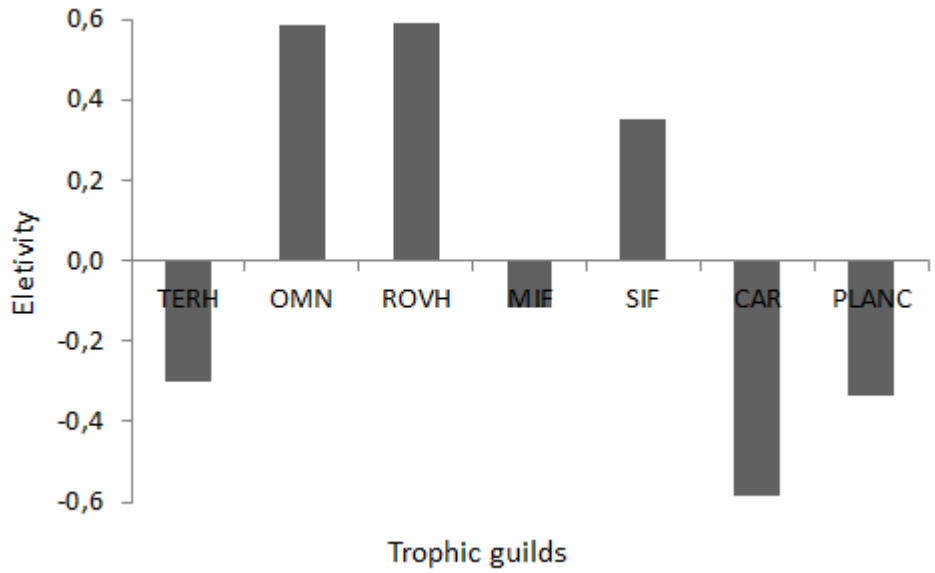

Fig. 4. Electivity (Invlev index) of abundance and agonistic interactions demonstrated by *S. fuscus* individuals for different trophic guilds.

The volume of an *M. alcicornis* colony affected the distribution *S. fuscus* sizes, particularly in a VL colony. The proportion of juveniles (<6 cm) was very similar among colonies with small, medium, and large volumes (21–27%). However, VL colonies included juveniles in 45% of their total distribution. The number of juveniles and adults in this colony volume were significantly different from those of the other colonies ($p < 0.0001$).

The volume of *M. alcicornis* colonies also affected the behavioral patterns of S. *fuscus* ($p < 0.001$). There was a clear tendency of increased agonistic behavior with an increase in colony size (Fig. 5). Agonistic behavior represented 9% of all behaviors in S colonies and 46% in VL colony. Coral feeding showed a similar tendency, whereas this tendency was reversed for protective posturing, which decreased from 43% in the S colonies to 8% in the VL colony. A similar tendency was again observed for algae feeding.

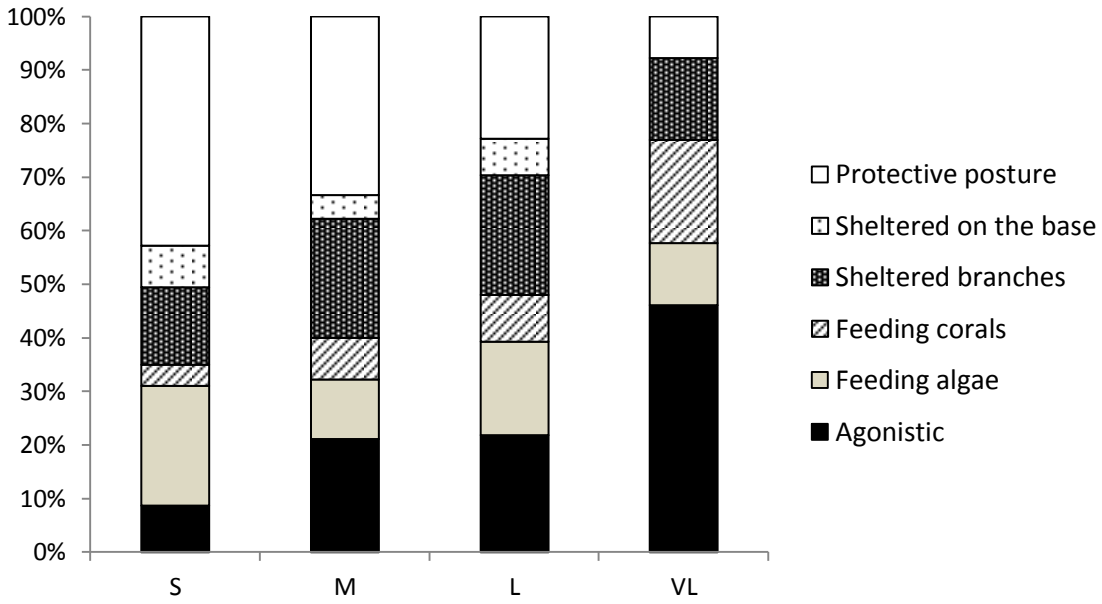

Fig. 5. Behavior patterns of *Stegastes fuscus* (protective posture, sheltered base, sheltered coral branches, feeding coral, feeding algae and agonistic) associated with coral colony size category (S = small, M = medium, L = large, and VL = very large) for *M. alcicornis*.

Discussion

The complex structure of branching corals such as *Millepora* spp. and *Acropora* spp. positively affect the distribution and abundance of reef fishes (Holbrook et al. 2000, Coni et al. 2012, Leal et al. 2013). In general, the richness and abundance of a fish species varied according to a colony's size and structural complexity (Lomolino 2001, Holbrook et al. 2002a, 2002b). In the present study, *M. alcicornis* coral colony volume positively affected the abundance and species richness of the associated reef fish, demonstrating that as the colony size increased, the abundance and richness of fish associated with the fire coral also increased. The colony volume was an important variable for determining which fish were associated with a given colony, but not the only variable. Environmental variables such as currents, turbidity, moon period, and time of year may also influence the abundance and diversity of species associated with a colony. *M. alcicornis* colony volumes between 0.03 and 0.71 m^3 did not correlate with the abundance and richness of species. Because of their small size, these colonies may have little structural complexity and therefore offer little shelter.

According to Coni et al. (2012), the volume of *Millepora* spp. colonies affected both the richness and abundance of fish species associated with Abrolhos Bank in

Northeast Brazil. A relationship between colony volume and species richness was expected, as the species-area relationship is one of the most general patterns in ecology (Lomolino 2000). The positive relationship between the abundance and richness of a fish species and the size of a coral colony was examined in previous studies (Holbrook et al. 2000, 2002a). Better resources normally affect the fitness (e.g., growth and survival rates) of associated species; therefore, superior competitors will first colonize these resources (Munday 2001). In the present study, the larger *M. alcicornis* coral colonies were more often inhabited by *S. fuscus.* It is important to point out that individuals of *S. fuscus* are recognized as superior competitors because of their high aggressiveness in Brazilian coral reefs (Osorio et al. 2006, Francini-filho et al. 2009).

S. fuscus represented more than half of all reef fish species sampled in the coral colonies (56.3%), which indicates a strong association between this species and the fire coral. The Brazilian endemic damselfish was also the most abundant species associated with *Millepora* spp. colonies in another reef complex and accounted for 43% of all fire coral colonies sampled (Coni et al. 2012). Johnson et al. (2011) observed the same relationship in the Caribbean between *Acropora pulchra* and the genus *Stegastes*; *Stegastes planifrons* prefer habitats with colonies of the branching coral *Acropora cervicornis* (Precht et al. 2010).

