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PESCA ARTESANAL E MANEJO: UMA ABORDAGEM TEMPORAL
COMPARATIVA EM TAMANDARÉ – PE

Recife

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

Área de Concentração: Biodiversidade

Orientadora: Profª. Drª. Beatrice Padovani Ferreira

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RESUMO

Pescarias artesanais de pequena escala são caracterizadas pela grande diversidade de petrechos e estratégias utilizadas na captura de múltiplas espécies e pelas funções econômicas, sociais, culturais e ecológicas que exercem. No Brasil, a pesca artesanal suporta muitas comunidades ao longo do litoral e estima-se que 2 milhões de pessoas estejam envolvidas na atividade e em seus processos. Nesse estudo, uma abordagem temporal comparativa foi utilizada para investigar a pesca costeira de pequena escala de Tamandaré, litoral sul de Pernambuco, que está inserida na Área de Proteção Ambiental Costa dos Corais. Perfis da pesca em dois períodos separados por desenvolvimentos de infraestrutura, crescimento populacional e turístico, transformações socioeconômicas assim como o estabelecimento de medidas de manejo foram comparados para observar mudanças e avaliar indícios que apontem para a sustentabilidade da atividade. No primeiro artigo, investigamos a relação entre a pesca e o turismo em Tamandaré. Os resultados revelaram que existe uma interação entre esforço de pesca e CPUE em Tamandaré que é influenciada por uma combinação de fatores e disponibilidade de emprego relacionada à temporada de turismo, apresentando uma boa oportunidade para discutir a necessidade de zonas de uso na APA Costa dos Corais que possam preservar as antigas tradições, conciliando a pesca e a conservação. No segundo artigo, foram observadas mudanças no perfil do pescador, captura por unidade de esforço, composição da captura e produtividade. No geral, os resultados indicaram consequências de um aumento na pesca de oportunismo associado ao crescimento da população costeira e fácil acesso aos recifes, mas também de inovação tecnológica e medida de manejo. Embora a zona de exclusão represente aproximadamente 10% da zona costeira de Tamandaré, não há indicativos de impactos negativos para a pesca apresentados pelos indicadores analisados, mas que a medida de manejo foi minimamente eficaz para manter a sustentabilidade da pesca ao longo de todo período estudado.

Palavras-chave: Pesca de pequena escala. Turismo. Área marinha protegida. Recifes de coral.

ABSTRACT

Small-scale artisanal fisheries are characterized by the great diversity of gears and strategies used to capture multiple species and by the economic, social, cultural and ecological functions they exert. In Brazil, artisanal fishing supports many communities along the coast and it is estimated that 2 million people are involved in the activity and its processes. In this study, a temporal comparative approach was used to investigate small-scale coastal fishing in Tamandaré, south of Pernambuco, which is part of the Costa dos Corais Environmental Protection Area (APACC). Fishery profiles in two periods separated by infrastructure, population growth and tourism developments, socioeconomic transformations as well as the establishment of management measures were compared to observe changes and evaluate indications that point to the sustainability of the activity. In the first article, we investigated the relationship between fishing and tourism in Tamandaré. The results revealed that there was an interaction between fishing effort and CPUE in Tamandaré that is influenced by a combination of factors and availability of employment related to the tourism season, what presented a good opportunity to discuss the need for zones of use APACC in order to preserve old traditions while conciliating fishing and conservation. In the second article, changes were observed in fisher profile, catch per unit effort, catch composition, and fishery productivity. In general, the results indicated the consequences of an increase in the fishing of opportunism associated with the growth of the coastal population and easy access to the reefs, but also of technological innovation and management measures. Although the no-take zone represents approximately 10% of the coastal zone of Tamandaré, there were no indications of negative impacts to fishing presented by the analyzed indicators, but that the management measure was minimally effective to maintain the fishing sustainability throughout the studied period.

Keywords: Small-scale fisheries. Tourism. Marine protected area. Coral reefs.

SUMÁRIO

1 INTRODUÇÃO GERAL

Pescarias artesanais de pequena escala são caracterizadas pela grande diversidade de petrechos e estratégias utilizadas na captura de múltiplas espécies e pelas funções econômicas, sociais, culturais e ecológicas que exercem. Essas pescarias empregam mais de 90% dos pescadores e trabalhadores que dependem da pesca no mundo, sendo fundamentais para a sobrevivência de milhões de pessoas que se dedicam à pesca tanto integralmente quanto sazonalmente ou ocasionalmente e, em tempos de necessidade, se tornam especialmente importantes para comunidades pesqueiras (FAO, 2015). Além da renda direta, a pesca de pequena escala é responsável por melhorar vidas através de mecanismos de ação coletiva, de compartilhamento de identidade cultural e de entendimento de normas sociais básicas com impactos extremamente positivos para empoderamento, bem-estar e autoestima individual e coletiva (BÉNÉ, 2006). A pesca artesanal é também um importante indicador de saúde ecossistêmica (CATELLA et al., 2012).

Devido a sua natureza imprevisível e arriscada, entretanto, a pesca é uma atividade com um elevado nível de vulnerabilidade. Isto não se deve apenas ao risco da atividade em si mas, também ao incerto retorno financeiro, que depende principalmente da disponibilidade de recursos que podem chegar a oscilar diariamente, mensalmente, sazonalmente ou anualmente (BÉNÉ, 2006). Pescadores e pescadoras frequentemente contribuem para o próprio fracasso ao destruir e sobreexplorar recursos nos quais são fortemente dependentes (FAO, 2003) Pescarias de todo o mundo têm entrado em situação de colapso (capturas abaixo de 10% do máximo previamente registrado) em velocidade bastante acelerada e, em 2003, 29% das espécies pescadas já haviam colapsado, e esse colapso deve-se principalmente ao esforço pesqueiro excessivo, que não é expresso apenas pela quantidade de barcos ou horas de pesca mas também pela evolução de tecnologias que possibilitam maior poder de captura (FROESE & KESNER-REYES, 2002; WORM et al., 2006). Além da sobrepesca, a depleção da atividade pesqueira deve-se também a práticas que divergem de leis e regulamentos que estabelecem, entre outras possíveis medidas de manejo pesqueiro, períodos proibidos à pesca, tamanho limite de captura de espécies e proibição de petrechos de pesca destrutivos. (WWF-BRASIL, 2016).

Paralelamente às ações antrópicas que ameaçam a continuidade da atividade pesqueira, mudanças climáticas e variações de temperatura e nível do mar contribuem, em escala global, para pressionar estoques pesqueiros por meio de impactos na produção primária e em habitats (SILVA, 2014). Sendo assim, a pesca é uma atividade que sofre fortemente com

forças naturais e os efeitos de tais transformações chegam a ser ser devastadores, afetando pescadores e pescadoras, comunidades e sociedades locais em inúmeros aspectos (DIEGUES, 1983; ABDALLAH & HELLEBRANDT, 2012).