Different behavioral categories were demonstrated by *S. fuscus* associated with *M. alcicornis* coral colonies. The observed ontogenetic behavioral changes highlighted the ontogenetic changes in how a species uses the hydrocoral habitat. Individuals less than 6 cm in length were observed more frequently among coral branches and feeding on corals. Their smaller body size may be advantageous because it allows access to better resources (e.g., branching colonies of *M. alcicornis*), which are not easily accessed by larger predators. Souza et al. (2011) reported that juveniles of *Stegastes rocasensis* were often associated with *Millepora* spp colonies. Juveniles of *S. fuscus* likely spend more time sheltering from predators in protected locations (Menegatti et al. 2003). Individuals of *S. planifrons* can kill scleractinian corals by biting their living tissue and cultivating algae on their skeleton (Kaufman 1977). In contrast, individuals greater than 6 cm in length were observed in the majority of samples eating algae in the *M*. *alcicornis* structure. Highly territorial species (e.g., *S. fuscus*) offer an increased

growth of algae in their territories (Ceccarelli et al. 2001). This behavior can affect the competitive interaction between algae and corals (Vine 1974, Lobel 1980, Sammarco et al. 1986). Pomacentridae can destroy large volumes of corals and promote algae growth in their place, resulting in reduced growth and living coral cover (Potts 1977, Wellington 1982). However, an alternative hypothesis assumes that associated fish can increase coral growth through nutrient input (Holbrook et al. 2008) and by removing toxic seaweeds (Dixson & Hay 2012). In this context, the ecological role of the Brazilian endemic *S. fuscus* and its consequences for the *M. alcicornis* coral host require further evaluation, mainly with field and laboratory experiments.

Adults of *S. fuscus* often performed protective posturing and showed agonistic interactions. The frequency of agonistic interactions usually increased with the size of the fish (Pereira & Ferreira 2012), as was previously reported for families Labridae (Jones 1984), Lutjanidae (Mueller et al. 1994), Haemulidae (Pereira & Ferreira 2012), and Pomacentridae (Menegatti et al. 2003, Souza et al. 2011). The aggressive behavior of *S. rocasensis* juveniles, another endemic Brazilian *Stegastes* species, was less than that of adults (Souza et al. 2011). Agonistic behaviors can be observed between species that are territorial, nonterritorial, or both (Robertson et al. 1976). These interactions are mainly due to competition for food, but may also occur with competition for space and habitat segregation (Johnson et al. 2011).

A large number of agonistic interactions occurred against potential food competitors, which were mainly roving herbivores, omnivores, and sessile invertebrate feeders. A similar trend was observed by Souza et al. (2011) for *S. rocasensis* between the most affected trophic guilds, herbivores and omnivores. Therefore, in the present study, food competition based on overlapping diets seems to be the main factor affecting reef fish communities associated with *M. alcicornis* coral colonies. Territorial aggression will escalate based on the degree of ecological overlap among the species entering the territory (Ebersole 1977, Harrington & Losey 1990, Draud & Itzkowitz 1995). Individuals of *S. rocasensis* guarding their egg clutches mainly showed agonistic reactions towards planktivores and omnivores, which could potentially prey on their eggs, whereas individuals without egg clutches in their territories showed agonistic interactions mainly towards herbivorous fish (Souza & Ilarri 2013 in press).

VL colonies contained a significant number of *S. fuscus* individuals that were less than 6 cm long, as compared with other colony size categories. These colonies have more space between their branches and can shelter a larger number of small individuals of *S. fuscus*. Larger habitat patches provide more space to find an optimal nesting site and a larger and more complex shelter to hide from predators (Eggleston et al. 1997).

The changes in behaviors demonstrated by individuals of S*. fuscus* were also influenced by the colony volume. There was a direct relationship between agonistic behavior and the volume of *M. alcicornis*. The larger colonies provided a greater amount of space for fish to associate with them. Thus, *S. fuscus* individuals required more time for protecting their territory. Another hypothesis is that *S. fuscus* decrease the frequency of protective posture behavior around larger colonies. Consequently, competitions between *S. fuscus* and other fish can increases because they no longer have complete control over the colonies.

Assuming the hypothesis that space is a limiting resource for coral reef fish is correct (Bonin et al. 2009), fire coral colonies can be considered habitats for superior competitors in Brazilian waters. However, *Millepora* spp. coral colonies are an important source of refuge and shelter for most juveniles (Coni et al. 2012, Leal et al. 2013). In this context, recruitment limitation (Doherty 1983) and predation (Talbot et al. 1978) theories suggest that fish abundance is kept bellow a given limit to reduce competition. However, not all species and life phases are tolerant to different nematocyst types and the powerful venoms contained in the fire coral *Millepora* spp. (Lewis 2006).

The genus *Millepora* is recognized as the only branched coral in the southwest Atlantic Ocean (Lewis 1989). In contrast, it is considered the coral most susceptible to bleaching among a huge diversity of taxa in the Pacific Ocean (Marshall & Baird 2000). The mortality of this hydrocoral can have consequences for the organisms that depend on them, and therefore affect the ecological patterns of reef fish communities.

In the present study, which is the first to focus on the ecological aspects of the fire coral *M. alcicornis,* an increase in coral colony volume favored a greater association (abundance and richness) with reef fish. Moreover, *M. alcicornis* colonies

were mainly inhabited by *S. fuscus,* which showed ontogenetic changes in their behavior that affected how other species used the habitat, especially with food and habitat competition. In this context, the presence of *S. fuscus* on *M*. *alcicornis* coral colonies may also benefit algae growth and influence competition between seaweed and coral. In the present study, which lasted 4 years, the same reef complex showed a clear increase in algae in the fire coral colonies that decreased the live coral cover.

Acknowledgements

The authors would like to thank Ronaldo Franici-Filho and Matthew Jankowski for helping in the manuscript preparation; Conselho Nacional de Desenvolvimento Científico e Tecnológico, Coordenação de Aperfeiçoamento de Pessoal de Nível Superior e Pesquisas Ecológicas de Longa Duração.

Reference List

Altmann J (1974) Observational study of behavior: sampling methods. Behavior 49: 227-265

Almany GR (2003) Priority effects in coral reef fish communities. Ecology 84: 1920-1935.

Almany GR (2004) Does increased habitat complexity reduce predation and competition in coral reef fish assemblage? Oikos 106:275-284

Anderson MJ, Gorley RN, Clarke KR (2008) PERMANOVA + for PRIMER: guide to software and statistical methods. PRIMER-E, Plymouth

Ault TR, Johnson CR (1998) Spatial variation in fish species richness on coral reefs: habitat fragmentation and stochastic structuring processes. Oikos 82:354-364

Bonin MC, Srinivasan M, Almany GR, Jones GP (2009) Interactive effects of interspecific competition and microhabitat on early post-settlement survival in a coral reef fish. Coral reef 28:265-274

Boschma H (1948) The species problem in *Millepora*. Zool Verh (Leiden) 1:3-115

Brooks AJ, Holbrook SJ, Schmitt RJ (2007) Patterns of microhabitat use by fishes in the patch-forming coral *Porites rus.* Raffles Bull Zool 14:245-254

Brown D, Edmunds PJ (2013) The hermit crab Calcinus tibicen lives commensally on *Millepora* spp. in St. John, United States Virgin Islands. Coral Reef 32:127-135

Cabaitan PC, Gomez ED, Aliño PM (2008) Effects of coral transplantation and giant clam restocking on the structure of fish communities on degraded patch reefs. J Exp Mar Biol Ecol 357:85-98

Ceccarelli DM, Jones GP, McCook LJ (2001). Territorial damselfishes as determinants of the structure of benthic communities on coral reefs. Oceanogr Mar Biol Annu Rev 39:355-389

Coni EOC, Ferreira MC, Moura RL, Meirelles PM, Kaufman L, Francini-Filho RB (2012) An evaluation of the use of branching fire-corals (*Millepora* spp.) as refuge by reef fish in the Abrolhos Bank, eastern Brazil. Environ Biol Fish 75:1-12.