Além das ameaças antrópicas e naturais citadas, gestores da pesca ainda precisam lidar com a recorrente situação de falta de dados sobre o estado dos estoques e dos ambientes que suportam esses estoques (FUJITA et al., 2014). A característica multiespecífica da pesca artesanal, junto com a distribuição heterogênea do esforço pesqueiro e o desembarque disperso das capturas, tornam a coleta de dados básicos, como esforço e captura, bem como a quantificação e administração de possíveis impactos, tarefas extremamente desafiadoras. Agências responsáveis terminam por ignorar as pescarias artesanais nas estatísticas oficiais ao as enquadrar como economicamente irrelevantes, no intuito de evitar custos de pesquisa meticulosos mesmo que, como no caso do Brasil, o volume total de desembarque da pesca artesanal seja maior que o da pesca industrial (RUSS, 1991; VASCONCELOS et al., 2007).

Para desacelerar e reverter esse cenário de degradação da pesca artesanal, iniciativas de manejo e conservação dos recursos marinhos tem focado no estabelecimento de áreas marinhas protegidas e de medidas de restrição da pesca (períodos de proibição da pesca de certas espécies, proibição de petrechos, etc.) como importante ferramentas para o manejo de espécies e do ecossistema costeiro como todo baseando-se em evidências científicas que apontam a recuperação de espécies alvo e não alvo e aumento da biodiversidade dentro dos limites das áreas protegidas assim como o aumento na produtividade pesqueira ao redor dessas áreas, com aumento médio na captura por unidade de esforço (FLOETER et al., 2006; WORM et al., 2006). Casos bem sucedidos de manejo participativo de pescarias de pequena escala também apontam tal ferramenta como promissora na proteção de pescarias (FLOETER et al., 2006).

No Brasil, a pesca artesanal suporta muitas comunidades ao longo do litoral e estima-se que 2 milhões de pessoas estejam envolvidas na atividade e em seus processos (VASCONCELOS et al., 2007). De acordo com o extinto Ministério de Pesca e Aquicultura, as pescarias comerciais e artesanais chegam a gerar juntas aproximadamente 585 mil toneladas de peixe marinho por ano, com grande maioria proveniente do setor artesanal, e contribuindo com R$ 5 bilhões para o produto interno bruto do país (BRASIL, 2010; WWF-BRASIL, 2016). No Nordeste, região de maior participação da pesca artesanal, as capturas representam 36,73% do total nacional e 96,3% dessas capturas vêm da frota artesanal concentrada principalmente na região costeira (BRASIL, 2010; WWF-BRASIL, 2016).

Nessas áreas os principais problemas da pesca incluem baixos níveis de organização entre as partes interessadas, conflitos entre diferentes setores pesqueiros (geralmente entre o artesanal e industrial que exploram os mesmos recursos e/ou habitats), poucas iniciativas bem sucedidas de manejo, e falta de políticas públicas ou políticas inadequadas para o manejo pesqueiro que, frequentemente, é provisório e exclusivamente focado em necessidades financeiras sem visar os impactos da sobreexploração de recursos (ISAAC et al., 2006). O setor pesqueiro no Brasil tem sido historicamente marcado pela descontinuidade de políticas, o último programa nacional de monitoramento pesqueiro ocorreu em 2008 e consequentemente o país esta deficiente de dados básicos de captura e esforço e também de dados socioeconômicos para subsidiar a regulamentação da pesca.

O presente estudo vai abordar a pesca artesanal de pequena escala que ocorre na costa do município de Tamandaré – PE como um estudo de caso de tentativa de manter a sustentabilidade da pesca por meio de áreas marinhas protegidas. Tamandaré é uma região com elevada biodiversidade (BARBOSA et al., 2016) que está inserida em um mosaico de unidades de conservação composto por quatro áreas protegidas com diferentes níveis de administração (municipal, estadual e federal) e que têm passado por intensas transformações nas últimas décadas. Essas relevantes transformações incluem tanto o estabelecimento de uma área marinha protegida e de uma área fechada para pesca, quanto o intenso desenvolvimento costeiro e expressiva expansão do turismo propulsionada por importantes iniciativas de desenvolvimento do turismo no Nordeste brasileiro (fatores somados ao rápido crescimento econômico do Brasil e evolução de tecnologias). Apesar de ser pouco estudada, a pesca costeira de pequena escala de Tamandaré contribui para aspectos ambientais e socioeconômicos da área.

2 OBJETIVOS

O objetivo geral da dissertação é comparar perfis da pesca costeira de pequena escala em Tamandaré em dois períodos separados pelo estabelecimento de medidas de manejo e por transformações socioeconômicas para então observar mudanças e avaliar indícios que apontem para a sustentabilidade da atividade. A estrutura desta dissertação consiste em dois capítulos em formato de artigos. O primeiro relata de qual forma a pesca e o turismo têm interagido em Tamandaré considerando o desenvolvimento do turismo no Nordeste do Brasil e a inserção da área de estudo em uma área marinha protegida. O segundo capítulo descreve mudanças no perfil dos pescadores e na captura desde quando houve o estabelecimento da área *no-take* para avaliar o atual estado da pescaria costeira de pequena escala em Tamandaré.

3 INTERACTIONS BETWEEN TOURISM AND FISHERIES MEDIATED BY A MARINE PROTECTED AREA IN THE NORTHEAST OF BRAZIL

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Resumo

Ecossistemas costeiros fornecem bens e serviços que podem trazer benefícios diretos e indiretos aos seres humanos como alimentos, recursos energéticos, regulação climática e local para atividades recreativas. No presente estudo investigamos a relação entre a pesca e o turismo no município de Tamandaré, localizado ao sul do estado de Pernambuco, uma importante área para os últimos desenvolvimentos do turismo e que está inserida na Área de Proteção Ambiental Costa dos Corais. Investigamos essa interação analisando as transformações da pesca nos últimos 20 anos através de uma abordagem antes-depois; comparando dois períodos (1999-2000 e 2016-2017) separados por desenvolvimentos de infraestrutura, crescimento populacional e turístico e transformações socioeconômicas. Em geral, as tipologias de pesca que sofreram aumento na frequência de uso relacionam-se com o crescimento da população e com a acessibilidade aos pontos de pesca, ou com inovações tecnológicas e o aumento da renda da população. Os resultados revelaram que existe uma interação entre esforço de pesca e CPUE em Tamandaré que é influenciada por uma combinação de fatores bióticos e disponibilidade de emprego relacionada à temporada de turismo. Merece destaque ainda as possíveis interações negativas entre o turismo e a pesca, como o desaparecimento de antigas tradições (ex. pesca de tainha), especialmente durante as temporadas de turismo mais intensas. Os resultados apresentam uma boa oportunidade para discutir a necessidade de zonas de uso na APA Costa dos Corais que possam preservar as antigas tradições, conciliando a pesca e a conservação.

Palavras-chave: Pesca de pequena escala. Turismo. Pesca recifal. Áreas marinhas protegidas.

Abstract

Coastal ecosystems provide valuable goods and services that can benefit humans directly or indirectly, including food, energy resources, climate regulation and favorable place for recreational activities. In the present study, we investigated the relation between fisheries and tourism in Tamandaré, in Northeastern Brazil and in the south of the state of Pernambuco, an important area for tourism latest developments that is inserted in the Costa dos Corais Environmental Protected Area. We investigate this tourism and small-scale fisheries interaction by looking into fisheries transformations over the last 20 years through a before and after approach comparing two distinct periods (1999-2000 and 2016-2017) separated by infrastructure developments, population and tourism growth and overall socio-economic transformations. In general, fisheries typologies that suffered an increase in frequency of use either relate to population growth and direct accessibility to fishing points or to technological innovation and increased income. Results revealed that there is an interaction between fisher effort and CPUE in Tamandaré that is influenced by a combination of biotic factors and employment availability related to the tourism season. The present work also highlighted possible negative interactions between tourism and fisheries, such as the demise of old traditions such as the seine fishery for mullets, especially during more intense tourism seasons. Results present a good opportunity for discussing the need for zones of use in the Costa dos Corais Protected Area that could preserve old traditions while conciliating fisheries and conservation.

Introduction

About 40% of the world's population lives within 100 km of a coastline and while the coastal zone covers only 6.3% of the world, it has been estimated that their goods and services are responsible for approximately 43% of the estimated total value of global ecosystem services (UN, 2017; Costanza, 1999). These goods and services can benefit humans directly or indirectly and include food, energy resources, climate regulation and favorable circumstances for recreational activities (Schuhmann and Mahon, 2015). Following worldwide tendency of coastal zone occupation, Brazil's coastal zone population represents approximately 26,6% of the country's inhabitants (IBGE, 2011). In the northeastern coast specifically, a region that concentrates one of the highest coastal population densities in the country, the presence of several high productivity ecosystems as the Atlantic forest, mangroves, estuaries and coral reefs has provided support for human settlement over the centuries (Moraes, 1999). Among these ecosystems, coral reefs stand out for providing important raw materials, coastal protection, nutrient cycling, maintenance of fisheries, and essential opportunities for tourism, recreation, education and research, thus having great ecological and economical importance (Maida and Ferreira, 1997; Barbier et al., 2011).

In regards to tourism, its market as a whole is composed of a combination of human, physical, social, cultural, economical and natural capital and, through direct and indirect interactions between them, is responsible for promoting human welfare (Brocklesby and Fisher, 2003; Neri and Soares, 2012). In the Northeast of Brazil, the activity is benefited by the high biodiversity and clear waters of tropical reefs, attracting tourists and being highly lucrative to individual economies (Barbier et al., 2011). However, the sustainability of tourism is often compromised by negative consequences of the misuse of natural resources that causes environmental problems such as changes in landscape, improper sanitation and resource degradation (Neri and Soares, 2012). As the pressure on coastal spaces increases, the development of opportunities for elites is facilitated and possibilities for exclusion of the less wealthy can also increase (Fabinyi, 2010).

In the northeastern coast of Brazil, as in many coastal tropical developing countries, tourism often interacts with fisheries, a sector that plays significant economical, social, cultural and ecological functions where they are present. However, fishing activities have been increasingly exposed to anthropogenic threats (e.g. overfishing and habitat degradation), natural threats (e.g. climate change) and a lack of public policies, especially for traditional users in tropical small-scale fisheries (Pauly, 1997; Froese and Kesner-Reyes, 2002; Silva,

2014). Thus, while tourism expands and fisher livelihoods suffer from such threats, fishers that originally depended exclusively on fisheries may resort to tourism as an opportunity to supplement their income (Salas et al., 2011). It is important to highlight that although most present coastal municipal districts in Brazil have developed from old fishermen villages dated back to the 18th century, the relationship between tourism and the fishery activity are seldom taken into account in tourism development plans in the coast of Brazil (Câmara-Cascudo, 1957; Diegues and Arruda, 2001; Ferreira and Maida, 2007).

Fishing and mollusk harvesting have been essential activities for indigenous people throughout the history of Brazil, with coastal fisheries being providers of protein for coastal farms, towns and villages (Vasconcellos et al., 2011). Tourism, on the other hand, has been stimulated since the late 1970s and accelerated through the 1990s, when the Federal Government and state governments in the Northeast of Brazil strongly invested resources in tourism (Siegel and Alwang, 2005). In 1994, with main funding from the Inter-American Development Bank (IADB) and financial execution of the Northeastern Bank (BNB), the creation of the Program for the Development of Tourism (PRODETUR/NE I) sought to create ideal conditions for the expansion and improvement in quality of touristic activities as well as improvement in livelihood of local populations (Paiva, 2014). In 2002, a second phase PRODETUR/NE II implemented projects encompassing sanitation, transportation, environmental protection, appreciation of cultural heritage, professional capacitation and institutional strengthening of states and municipalities to deal with tourism (Paiva, 2014). Overall, these programs allowed for relevant advances in tourism activities through the creation of infrastructure, airport renovations and implementation of roads that facilitated the access to touristic destinations. Consequently, Brazilian tourism has exhibited a dramatic growth: foreign tourists increased from 1.8 million in 1994 to over 5.1 million in 2000, while domestic tourism grew approximately 60 per cent during the same period (Siegel and Alwang, 2005). Moreover, Brazil has also experienced a rapid economic expansion since the first decade of the 21st century driven by income increase and social mobility - 10% of the country's population has entered in the middle class in 2010, consequently boosting the population's acquisitive power (WWF-Brasil, 2016).

The present study used a before and after approach to determine if the small-scale artisanal fishery of Tamandaré, in the state of Pernambuco and 100km distant from the large capital of Recife, suffered any transformations over the last 20 years and how possible transformations were related to the tourism expansion. The municipality of Tamandaré is an

important area for tourism latest developments as well as for fisheries and biodiversity conservation, with several protected areas established in the region (Ferreira et al., 2006). A before and after approach was used to compare two distinct periods separated by population and tourism growth, infrastructure developments, and overall socio-economic transformations, and to specifically answer the following questions: (i) Were there any changes in fishing gears, crafts and propulsion types? (ii) Has the frequency of use of fishing gears changed? Can the changes be related to tourism growth? (iii) How does the fisher effort vary between seasons of the same period? Is there a common trend in both periods? (iv) How does catch per unit effort (CPUE) vary between seasons and periods? Can these indices relate to each other?