De'ath G, Fabricius K (2000) Classification and regression trees: A powerful yet simple technique for ecological data analysis. Ecology 81:3178-3192

De'ath G (2002) Multivariate regression trees: a new technique for modeling species environment relationships. Ecology 83:1105–1117

Dixson DL, Hay ME (2012) Corals Chemically Cue Mutualistic Fishes to Remove Competing Seaweeds. Science 338: 804-807

Doherty PJ (1983) Troplcal territorial damsrlfishes: is density limited by aggression or recruitment?. Ecology 64:176-190

Draud MJ, Itzkowitz M (1995) Interspecific aggression between juveniles of two Caribbean Damselfish species (Genus *Stegastus*). Copeia 431-435

Ebersole JP (1977) Adaptive significance of interspecific territoriality in the reef fish *Eupomacentrus leucostictus*. Ecology 58:914-920

Eggleston DB, Lipcius RN, Grover JJ (1997) Predation and shelter size effects on coral reef fish and spiny lobster prey. Mar Ecol Prog Ser 149:43-59

Eklöv P, Diehl S (1994) Piscivore efficiency and refuging prey: the importance of predator search mode. Oecologia 98:344-353

Ferreira CEL, Floeter SR, Gasparine JL, Joyeux JC, Ferreira BP (2004) - Trophic structure patterns of Brazilian reef fishes: a latitudinal comparison. J Biogeogr 31: 1093-1106

Francini-FIlho RB, Ferreira CM, Coni EOC, Moura RL, Kaufman L (2009) Foraging activity of roving herbivorous reef fish in eastern Brazil: Influence of resource availability and

interference competition. Journal of the Marine Biological Association of the United Kingdom 90:481

Garcia TM, Matthews-Cascon H, Franklin-Junior W (2008) Macrofauna associated with branching fire-coral *Millepora alcicornis* (Cnidaria: Hydrozoa). Braz. J. Oceanogr. 57:153-155

Garpe KC, Yahya SAS, Lindahl U, Öhman MC (2006) Long-term effects of the 1998 coral bleaching event on reef fish assemblages. Mar Ecol Prog Ser 315:237-247

Gladfelter WB, Gladfelter EH (1978) Fish community structure as a function of habitat structure on West Indian patch reefs. Rev Biol Trop 26:65-84

Graham NAJ, Nash KL (2012) The importance of structural complexity in coral reef ecosystems. Coral Reefs 32:315-326.

Grober-Dunsmore R, Frazer TK, Lindberg WJ, Beets J (2007) Reef fish and habitat relationships in a Caribbean seascape: the importance of reef context. Coral Reefs 26: 201-216

Hata H, Kato M (2004) Monoculture and mixed-species algal farms on a coral reef are maintained through intensive and extensive management by damselfishes. J Exp Mar Biol Ecol 313:285-296

Harrington ME, Losey GS (1990) The importance of species identification and location on interspecific territorial defense by the damselfish, *Stegastes fasciolatus*. Environ Biol Fish 27:139-145

Hixon MA, Beets JP (1993) Predation, prey refuges and the structure of coral reef fish assemblages. Ecol Monogr 63:77-101

Hobbs JPA, Munday PL (2004) Intraspecific competition controls spatial distribution and social organization of the coral-dwelling goby *Gobiodon histrio*. Mar Ecol Prog Ser 278:253-259

Holbrook SJ, Brooks AJ, Schmitt RJ (2000). Spatial patterns in abundance of a damselfish reflect availability of suitable habitat. Oecologia 122:109-120

Holbrook SJ, Brooks AJ, Schmitt RJ (2002a) Variation in structural attributes of patch-forming corals and patterns of abundance of associated fishes. Mar Freshw Res 53: 1045-1053

Holbrook SJ, Brooks AJ, Schmitt RJ (2002b) Predictability of fishes assemblages on coral patch reefs. Mar Freshw Res 53:181-188

Holbrook SJ, Schmitt RJ, Brooks AJ (2008) Resistance and resilience of a coral reef fish community to changes in coral cover. Mar Ecol Prog Ser 371:263-271

Johnson MK, Holbrook SJ, Schmitt RJ, Brooks AJ (2011) Fish communities on staghorn coral: effects of habitat characteristics and resident farmerfishes. Environ Biol Fish 91:429-448

Jones GP (1984) Population ecology of the temperate reef fish *Pseudolabrus celidotus* Bloch and Schneider (Pisces: Labridae). II. Factors influencing recruitment. J Exp Mar Biol Ecol 75:257-276

Jones GP (1988) Ecology of rocky reef fish of north-easternern Australia. New Zealand: view. N Z J. Mar Freshw Res 22:445-462

Kaufman L (1977) The three spot damselfish: effects on benthic biota of Caribbean coral reefs. Proc 3th Int Coral Reef Symp 1:559–564

Leal ICS, Pereira PHC, Araújo ME (2013) Coral reef fish association and behaviour on the fire-coral *Millepora* spp. in north-east Brazil. Journal of the Marine Biological Association of the United Kingdom 93:1703:1711

Lewis JB (1989) The ecology of *Millepora* - a review. Coral Reefs 8:99-107

Lewis JB (2006) Biology and ecology of the hydrocoral *Millepora* on coral reefs. Adv Mar Biol 50:1-55

Lobel PS (1980) Herbivory by damselfishes and their role in coral reef community ecology. Bull Mar Sci 30:273-289

Lomolino MV (2001) Elevational gradients of species diversity: historical and prospective views. Glob Ecol Biogeogr 10:3-13

Luckhurst BE, Luckhurst K (1978) Analysis of influence of substrate variables on coral reef fish communities. Mar Biol 49: 317-324

MacNeil MA, Graham NAJ, Polunin NVC, Kulbicki M, Galzin R, Harmelin-Vivien M, Rushton SP (2009) Hierarchical drivers of reef-fish meta community structure. Ecology 90:252–264

Mahoney BM (1981) An examination of interspecific territoriality in the dusky damselfish, *Eupomacentrus dorsopunicans*. Bull Mar Sci 31:141-146

Marshall PA, Baird AH (2000) Bleaching of corals on the Great Barrier Reef: Differential susceptibilities among taxa. Coral Reefs 19:155-163

McCormick MI (1994) Variability in age and size at settlement of the tropical goatfish *Upeneus tragula* (Mullidae) in the northern Great Barrier Reef lagoon. Mar Ecol Prog Ser 103:1-5

McClanahan TR, Arthur R (2001) The effect of marine reserves and habitat on populations of East African coral reef fishes. Ecol Appl 11:559-569

Menegatti JV, Vescovi DL, Floeter SR (2003) Interações agonísticas e forrageamento do peixe-donzela, *Stegastes fuscus* (Perciformes: Pomacentridae). Natureza on line 1: 45-50

Mueller KW, Dennis GD, Eggleston DB, Wicklund RI (1994) Size-specific social interactions and foraging styles in a shallow water population of mutton snapper, *Lutjanus analis* (Pisces: Lutjanidae), in the central Bahamas. Environ Biol Fish 40:175-188

Munday PL (2001) Fitness consequences of habitat use and competition among coral-dwelling fishes. Oecologia 128:585-593

Munday PL (2004) Competitive coexistence among coral dwelling fishes: the lottery hypothesis revisited. Ecology 85:623-628.

Osório RM, Rosa IL, Cabral H (2006) Territorial defense by the Brazilian damsel *Stegastes fuscus* (Teleostei:Pomacentridae) J Fish Biol 69:233-242.

Pereira PHC, Ferreira BP (2012) Agonistic behavior of *Haemulon* spp. coral reef fishes (Actinopterygii: Hamulidae) in Northeastern Brazil. Cybium 36:361-367

Pereira PHC, Leal ICS, Araújo ME, AT Souza (2012) Feeding association between reef fishes and the fire-coral *Millepora* spp. (Cnidaria: Hydrozoa). Marine Biodiversity Records 5:1-4

Potts DC (1977) Suppression of coral populations by filamentous algae within damselfish territories. J Exp Mar Biol Ecol 28:207-216

Precht WF, Aroson RB, Moody RM, Kaufman L (2010) Changing patterns of microhabitat utilization by the threespot damselfish, *Stegastes planifrons*, on Caribbean reefs. PLoS ONE 5:10835

Robertson DR (1984) Cohabitation of competing territorial damselfishes on a Caribbean coral reef. Ecology 65:1124-1135

Robertson DR (1996) Interspecific competition controls abundance and habitat use of territorial Caribbean damselfishes. Ecology 77:885-899

Robertson DR, Sweatman HPA, Fletcher EA, Cleland MG (1976) Schooling as a mechanism for circumventing the territoriality of competitors. Ecology 57:1208-1220

Sale PF (1977) Maintenance of high diversity in coral reef fish communities. Am Nat 111:337-359

Sammarco PW, Carleton JH, Risk MJ (1986) Effects of grazing and damselfish territoriality on bioerosion of dead corals: direct effects. J Exp Mar Biol Ecol 98:1-19

Schiemer L, Niedermuller S, Herler J (2009) The influence of colony size and coral health on the occupation of coral-associated gobies (Pisces: *Gobiidae*). Coral Reefs 28:137–142

Shulman M.J. (1984) Resource limitation and recruitment patterns in a coral reef fish assemblage. J Exp Mar Biol Ecol 74:85-109

Souza AT, Ilarri MI, Rosa IL (2011) Habitat use, feeding and territorial behavior of a Brazilian endemic damselfish *Stegastes rocasensis* (Actinopterygii: Pomacentridae). Environ Biol Fish 91:133-144

Syms C, Jones GP (2000) Disturbance, habitat structure, and the dynamics of a coral-reef fish community. Ecology 81:2714-2729

Talbot FH, Russell BC, Anderson GRV (1978) Coral reef fish communities: unstable high-diversity systems? Ecol Monogr 49:425-440

Vine PJ (1974) Effect of algal grazing and aggressive behaviour of the fishes *Pomacentrus lividus* and *Acanthurus sohal* on coral-reef ecology. Mar Biol 24:131-136

Wellington GM (1982) Depth zonation of corals in the Gulf of Panama: control and facilitation by resident reef fishes. Ecol Monogr 52:223-24

Remote video *versus* diver observation analysing reef fish community in association with *Millepora alcicornis* coral colonies.