Methodology

Study area

Tamandaré is located in the northeastern coast of Brazil ($8^o47'20''$ S, $35^o06'45''$W), state of Pernambuco, and extends for approximately 14 km of coast forming an open ocean embayment (Fig. 1). The area has a hot and humid coastal tropical climate, with seasons marked by two distinct periods: a rainy season from March to August and a dry season from September to February (Ferreira et al., 2006). Average annual precipitation is the highest in July (526 mm) and lowest in December (81 mm). The monthly variations of such parameters confirm a seasonality marked by two distinct periods and two transitional periods: December to February, summer months, have higher temperatures, higher salinity, higher water transparency and NE winds are predominant; between March and May a transitional period is observed; in the winter months of July to August precipitation is higher and temperatures, salinity and water transparency are the lowest, with SE winds predominant (Ferreira et al., 2006). After winter, the spring months are again characteristic of a new transitional period with the elevation of these values. The tide cycle is semidiurnal with a maximum amplitude of about 2,5 meters (Venekey et al., 2014).

Tamandaré is inserted in the Costa dos Corais Environmental Protection Area, created in 1997 to guarantee the conservation of coral reefs, beaches, mangroves and continental shelf with the sustainable use of natural resources along 135 km of coast. Costa dos Corais is the largest Brazilian marine environmental protection area, covering a total area of 413,563 hectares, and the first federal marine protected area to include the coastal reefs that are part of the unique Brazilian reef system, the only coral reefs in the South Atlantic (Maida and

Ferreira, 1997). The area is a multiple use MPA, meaning that uses have to be conciliated with conservation and guarantee sustainability of resources and minimize conflicts. The Management Plan was published in 2012 (ICMBIO, 2012).

Figure 1. Map of the study area showing (a) Brazil, (b) Costa dos Corais APACC, (c) Tamandaré's coastal zone with no-take area outlined in white.
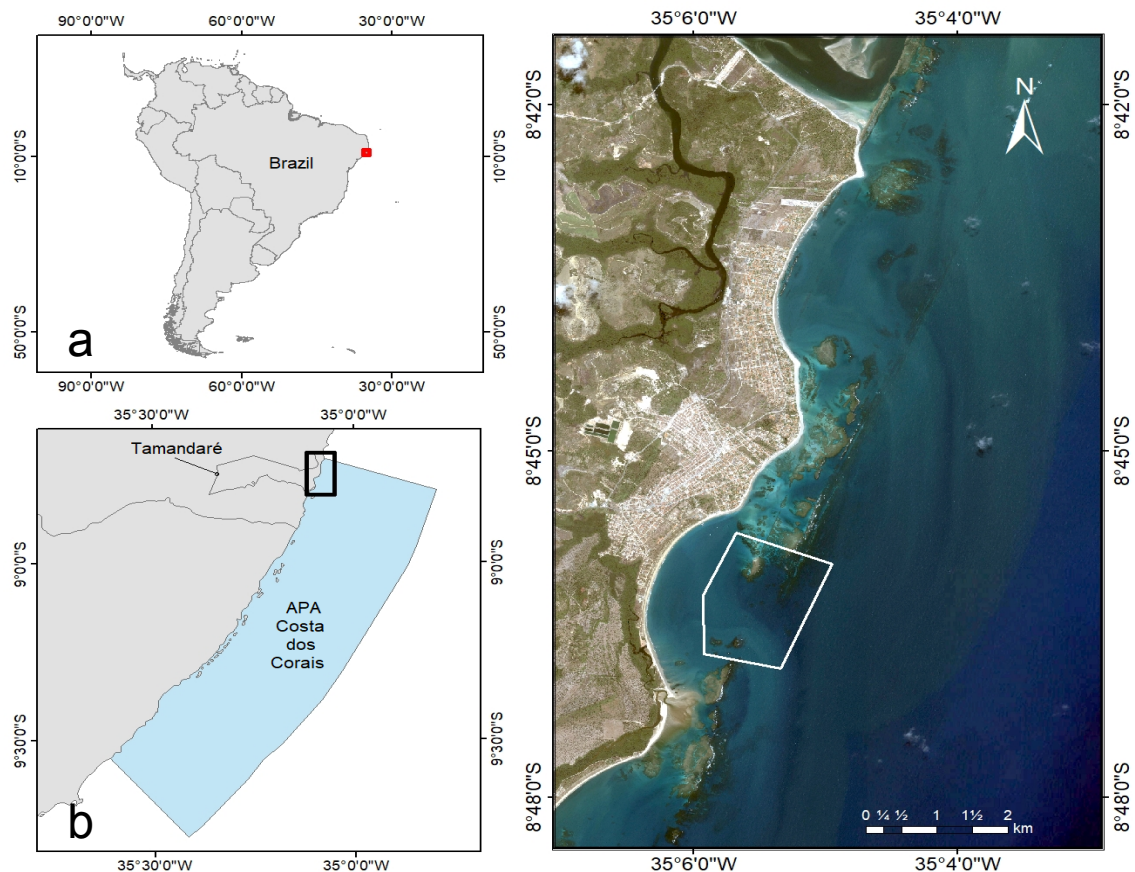
Source: author

Tourism

Tamandaré remained as a small fishers and farmers village for the first half of the 20th century with an economy dependent on coconut production and on the fishery (Lima, 2006). It had little economical importance to the state of Pernambuco until the beginning of the 1970 but from 1970 to 1990 a growing demand for summer vacation areas attracted population coming especially from Recife and the interior of the state and boosted the construction of hotels, condos and marinas and the distribution of land (Lima, 2006). As the region was the target for great expansion due to projected road infrastructure development to the famous destination of Carneiros' beach, the IADB funded the Recifes Costeiros Project in 1998,

aiming to mitigate development impacts through technical assistance offered for the development of a co-management structure and for the elaboration of a management plan for the Costa dos Corais Environmental Protection Area APACC (Ferreira et al., 2006).

Although there is a lack on official tourism data, tourism definitely provides employment in restaurants, hotels, and stores that are entirely active during summer and in popular boat tour activities that consists in day trips to reefs. There is also a clear dominance of second home tourism where vacationers only use the coastal area during the summer months (mainly January and February) (Lima, 2006), but this dominance started to shift with a massive increase of one daytrip visitors through tourism tours and also with a over 10 fold increase in the number of hotels and smaller inns in the town (Tamandaré Secretary of Tourism, *pers. comm.*).

Fishery

Fishing in Tamandaré is predominantly small scale according to Brazilian legislation that classifies artisanal small vessels as smaller than 20 Gross Registered Tonnage (GRT), this applies even to the motorized fleet that operates across the continental shelf (Law 11959/09). The interactions described here relate to the small scale fleet and other typologies that use fishing grounds near the coast with fishers generally reaching them with small artisanal vessels (*jangadas*) that might be propelled by sail, row or small outboard motors, swimming and even by walking up to of reefs once a semidiurnal tide pattern in the area allows for easy access by foot during low tides, particularly during spring tides. While landings from commercial fisheries go through trading sites such as fisher associations, the small individual landings from the subsistence fishery are pulverized as the product may be consumed or traded directly to local consumers (Ferreira and Maida, 2007).

Data collection

The Recifes Costeiros project conducted fishery initial data collection in Tamandaré from 1998 to 2004 with data collection restarting in 2015 and continuing to be collected until present date due to another important multi-institutional collaboration of the Projeto SOS Mata Atlântica to the Instituto Recifes Costeiros (former PRC) for the maintenance and effectiveness evaluation of the Marine Life Preservation Zone of the Municipal Park of Tamandaré (no-take zone) through funding from Fundação SOS Mata Atlântica and Fundação Toyota.

On both periods studied, data was collected on a weekly basis, on random days, and primarily during low tide when most fishers were at sea. There was a difference, however, in the data collection scheme. In the first period, four field agents were positioned at fixed points along the study area and counted from shore the number of fishers by gear, fishing craft and propulsion. During landing of catches, fishers were interviewed for individual information and catches were sampled. In the second period, field agents traveled the area by boat and performed a fishing effort census registering the number of fishers by gear, fishing craft and propulsion. Afterwards, at landing sites along the coast or at sea, fishers were interviewed for individual information and catches were sampled. In both periods, data registered included fisher main occupation, years of fishing experience, time of entry and exit at sea as well as species captured and total catch weight. Effort was presented by the number of fishers per day and catches by catch per unit effort (CPUE) presented in kilograms of catch per fisher per day (kg/fisher per day).

Two 12-months periods of reliable data were selected from the historical database in order to compare and evaluate two distinct scenarios separated by intense transformations: the period of July 1999 – June 2000 and July 2016 – June 2017, when pilot studies had been concluded.

Data analysis

Types of fishing gear, craft and propulsion type used in both periods were listed to determine presence/absence of categories that revealed continuation, innovation or vanishing of traditions. Differences in proportions of gear use between periods were tested using the χ^2 contingency test and adjusted residuals indicated what gears contributed the most to overall differences (Zar, 2010).

For analysis, monthly data were grouped in the four seasons of the year – spring, summer, fall, winter – and trends of fisher effort (number of fishers per day) and CPUE were observed for 1999/2000 and 2016/2017. Due to a lack of official tourism data, summer season was considered as the only touristic season. Analysis was done considering the most used gears of line and spear separately. Effort and CPUE data were tested for normality and homoscedasticity using Shapiro-Wilk and Levene's tests, respectively. CPUE data was log(x+1)-transformed.

A total of 147 days of survey were conducted in the period of 1999/2000 and 93 days in 2016/2017. In order not to bias effort results due to sampling effort differences, a one-way

ANOVA compared numbers of fishers per day among seasons of the same period and seasonal trends were qualitatively compared between periods. A two-way ANOVA then compared CPUE (kg/ fisher per day) values among season and among periods. Where significant results were found, post hoc multiple comparisons were performed using Tukey's test. Extreme catches were removed from data analysis.

Results

Overall, craft types, propulsion methods and fishing gears utilized in the small-scale artisanal reef fishery in Tamandaré differed slight between 1999/2000 and 2016/2017. Crafts types present on both periods included *jangada*, canoes and large motorboat; propulsion methods utilized in both periods were row, outboard motor, swim and foot; gears utilized in both periods were large beach seine, cast net, gill net, line, octopus hook, needlefish seine net, seine net, pole spear and mullet seine. However, results revealed important structural changes in the fleet including the total substitution of traditional *jangadas* propelled by sails by small, affordable outboard motors as the main propulsion strategy to access to fishing grounds farther from the coast. The spear pressure gun represented an important gear innovation for the fishery in the recent period.

Table 1 summarizes descriptions of gears and relates them with vessel propulsion method used, level of tourism interaction, and trend of use throughout periods studied (either stable, increase, or decrease).

Table 1. Gear description, propulsion method utilized by fishers with respective gears, level of tourism interaction (low, moderate, or high) and trend of frequency of gear use between 1999/2000 and 2016/2017 (stable, increase, decrease).

	Description	Propulsion	Tourism interaction	Trend of use
Line	pole or hand line with metal hooks of different sizes	by foot; motor; row	low	stable
Spear pole	makeshift gun made out of iron pole and surgical rubber band	motor; row; swim	high	decrease
Spear gun	air powered gun	swim	high	increase (new gear)
Octopus hook	iron pole with hooked end	by foot; motor; row; swim	low	increase
Gill net	net that hangs vertically to trap fish through gills	by foot; motor; row	moderate	stable
Mullet seine net	directed mullet fishing net that hangs vertically in the water and is drawn together to encircle fish	row	high	decrease
Cast net	throw net with small weights on the end	by foot	high	decrease
Seine net	net that hangs vertically in the water and is drawn together to encircle fish	row	high	decrease
Needlefish seine net	directed needlefish fishing net that hangs vertically in the water and is drawn together to encircle fish	row	high	stable

Source: author

Nine major categories of fishing gears were identified with a significant difference in overall frequency of gear utilization between periods (Chi- χ^2; p< 0.001) (Fig. 2). Adjusted residuals revealed that the gears that contributed the most for this difference were beach seine, octopus hook, seine net, mullet seine net, cast net and spear. The frequency of octopus hook and spear fishing increased while large beach seine, seine net, mullet seine net and cast net fishing declined. There was a massive replacement of rudimentary makeshift pole spears by more potent pressure spear guns as a crucial technological innovation: while in the early period the spear poles dominated with 19,91% they now represent a mere 3,83% of the total. Line remained as the dominant gear (40.8% and 46.2% in 1999/2000 and 2016/2017, respectively) followed by spear fishing.