Isabela Carolina Silva Leal

Departamento de Oceanografia, CTG, Universidade Federal de Pernambuco (UFPE)

Av. Arquitetura, s/n, Cidade Universitária, Recife, PE, 50670-901, Brazil.

Autor Correspondente - Isabela Carolina Silva Leal

Departamento de Oceanografia, CTG, Universidade Federal de Pernambuco (UFPE)

Av. Arquitetura, s/n, Cidade Universitária, Recife, PE, 50670-901, Brazil.

Telefone: (081) 2126-7221

E-mail: leal.ics@gmail.com

Abstract

Underwater visual census (UVC) is often considered the most popular technique quantifying reef fish assemblages. However, remote video analysis has been gaining attention as another important tool during fish community assay. The present study aimed to analyze the use of two different observation methods (remote video and diver observation) on the abundance and richness of associated reef fishes within colonies of fire-coral *Millepora alcicornis*. Observations were performed from September 2012 to April 2013 at Tamandaré Reefs, Northeast Brazil. The richness and abundance of associated reef fishes presented non-significant difference depending on the used methodology. The present study represented the first one investigating the use of different methodologies and their influence in the abundance and richness species associated with coral colonies. The results indicate that both evaluated methodology (remote video and diver observation) are similar during fire-coral community association analyses. However, small differences associated with the ability of each method to detect certain species and also relative detectability of fish species by different methods was observed. Can be affirmed that the accuracy of the view of the researcher easily detects cryptic fish (e.*g* *Epinephelus adscensionis*, *Pareques acuminatus* and *Muraena pavonina*) while the camera can capture images of fish faster and avoidant (e.g *Aluterus scriptus*) to human presence.

Key-words: Visual census; Methodologies; Coral-fish association; South Atlantic reefs.

Introduction

Visual survey techniques are used widely to estimate abundances of target organisms in terrestrial (Caughley *et al*. 1976; Caughley 1977; Francis 1994) and aquatic ecosystems (Keast & Harker 1977; Solazzi 1984). Furthermore, much of our understanding of marine ecosystems and their processes are supported by data collected via diver-based underwater visual censuses (UVC). UVC technique was first used by Brock (1954) and is the most popular method for studying the distribution of tropical fishes and also is widely employed in reef fish ecological studies (Sale 1997). Underwater visual censuses (UVC) performed by divers or snorkelers are commonly used to estimate population densities and diversity of coral reef fish (Edgar *et al.* 2004; Kulbicki *et al.* 2007; Samoilys & Carlos 2000). These technique has the advantage of allowing easy identification of many species, the possibility of observing fish behaviour and the fact that it is a non-destructive method (Jind 2012).

Many studies have highlighted sources of bias that have the potential to affect the accuracy and precision of results obtained via diver censuses (Brock 1982; Sale & Sharp 1983; Thompson & Mapstone 1997; Edgar *et al.* 2004). For instance, some fish species are attracted to diver's presence conducting surveys. As a result, diver-based techniques tend to overestimate the abundance of these species (Watson *et al.* 2010). The opposite is true for fish species that avoid diver's presence. For schools of fish between 5 and 20 fishes it is often possible to make accurate counts if the fishes are not moving too fast and if they are of homogeneous size (Harmelin-Vivien *et al.* 1985). Acknowledgement of the limitations of UVCs has led to an examination of the relative merits of alternative methods of quantifying variables within marine ecosystems (Green & Alevison 1989; Harvey *et al*. 2001a, b; Tessier *et al*. 2005), therefore, including the use of remote video recorders (Willis & Babcock 2000; Willis *et al*. 2000; Cappo *et al*. 2004; Harvey *et al*. 2004).

Remote video systems provide an alternative or complementary method to the traditional direct diver observation during reef community analyses (Dunlap & Pawlik 1996; Bellwood & Fulton 2008; Burkepile & Hay 2011). For many authors the main advantages of remote video methods are that images can be checked by several observers as many times as necessary, and that they provide useful records of

abundance, richness, size and species behavior (Willis and Babcock 2000; Willis *et al*. 2000). Furthermore, video can offer a solution to some of the biases caused by attraction or repulsion of some fish to diver's presence and also deployable to much greater depths than divers (Francour *et al*. 1999). On the other hand, there are also important limitations associated with this technique, such as the water transparency and difficulty in identifying species with cryptobenthic habits (*i.e.* Blenniidae and Gobiidae) (Longo & Floeter 2012; Jind 2012).

In this context, the present study aimed to compare the efficiency of remote video and diver observation technique analyzing reef fish association on *Millepora alcicornis* coral colonies. Specifically, both techniques were used in similar ecological situation to estimate fish abundance and richness within coral colonies and then statistically compared.

Methods

Study site description

This study was conducted in the coastal reefs located in the municipality of Tamandaré (88 °44'54''S and 36 ° 6'14''W). Tamandaré is located 110 km from Recife, capital of Pernambuco State. The reef complex studied is located within the "Area de Preservação Ambiental Costa dos Corais" (Coral Coast MPA). Observations were conducted on the "Ilha do Norte" reef (Fig.1) located between 300 to 600m from the shoreline, in average depth of 0.5m. This reef is covered by macroalgae species, hermatypic corals (*Favia gravida*, *Montastrea cavernosa*, *Mussismilia* spp. and *Porites astreoides*) (Lamarck, 1816) and colonies of the hydrocorals *Millepora alcicornis* and *Millepora braziliensis*, (Ferreira & Maida, 2006) with *M. alcicornis* being the most abundant fire-coral species.

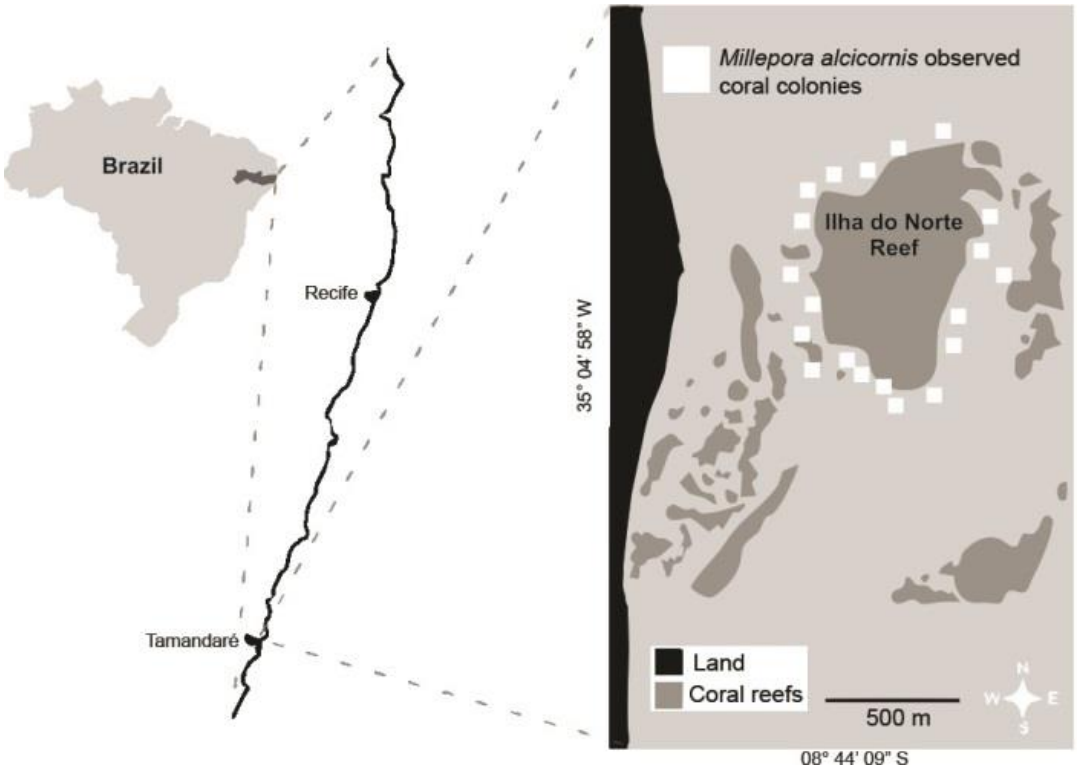

Fig.1. Map of the study volume, "Ilha do Norte" reef in Tamandaré municipality – Northeast Brazil, indicating the *Millepora alcicnornis* colonies.