Figure 2. Relative importance of fishing gears to the fishery in the periods of 1999/2000 and 2016/2017. Arrows indicate gears that contribute the most to significant differences between periods.
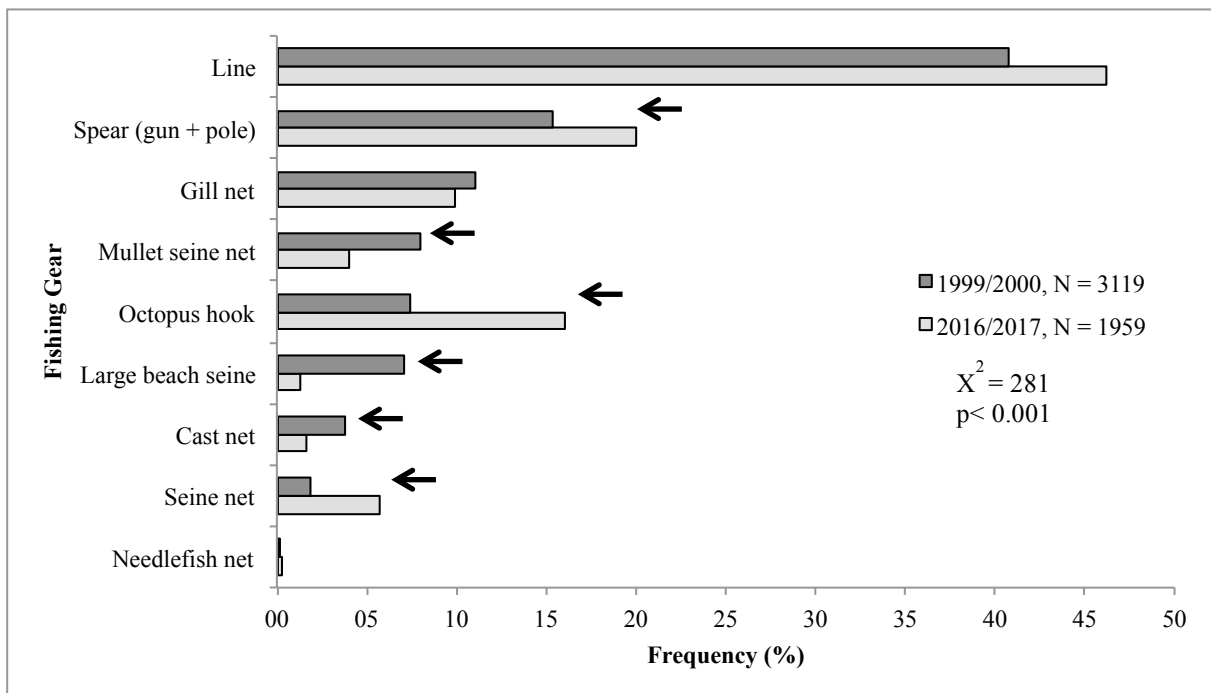
Source: author

Regarding analysis of seasonal trends of fisher effort and CPUE, results reveals an overall inverse variation pattern between these indicators for both periods studied (Fig. 3). In the earlier period, 1999/2000, mean fisher effort was the lowest during the summer even though greater catches were recorded during this season. In 2016/2017 a similar trend is observed although fisher effort is lower during spring and summer and CPUE is higher for spring and summer as well.

Figure 3. Variation of number of fishers per day and CPUE per season in 1999/2000 and 2016/2017. All gears considered. Whiskers represent standard error.

Source: author
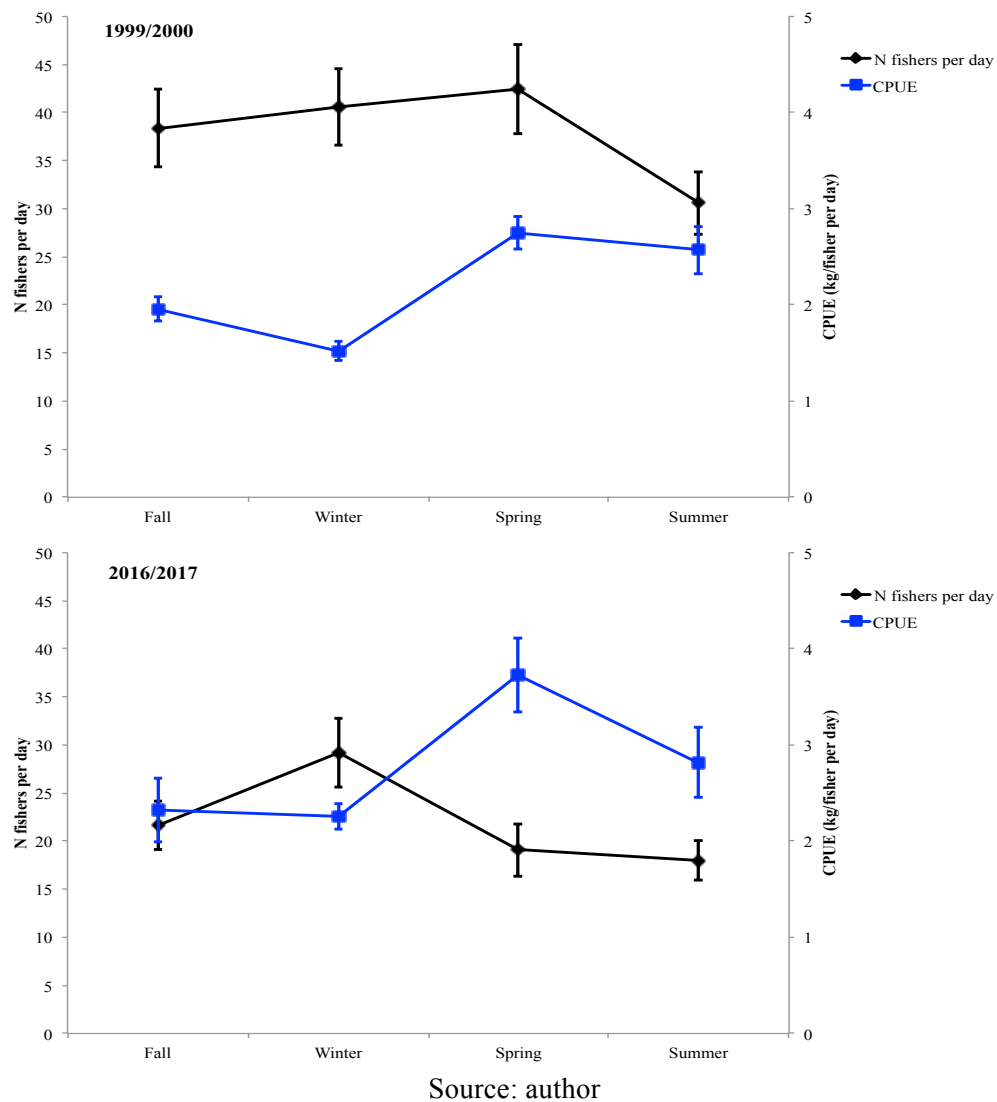
Fisher effort and CPUE for the dominant gears line and spear showed several significant variations among seasons for both periods (Fig. 4). In the line fishery, the number of fishers per day was not significantly different among seasons (F=0.889, p= 0.449) in 1999/2000 (although there is a clear decrease towards the summer months) but in 2016/2017 there was a significantly higher number of fishers per day during the winter compared to summer months (F=3.652, p< 0.05).

CPUE results of the line fishery showed that CPUE was not significantly different among periods, but there was a significant difference among seasons, where lower CPUE values were observed in the winter (Table 2). For spear, differences were significant among

period (higher CPUE in 2016/2017), among seasons (higher CPUE in the spring when compared to fall and winter), and there were significant interactions (Table 2).

Table 2. Statistical results from two-way ANOVA analysis of CPUE among periods and seasons

	F	*p*
Line fishing		
Period	0,15	0,695
Season	14,15	**5,98x10⁻⁹**
Period x Season	0,67	0,568
Spear fishing		
Period	4,99	**0,0263**
Season	10,06	**2,592x10⁻⁶**
Period x Season	3,22	**0,023**

Significant p-values are in bold.

Source: author

Figure 4. Variation of number of fishers per day and CPUE per season of the year in 1999/2000 and 2016/2017. Values for line fishing on the left and spear fishing on the right. Whiskers represent standard error.
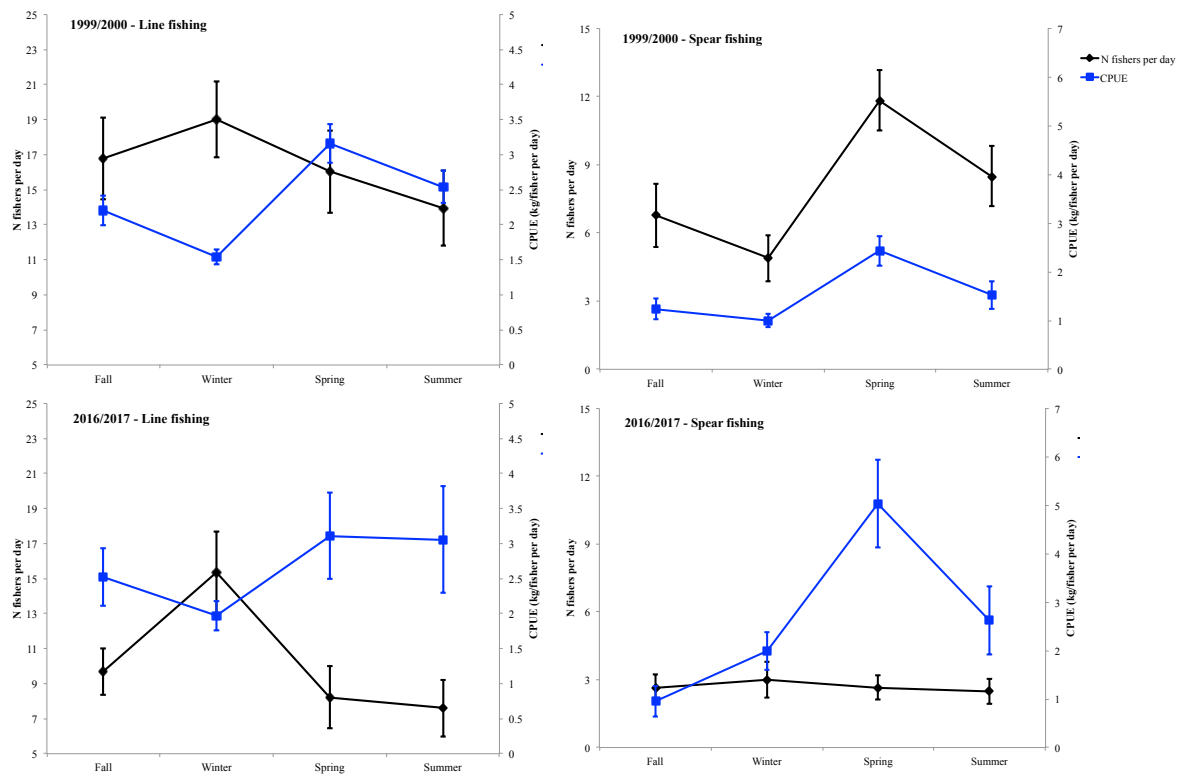
Source: author

Discussion

In general, fisheries typologies that suffered an increase in frequency of use either relate to population growth and direct accessibility to fishing points (e.g. line and octopus hook) or to technological innovation (e.g. spear guns and outboard engines) as well as to increased income (spear guns are more expensive than hand made spear poles, as outboard engines and fuel also cost more). The dominance of line fishing in Tamandaré agrees with the idea of accessible/cheap fishing that does not require much experience (although greater experience does determine better catches, Silveira et al., in prep), expensive equipment or even a craft once fishers may stay at the beach or easily walk up to the reefs. On the contrary, the decline in the frequency of large beach seine, seine net, mullet seine net and cast net fishing indicates the fading of practices that often require or are more successful when performed by fishers with greater experience, tradition and by multiple fishers at a time. For instance, it has been noted a decrease in traditional mullet fishing with mullet seine net that is mainly attributed to the fading of mullet fishing culture that has not been passed on through generations but also strongly due to alternative employment and tourist boat movements that disturb the activity. This method of fishing used to be composed of one experienced observer at the beach that would initially detect fish through water movement and signal for partners to quietly approach and then encircle the fish school while hitting the water with a paddle. Therefore, the movement of motorboats, estimated at 500 boats circulating during the high season, certainly has an impact of the fishery (Lima, 2006). In a particular tourism peak day, we observed more than 70 motor vessels and over 200 people circulating at once in a sunny day in areas originally designated to fisheries.

There is interplay between fisher effort and CPUE in Tamandaré that is influenced by a combination of factors and employment availability related to the tourism season. In the summer, when opportunities of alternative employment is high, a trend of decrease in mean number of line fishers at sea is observed and this tends to increase towards the winter when rainfall reduces tourism to a minimum. Mean CPUE values of the line fishery, on the other hand, decrease in the winter months possibly indicating that fishers who resort to the activity in the winter are those with less skills. This overall trend was true for both periods analyzed, indicating the interactions of the line fishery have remained similar. However, the spear fishery showed different trends among the two periods: while there was a significant higher number of fishers during the spring in 1999/2000, the 2016/2017 period did not show significant differences in spear fisher effort among seasons, with a considerably steady

number of fishers at sea throughout all seasons. This can be attributed to the fact that young spear fishers are the ones most involved in tourism trade: in fact, most members of the Jangadeiros fisher's association (see below) nowadays are involved in the tourism trade although may still fish commercially. The spear fishing CPUE values, however, remain significantly higher during the spring for both periods, a season with greater water transparency and lower tourism flux than summer vacations. In addition, according to fishers, the springtime always yields better catches as, after the bad conditions for fishing during winter, the fish stocks have "rested" from intense fishing pressure throughout the wet season.