Sampling techniques

The underwater observations were conducted from September 2012 to April 2013, during the dry season. A total of 135 min of diver observation were performed and samples were collected between 0800 am and 1400 pm in low tide. Observations time and coral colony distance from observer were standardized during the whole research in 5 minutes and 1.5 meter respectively.

Eight colonies of *Millepora alcicornis* of different sizes (previously measured and tagged) were chosen for analysis for the two different types of methodology were used (remote video and diver observation technique). Three replicas of each method of analysis were performed for each colony. In order to avoid possible methodological errors between the two types of methodologies were performed under the same conditions of tide, time of day and time of year.

Remote Video

Remote video technique was performed by a video camera Go Pro Hero 2 fixed in a weight tripod (Fig. 2). The system was carried down by a diver and placed in front of the *Millepora alcicornis* coral colonies at a distance of 1.5 m average. Once the system was placed in front of the coral colonies an acclimation period of at least 5 minutes was accomplished in all the samples to avoid camera influence.

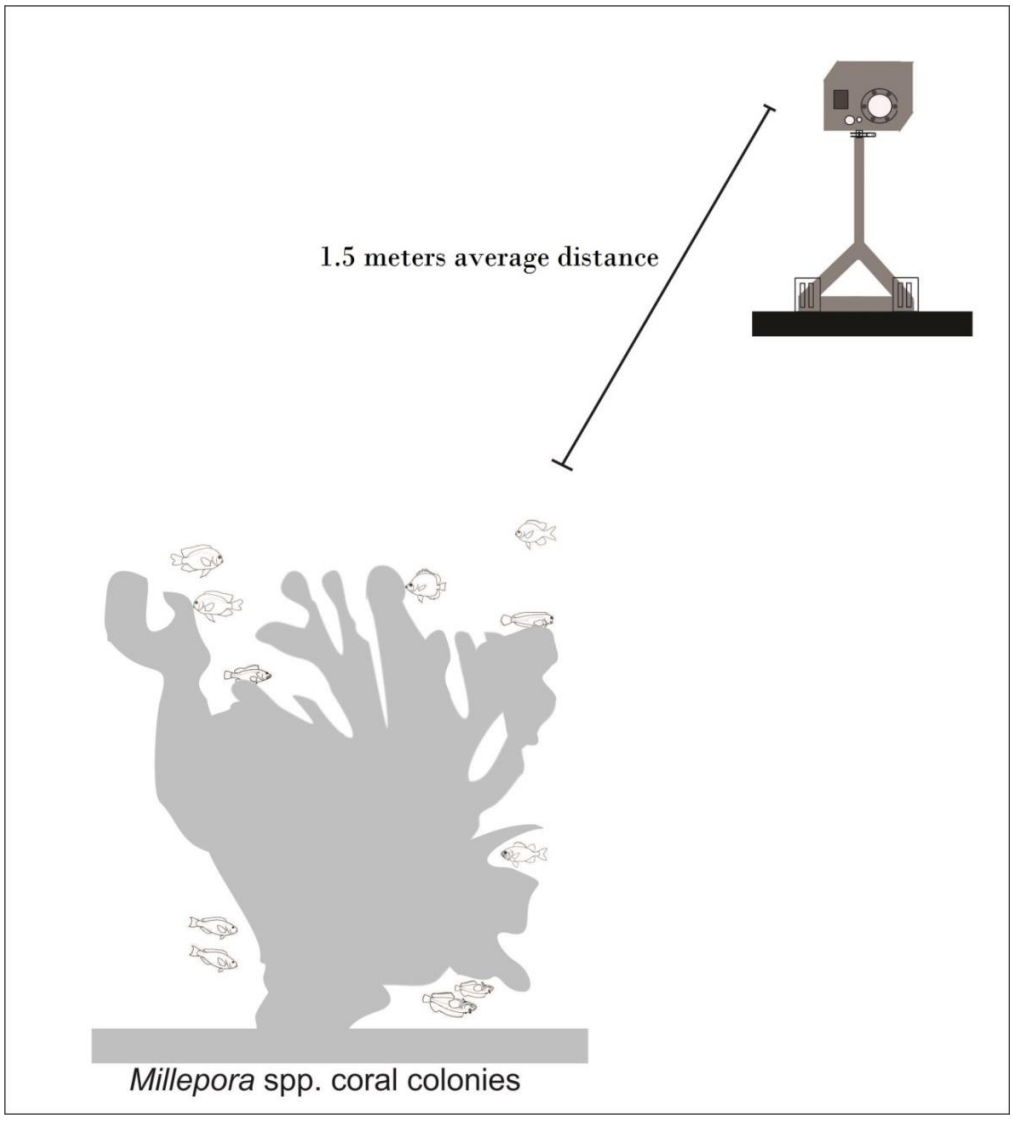

Fig.2. Video camera Go Pro Hero 2 fixed in a weight tripod in front of the *Millepora alcicornis* coral colony.

Diver observation technique

Diver observation technique was performed using free diving (*snorkeling*) by the same diver during the whole research. The diver remained stationary at an average of 1.5 m away from the colonies of *Millepora alcicornis*. All records were recorded on a clipboard PVC and later analyzed. The same acclimation period (at least 5 minutes) was accomplished to avoid the diver influence on reef fish community.

Data Analyze

A Mann-Whitney test was used to compare the total number of individuals and species by the two different observation methods (remote video and diver observation).

Results

During the remote video technique analysis a total of 141 reef fish individuals belonging to 10 families and 14 species were recorded in association with *Millepora alcicornis* coral colonies. Using the observations performed through the diver, 138 individuals of reef fish belonging to 11 families and 16 species were observed (Table 1). Diver observation and remote video were similar regarding the abundance (p= 0.56) and richness (p= 0.91), not showing significant differences between them for both methods.

Table 1 – Reef fish species and number of individuals recorded in association with *Millepora alcicornis* coral colonies using the two different methods.

Family	Remote video	N. Individuals	Diver observation	N. Individuals
Pomacentridae	*Stegastes fuscus*	99	*Stegastes fuscus*	78
Holocentridae	*Holocentrus adscensionis*	14	*Holocentrus adscensionis*	20
Pomacentridae	*Abudefduf saxatilis*	9	*Abudefduf saxatilis*	7
Labridae	*Sparisoma axillare*	4	*Sparisoma axilare*	1
Epinephilidae	*Cephalopholis fulva*	3	*Cephalopholis fulva*	4
Labridae	*Scarus zelindae*	3	*Scarus zelindae*	1
Monacanthidae	*Aluterus scriptus*	2	-	-
Pomacentridae	*Acanthurus coeruleus*	1	*Acanthurus coeruleus*	5
Haemulidae	*Anisotremus virginicus*	1	*Anisotremus virginicus*	1

Chaetodontidae	*Chaetodon striatus*	1	*Chaetodon striatus*	3
Labridae	*Haliocheres braziliensis*	1	*Haliocheres braziliensis*	1
Bleniidae	*Ophioblenius trinitatis*	1	*Ophioblenius trinitatis*	5
Labrisomidae	*Labrisomus nuchipinnis*	1	*Labrisomus nuchipinnis*	1
Holocentridae	*Myripristis jacobus*	1	*Myripristis jacobus*	4
Epinephilidae	-	-	*Ephinephelus adscensionis*	4
Scianidae	-	-	*Pareques acuminatus*	2
Muraneidae	-	-	*Muraena pavonina*	1

From a total of 17 species recorded in the present study, only one occurred exclusively through the remote video (*e.g. Aluterus scriptus*) and one tree exclusively through diver observation method (*e.g. Pareques acuminatus, Epinephelus adscensionis and Muraena pavonina*) (Table. 1).

Lastly, the present study summarizes researches conducted to date highlighting advantages and disadvantages for each type of used methodology (Table 2).

Table 2 – Review of techniques for reef fish data collection, with advantages and disadvantages according previous researchers and the present study data. UVC = Underwater Visual Census./ Stereo – DOV = Diver-operated stereo video

Reference	Site	Method	Advantages		Disadvantages		Authors observation
Jind 2012	Caribean Sea	UVC Vs. Stereo – DOV	**Stereo-DOV** Precise and accurate fish length estimates, less influenced by observer bias, short survey duration and permanent record.	**UVC** Cost-effective, easy to use, quick data on abundance and diversity and also cryptic species detection.	**Stereo-DOV** High initial cost of equipment, time consuming for video analysis, cryptic species error and underestimates fish density and species richness.	**UVC** Inaccurate fish length estimates, influenced by observer bias, long survey duration, no permanent record and multiple observers error.	Difference in species richness estimates between methods may in part be explained by the longer duration of UVC compared to stereo-DOV.
Longo and Floeter 2012	Northeast Brazil	Remote video Vs. diver observation	**Remote video** Data stored for further analyses, ability to evaluate the community across several functional groups and ability to observe in detail a single interaction.	**Diver observation** -	**Remote video** Water transparency can difficult, also the difficulty in identifying species with cryptobenthic habits (*i.e.* Blenniidae and Gobiidae).	**Diver observation** -	The diver presence did not affected the fish behaviour. Both methods were equally efficient.
Fox and Bellwood 2008	The Great Barrier Reef, Australia	Direct Vs. indirect methods (UVC)	**Remote video** Better analyses of functional impacts, reduce levels of diver experience and removes some of the subjectivity from observations made under water.	**UVC** -	**Remote video** Lower estimates of herbivore impact recorded by videos	**UVC** -	Similar levels of biomass were recorded for both methods. The presence of the diver did not affect the study.
Present study	Tamandaré reefs - Northeast Brazil	Remote video *versus*. diver observation	**Remote video** Data stored for further analyses, increases the chance to record species that avoid diver's presence.	**UVC** Diver peripheral and accuracy vision record more cryptobenthic species and also increases the chance to record hidden species within the *Millepora* spp. coral branches.	**Remote video** Absence of peripheral vision restricting some species record.	**UVC** Diver presence scare off some species that are skittish.	Both methods were effective for the purpose of the work. Showing no significant differences between abundance and species richness depending on the used. methodology.

Discussion

The use of different methodologies to investigate reef fish communities and their behavior has been discussed over the last decades (Caughley *et al*. 1976; Jind 2012). Previous studies have highlighted the wariness of fish in the presence of divers and its potential to impact abundance surveys (Chapman *et al*. 1974; Kulbicki 1998; Harvey *et al*. 2004). Moreover, according to Harvey *et al*. (2004), both inexperienced and experienced scientific divers are unable to accurately estimate the distance to fishes**;** therefore, inaccurate the total area surveyed in UVC methods. There are also important limitations associated with the remote video technique, such the difficulty in identifying species with cryptobenthic habits (*i.e.* Blenniidae and Gobiidae) and consequently their effect on the benthic community (Longo & Floeter 2012).

In the present study, similar fish abundance and richness were recorded by the diver observation and remote video methods. The same trend was observed for Longo and Floeter (2012) where a similar number of species was recorded for the same two types of methodologies (remote video and direct observation). It could suggest that the presence of divers and remote video did not significantly affect the results of reef fish assemblages associated with fire coral *Millepora alcicornis*, in the present study.

However, three species were restricted only by diver observation technique (*e.g Epinephelus adscensionis, Muraena pavonina, Pareques acuminatus*). These species were already recorded sheltering in crevices and cavities of *Millepora alcicornis* coral colonies (Leal *et al*. 2013). This type of behavior is likely to be favored during direct observation technique where the diver can record better than video camera individuals placed within the crevices and recesses of the *M*. *alcicornis* colonies. In contrast, the species *Aluterus scriptus* could potentially avoid the diver presence were only recorded by the remote video method. Individuals of *A. scriptus* are not commonly seen in coastal reefs. Adults are usually seen along deep coastal slopes or outer reef drop-offs in about 20 meters depth (Kuita and Tonozuka, 2001). The food items of *A. scriptus* may have been the main reason for the species have been recorded associated colonies of *M. alcicornis*. *A. scriptus* feed on algae, seagrass, hydrozoans, gorgonians, colonial anemones, and tunicates (Weitkamp and Sullivan, 2003).

A recent study comparing UVC to stereo-DOV also found higher estimates of abundance and species richness by UVC compared to stereo-DOV (Pelletier *et al*.

2011). The traditional underwater visual census (UVC) techniques would probably survey greater species richness and abundance due to the advantages of the human eye (Le Grand 1968) compared to video cameras. This could be due water visibility issues (Longo & Floeter 2012) and also by the reduction movement capability of stationary cameras, compared with diver observation that can increase the coverage angle.

An important discussion for explanations about differences in species richness estimates between methods has to do with the relative detectability of fish species by different methods (Edgar 2004; Bozec *et al*. 2011). Numerous factors influence the detectability of fish, including fish size and behaviour, visibility, diver expertise, habitat complexity, and survey duration (Edgar *et al*. 2004; Pelletier *et al*. 2011; Ward-Paige *et al*. 2010; Bozec *et al*. 2011). The degree to which these factors influence fish detectability depends on how they interact with the particular used method.

In general, remote video allow images to be recorded and later analysed as many times as necessary, also less influenced by observer bias and provides permanent record. In contracts, the classic UVC do not require expensive equipment coasts, is easy to operate and also increase the accuracy for hidden and cryptobenthic species. The same trade was also observed during the present study, with most of the vantages and advantages summarized in Table 2.

The main conclusions of this study are that both methods were effective for the purpose of the work showing no significant differences between abundance and species richness depending on the methodology used. Although not presented significant differences between both methods is suggested that the use of the video camera to be a complementary method to the visual census. In this context, it is essential that research aims are previously defined; thus, the most appropriate technique may be chosen avoiding all the methodological issues mentioned herein.

Acknowledgment

The authors would like to thank Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) e Pesquisas Ecológicas de Longa (PELD) for the financial support.

References

Bellwood D.R., Fulton C.J. (2008) Sediment-mediated suppression of herbivory on coral reefs: Decreasing resilience to rising sea levels and climate change? *Limnology and Oceanography*, 53, 2695-2701.

Bozec Y.M., Kulbicki M., Laloë F., Mou-Tham G., Gascuel D. (2011) Factors affecting the detection distances of reef fish: implications for visual counts. *Marine Biology*, 158, 969-981.

Brock R.E. (1982) A critique of the visual census method for assessing coral reef fish populations. *Bulletin of Marine Science,* 32, 269-276.

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

Burkepile D.E., Hay M.E. (2008) Herbivore species richness and feeding complementarity affect community structure and function on a coral reef. *Proceedings of the National Academy of Sciences of the United States of America*, 105, 16201-16206.

Caughley, G. (1977). Analysis of vertebrate populations. Wiley, London.

Caughley, G.R., Sinclair R., Scott-Kemmis D. (1976) Experiments in aerial survey.*Journal of Wildlife Management*, 40, 290-300.

Coni E.O.C., Ferreira M.C., Moura R.L., Meirelles P.M., Kaufman L., Francini-Filho R.B. (2012) An evaluation of the use of branching fire-corals *(Millepora spp.)* as refuge by reef fish in the Abrolhos Bank, eastern Brazil. *Environmental Biology of Fish*, 75,1-12.

Chapman C.J., Johnstone A.D.F., Dunn J.R., Creasey D.J. (1974) Reactions of fish to sound generated by diver's open-circuit underwater breathing apparatus. *Marine Biology*, 27, 357-366.

Dunlap M., Pawlik J.R. (1996) Video-monitored predation by Caribbean reef fishes on an array of mangrove and reef sponges. *Marine Biology*, 126,117-123.

Edgar G.J., Barrett N.S., Moroton, A.J. (2004) Bias associated with the use of underwater visual census techniques to quantify the density and size-structure of fish populations. *Journal Experimental Marine Biology* Ecology, 308, 269-290.

Francis C. M. (1994) Population changes of boreal forest ducks - A comment. *Journal of Wildlife Management* 58: 582-586.

Francour P., Liret C., Harvey E. (1999) Comparison of fish abundance estimates made by remote underwater video and visual counts. *Naturalista sicil*, 23, 155-168.

Jind S. (2012) A comparison of two underwater visual sampling techniques used to estimate
tropical reef fish communities.

Harmelin-Vivien M.L., Harmelin J.G., Chauvet C., Duval C., Galzin R., Lejeune P., Barnabe´ G., Blanc F., Chevalier R., Duclerc J., Lasserre G. (1985) Evaluation visuelle des peuplements et populations de poissons: me´thodes et proble`mes. *Rev Ecol Terre Vie*, 40,467–540.

Harvey E.S., Fletcher D., Shortis M.R. (2001a) A comparison of the precision and accuracy of estimates of reef-fish lengths made by divers and a stereo-video system. *Fishery Bulletin*, 99, 63-71.

Harvey E., Fletcher D., Shortis M.R., Kendrick G.A. (2004) A comparison of underwater visual distance estimates made by scuba divers and a stereo-video system: implications

for underwater visual census of reef fish abundance. *Marine Freshwater Research*, 55, 573-580..

Keast A., Harker J. (1977) Fish distribution and benthic invertebrate biomass relative to depth in an Ontario lake. *Environmental Biology of Fishes*, 1, 181-188.

Kulbicki M. (1998) How the acquired behaviour of commercial reef fishes may influence the results obtained from visual censuses. *Journal of Experimental Marine Biology and Ecology, 222*, 11–30.

Kulbicki M., Sarramegna S., Letourneur Y., Wantiez L., Galzin R., Mou-Tham G., Chauvet C., Thollot P. (2007) Opening of an MPA to fishing: Natural variations in the structure of a coral reef fish assemblage obscure changes due to fishing. *Journal of Ex perimental Marine Biology Ecology*, 353,145-163.

Leal I.C.S., Pereira P.H.C., Araújo M.E. (2013) Coral reef fish association and behaviour on the fire-coral *Millepora* spp. in north-east Brazil. *Journal of the Marine Biological Association of the United Kingdom*, 93:1703-1711.

Pelletier D., Leleu K., Mou-Tham G., Guillemot N., Chabanet P. (2011) Comparison of visual census and high definition video transects for monitoring coral reef fish assemblages. *Fisheries Research,* 107, 84-93.

Pereira P.H.C., Leal I.C.S., Araújo M.E., Souza A.T. (2012) Feeding association between reef fishes and the fire-coral *Millepora* spp. (Cnidaria: Hydrozoa). *Marine Biodiversity Records*, 5,1-4

Sale P.F. (1997) Visual census of fishes: how well do we see what is there? In: Proc 8th int coral reef symp 2:1435–1439

Sale P.F., Sharp B.J. (1983) Correction for bias in visual transect censuses of coral reef fish. *Coral Reefs*, 2, 37-42.

Samoilys M.A., Carlos G. (2000) Determining methods of underwater visual census for estimating the abundance of coral reef fishes. *Environmental Biology of Fishes,* 57, 289-304.

Solazzi M.F. (1984) Relationship between visual counts of coho salmon (Oncorhynchus kisutch) from spawning fish surveys and the actual number of fish present. In: Symons PEK, Waldichuck M (eds) Proceedings of the workshop on stream indexing for salmon escapement estimation. Can Fish Aquat Sci Tech Rep 1326:175-186.

Tessier E., Chabanet P., Pothin K.., Soria M., Lasserre G. (2005) Visual censuses of tropical fish aggregations on artificial reefs: slate versus video recording techniques. *Journal Exerimental of Marine Biology and Ecology*, 315, 17-30.

Thompson A.A., Mapstone B.D. (1997) Observer effects and training in underwater visual surveys of reef fishes. *Marine Ecology Progress Series,* 154, 53-6.

Ward-Paige C., Mills Flemming J., Lotze H.K. (2010) Overestimating fish counts by non-instantaneous visual censuses: consequences for population and community descriptions. *PLoS ONE*, 5, 11722.

Watson D.L., Harvey E.S., Fitzpatrick B.M., Langlois T.J., Shedrawi G. (2010) Assessing reef fish assemblage structure: how do different stereo-video techniques compare? *Marine Biology,* 157, 1237-1250.

Weitkamp, D.E. and R.D. Sullivan, 2003. Gas bubble disease in resident fish of the lower clark fork river. Trans. Am. Fish. Soc. 132(5):865-876.

Willis T.J. (2001) Visual census methods underestimate density and diversity of cryptic nreef fishes. *Journal of Fish Biology*, 59, 1408-1411

Willis T.J., Babcock R.C. (2000) A baited underwater video system for the determination of relative density of carnivorous reef fish. *Marine Freshwater Research*, 51,755-763.

Willis T.J., Millar R.B., Babcock R.C. (2000) Detection of spatial variability in relative density of fishes: comparison of visual census, angling, and baited underwater video. *Marine Ecology Progress Series*, 198, 249-260.

Considerações finais

Através do presente estudo foi possível concluir que o volume das colônias de *Millepora alcicornis* afetou tanto abundância quanto a riqueza das espécies associadas. Dentre as espécies associadas às colônias, *Stegastes fuscus* foi a mais abundante, mostrando que as colônias do coral-de-fogo desempenham importante função na ecologia desses peixes. Quando associados às colônias de *M. alcicornis,* indivíduos desta espécie desempenharam diferentes tipos de comportamentos (postura de proteção, abrigado na base do coral, abrigado entre as fendas, mordendo pólipos, mordendo algas e agonístico). Esses comportamentos foram relacionados com o tamanho do corpo desses indivíduos e os resultados mostraram que indivíduos menores ou maiores que 6 cm apresentam variações ontogenéticas de comportamento para essa espécie. A mudança no padrão de colorido desses peixes coincide também com a classificação das duas categorias de tamanhos.

As categorias de tamanhos das colônias influenciaram no tamanho dos indivíduos de *S. fuscus* associados. Colônias categorizadas como muito grandes agregaram uma quantidade significativa de indivíduos de *S. fuscus*, menores que 6 cm, quando comparadas com as outras categorias de tamanhos de colônias. Colônias muito grandes possuem mais espaço e consequentemente favorecem uma maior associação dos indivíduos menores, servindo como área de abrigo para esses peixes.

As mudanças de comportamentos realizados pelos indivíduos de *S. fuscus* também foram influenciados pelo volume das colônias. Verificou-se uma relação direta entre o comportamento agonístico e o volume de *M. alcicornis.* Quanto maiores as colônias, mais espaço disponível para que os peixes se associarem a elas. Com isso, os indivíduos de *S. fuscus* precisam gastar mais tempo protegendo seu território. Outra hipótese estaria relacionada ao fato dos *S. fuscus* diminuírem a frequência do comportamento de postura de proteção em volta das maiores colônias. Consequentemente as competições efetuadas pelos indivíduos de *S. fuscus* com outros peixes aumenta, pois eles passam a não ter mais domínio total sobre as colônias. Entre os comportamentos observados foi possível concluir que *S. fuscus* é a espécie mais

agressiva com os peixes herbívoros errantes, onívoros e comedores de invertebrados sésseis, por causa de sobreposição alimentar.

É possível concluir que os corais-de-fogo da espécie *M. alciconis* desempenham importante papel ecológico para os peixes que vivem a ela associados, com destaque para espécie *S. fuscus*. O fato desses peixes morderem os pólipos das colônias pode favorecer o crescimento de alga nas mesmas e aumentar a competição entre alga e coral. Por consequência, as chances de morte de tecido das colônias de *M. alcicornis* podem aumentar devido ao crescimento das algas.

Os dois diferentes tipos de metodologias utilizadas (câmera de vídeo X observação pessoal) mostraram-se eficientes quando utilizadas para testar abundância e riqueza da ictiofauna em associação com as colônias de *M. alcicornis*. Apesar de não ter apresentado diferenças significativas entre ambos os métodos, sugere-se que o uso da câmera de vídeo seja um complemento ao método de censo visual. A câmera detecta espécies que muitas vezes se afastam pela presença do mergulhador. No entanto, o método de censo visual resulta no fato do mergulhador ter um campo de visão mais amplo e consequentemente observar toda a dimensão das colônias de *M. alcicornis.* Assim, através desse método é possível detectar aquelas espécies que ficam escondidas entre as ramificações do coral-de-fogo.

Referências gerais

Almany, G. R. 2004. Does increased habitat complexity reduce predation and competition in coral reef fish assemblage? Oikos, 106:275-284.

Almany, G. R. 2003. Priority effects in coral reef fish communities. Ecology 84: 1920-1935.

Amaral, F. D. 2008. An overview of 116 the shallow-water calcified hydroids from Brazil (Hydrozoa: Cnidaria), including 117 the description of a new species. Zootaxa, 1940: 56-68.

Bellwood, D. R., Fulton, C. J. 2008. Sediment-mediated suppression of herbivory on coral reefs: Decreasing resilience to rising sea levels and climate change? Limnology and Oceanography, 53: 2695-2701

Brock, V. E. 1954. A preliminary report on a method of estimating reef fish populations. Journal of Wildlife Management, 18: 297–308.

Burkepile, D. E., Hay, M. E. 2008. Herbivore species richness and feeding complementarity affect community structure and function on a coral reef. Proceedings of the National Academy of Sciences of the United States of America, 105: 16201-16206.

Cairns, S. D., Hoeksema, B. W., Van Der Land, J. 1999. Appendix: List of the extant stony corals. Atoll Research Bulletin, 459, 13–46.

Ceccarelli, D. M., Jones, G. P., McCook, L. J. 2001. Territorial damselfishes as determinants of the structure of benthic communities on coral reefs. Oceanogr Mar Biol Annu Rev, 39:355-389

Coni, E. O. C., Ferreira MC, Moura R. L, Meirelles, P. M., Kaufman, L., Francini-Filho, R. B. 2012. An evaluation of the use of branching fire-corals (*Millepora* spp.) as refuge by reef fish in the Abrolhos Bank, eastern Brazil. Environ Biol Fish, 75:1-12.

Dixson, D. L., Hay, M. E. 2012. Corals Chemically Cue Mutualistic Fishes to Remove Competing Seaweeds. Science, 338: 804-807.

Dunlap, M., Pawlik, J. R. 1996. Video-monitored predation by Caribbean reef fishes on an array of mangrove and reef sponges. Marine Biology, 126,117-123.

Edgar, G. J., Barrett, N. S., Moroton, A. J. 2004. Bias associated with the use of underwater visual census techniques to quantify the density and size-structure of fish populations. Journal Experimental Marine Biology Ecology, 308: 269-290.

Edmunds P. J. 1999. The role of colony morphology and substratum inclination in the success of *Millepora alcicornis* on shallow coral reefs. Coral Reefs, 18:133–140.

Eklöv, P., Diehl, S. 1994. Piscivore efficiency and refuging prey: the importance of predator search mode. Oecologia, 98:344-353.

Graham, N. A. J. Nash, K. L. 2012. The importance of structural complexity in coral reef ecosystems. Coral Reefs, 32:315-326.

Hixon, M. A., Beets, J. P. 1993 Predation, prey refuges and the structure of coral reef fish assemblages. Ecol Monogr, 63:77-101.

Hyman, L. H. 1940. The Invertebrates: Protozoa through Ctenophora. McGraw- Hill Book Company, New York and London.

Holbrook, S. J., Brooks, A. J., Schmitt, R. J. 2000. Spatial patterns in abundance of a damselfish reflect availability of suitable habitat. Oecologia, 122:109-120.

Holbrook, S. J., Brooks, A. J., Schmitt, R. J. 2002a. Variation in structural attributes of patch-forming corals and patterns of abundance of associated fishes. Mar Freshw Res, 53: 1045-1053.

Holbrook, S. J., Brooks, A. J., Schmitt, R. J. 2002b. Predictability of fishes assemblages on coral patch reefs. Mar Freshw Res, 53:181-188.

Holbrook, S. J., Schmitt, R. J., Brooks, A. J. 2008. Resistance and resilience of a coral reef fish community to changes in coral cover. Mar Ecol Prog Ser, 371:263-271.

Johnson, M. K., Holbrook, S. J., Schmitt, R. J., Brooks, A. J. 2011. Fish communities on staghorn coral: effects of habitat characteristics and resident farmerfishes. Environ Biol Fish, 91:429-448.

Jones, G. P. 1988. Ecology of rocky reef fish of north-easternern Australia. New Zealand: view. N Z J. Mar Freshw Res, 22:445-462.

Kulbicki, M., Sarramegna, S., Letourneur, Y., Wantiez, L., Galzin, R., Mou-Tham, G., Chauvet, C., Thollot, P. 2007. Opening of an MPA to fishing: Natural variations in the structure of a coral reef fish assemblage obscure changes due to fishing. Journal of Ex perimental Marine Biology Ecology, 353**:**,145-163

Leal, I.C.S., Pereira, P. H. C., Araújo, M.E. 2013. Coral reef fish association and behaviour on the fire-coral *Millepora* spp. in north-east Brazil. J M Biol Assoc U K, 93:1703-1711.

Leão, Z. M. A. N.; Dominguez, J. M. L. Tropical Coast of Brazil. Marine Pollution Bulletin. 2000. 41:112 – 122.

Lewis, J. B. 2006. The ecology of *Millepora* - A review. Coral Reefs, 8:99–107.

Lomolino, M. V. 2001. Elevational gradients of species diversity: historical and prospective views. Glob Ecol Biogeogr, 10:3-13.

Munday, P. L. 2004. Competitive coexistence among coral dwelling fishes: the lottery hypothesis revisited. Ecology, 85:623-628.

Oliveira, M. D. M., Leão, Z.M.A. N.; KIKUCHI, R. K. P. Cultivo de *Millepora alcicornis* como uma ferramenta para restauração e manejo dos ecossistemas recifais do Nordeste do Brasil. Revista de Gestão Costeira Integrada, 8(2):183-201. 2008.

Pereira, P. H C., Leal, I.C.S., Araújo, M.E., Souza, A.T. 2012. Feeding association between reef fishes and the fire-coral *Millepora* spp. (Cnidaria: Hydrozoa). Marine Biodiversity Records 5:1-4.

Pott, D. C. 1977. Suppression of coral populations by filamentous algae within damselfish territories. J Exp Mar Biol Ecol, 28:207-216.

Robertson, D. R., Sweatman, H.P.A., Fletcher, E.A., Cleland, M.G. 1976. Schooling as a mechanism for circumventing the territoriality of competitors. Ecology, 57:1208-1220.

Samoilys, M. A., Carlos, G. 2000. Determining methods of underwater visual census for estimating the abundance of coral reef fishes. Environmental Biology of Fishes, 57: 289-304.

Schiemer, L., Niedermuller, S., Herler, J. 2009. The influence of colony size and coral health on the occupation of coral-associated gobies (Pisces: *Gobiidae*). Coral Reefs, 28:137–142.

Souza, A.T., Ilarri, M. I., Rosa, I. L. 2011. Habitat use, feeding and territorial behavior of a Brazilian endemic damselfish *Stegastes rocasensis* (Actinopterygii: Pomacentridae). Environ Biol Fish, 91:133-144.

Watson, D .L., Harvey, E. S., Fitzpatrick, B. M., Langlois, T. J., Shedrawi, G. 2010. Assessing reef fish assemblage structure: how do different stereo-video techniques compare? Marine Biology, 157**:** 1237-1250.

Weerdt, W. H.1984. 1984. Taxonomic characters in Caribbean *Millepora* species (Hydrozoa, Coelenterata). Bijdr Dierk, 54: 243-262.

Willis, T. J., Babcock, R. C. 2000. A baited underwater video system for the determination of relative density of carnivorous reef fish. Marine Freshwater Research, 51:755-763.

Willis, T. J., Millar, R. B., Babcock, R. C. 2000. Detection of spatial variability in relative density of fishes: comparison of visual census, angling, and baited underwater video. Marine Ecology Progress Series, 198: 249-260.