As previously mentioned, the traditional sail *jangadas*, which are characteristic of Northeastern Brazil and are a valuable cultural heritage from African, indigenous and Portuguese cultures, had vanished. The availability of cheap outboard engines, an adaptation that spread quickly on continental waters in Brazil (INPE, 2009) and reached the marine areas in the last 10 years, replaced older engines as younger fishers replace older ones. However, *jangadas* have a profound symbolic and cultural meaning to the region and are part of the seascape and of the northeast identity and culture (Diegues, 1999). In recognition of this importance, a recent initiative from the local fisher association (*Associação de Jangadeiros de Tamandaré*) funded by Toyota do Brasil Foundation and SOS Mata Atlântica Foundation and supported by IRCOS, UFPE, CEPENE and municipal government is trying to restore the tradition as a touristic attraction in order to outcome cultural loss, aggregate touristic value and thus generate income to members of the association. The association was founded in 2003 in a post tourism development scenario, and although it was deactivated from 2012 to 2016 its activities were resumed in 2017. Currently, its membership board is composed of 35 members who are fishers that complement their income with community-based tourism activities as well as members that main occupation is related to the support of the nautical tourism in the area primarily during summer months.

The potential of fishers to switch to tourism activities is influenced by several geographical and social factors and, as shown in other places around the world, the livelihood focus of people might be related to the intensification of fishing effort and not so much by a shift to other more sustainable forms of livelihood (Fabinyi, 2010). In Tamandaré, such permanent shift will depend on employment opportunities being available beyond the summer months, as after January and February, houses, condos and several restaurants, stores and small hotels close their doors thus removing many people from tourism related jobs (Lima, 2006).

The present work also highlighted possible negative interactions between tourism and fisheries, such as the demise of old traditions such as the seine fishery for mullets, especially during more intense tourism season. Zoning is a central instrument for sustainable resource use in MPA and is a part of the APACC Management Plan. Multiple zones with specific rules for activities have been already established, including no-take zones, zones exclusive to tourism and zones for protected species (manatees). Zones that are exclusive to fisheries have not yet been implemented (ICMBio, 2012). Since 2017 and for the whole course of 2018 the APACC management plan is under revision, and the zoning plan is also under discussion (ICMBio, 2017). This could be a good opportunity to discuss the need for such zones that could preserve old traditions and conciliate fisheries and conservation.

The interaction between consumptive and non-consumptive direct uses should always be acknowledged and incorporated into integrated management strategies that use an ecosystem approach recognizing the connectivity of species and the interacting social and political structures in the reef environment (Mangi et al., 2007). Strategies should bring users of services together in order to find ways to use more services in a sustainable way or to add value to services already in use (Lopes et al., 2015).

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4 TEMPORAL CHANGES IN A SMALL-SCALE ARTISANAL REEF FISHERY: AN INVESTIGATION OF SUSTAINABILITY

Resumo

A pesca artesanal de pequena escala desempenha relevantes funções econômicas, sociais, culturais e ecológicas em todo o mundo, empregando mais de 90% dos pescadores mundiais, e melhorando seu meio de subsistência não apenas como resultado da renda direta, mas através de mecanismos extremamente positivos e impactos para o empoderamento, bem-estar e autoestima individual e coletiva. Em ambientes de recifes de coral, os efeitos da remoção direta de espécies combinada a destruição do habitat podem prejudicar tais impactos positivos da pesca, resultando em diferentes níveis de sobrepesca que podem terminar na destruição indiscriminada de recursos, a sobrepesca Malthusiana. Juntamente com a sobrepesca, a gestão inadequada ou muitas vezes inexistente ameaça ainda mais a perpetuação da pesca em países em desenvolvimento, onde a degradação da pesca tem sido documentada ao longo dos anos. Neste trabalho, adotamos uma abordagem de estudo de caso para observar uma tentativa de manter a sustentabilidade de uma pescaria de pequena escala através do estabelecimento de uma área marinha protegida e de uma zona de exclusão da pesca em uma comunidade costeira onde a pesca desempenha um papel significativo no Brasil, o município de Tamandaré. A coleta de dados e entrevistas com os pescadores foram realizadas em dois períodos distintos separados por intensas transformações e os dados de esforço por petrecho e as capturas foram analisados. No geral, os resultados indicam consequências de um aumento na pesca de oportunismo associado ao crescimento da população costeira e fácil acesso aos recifes, mas também de inovação tecnológica e medida de manejo. Embora a zona de exclusão represente aproximadamente 10% da zona costeira de Tamandaré, não há indicativos de impactos negativos para a pesca apresentados pelos indicadores analisados, mas que a medida de manejo foi minimamente eficaz para manter a sustentabilidade da pesca ao longo de todo período estudado.

Palavras-chave: Pesca recifal. Manejo. Área marinha protegida. Sustentabilidade.

Abstract

Small-scale artisanal fisheries perform relevant economical, social, cultural and ecological roles throughout the world, employing more than 90% of the world's fishers and fishing related workers while improving livelihoods not only as a consequence of direct income but through mechanisms that have extremely positive impacts for empowerment, well-being and individual and collective self-esteem. In coral reef environments, effects of direct removal of species combined with habitat destruction may impair such beneficial possibilities by resulting in different levels of overfishing that may terminate in the indiscriminate destruction of resources, the Malthusian overfishing. Along with overfishing, inadequate or inexistent management further threatens the perpetuation of small-scale fisheries tropical developing countries where fisheries degradation has been documented over the years. In this study, we take a case study approach to observe an attempt of maintaining the sustainability of a small-scale fishery through the establishment of a marine protected area and a no-take zone in a coastal community where fishing plays a significant role in Brazil, the municipality of Tamandaré. Data collection and fisher interviews were conducted in two distinct periods separated by intense transformation and effort data by gear and catches were analyzed. Overall, results indicate consequences of an increase in opportunistic fishing associated with growing coastal population and easy accessibility to reefs, but also of fishery innovation and management measures. Even though the no-take zone represents approximately 10% of Tamandaré's coastal zone, there are no indicatives of negative impacts to the local fishery presented by the indicators we analyzed but rather that the management measure was minimally effective in order to maintain catches stable throughout the period.

Keywords: Reef fishery. Management. Marine protected area. Sustainability.

Introduction

Small-scale artisanal fisheries perform relevant economical, social, cultural and ecological roles throughout the world, employing more than 90% of the world's fishers and fishing related workers while improving livelihoods not only as a consequence of direct income but through mechanisms that have extremely positive impacts for empowerment, well-being and individual and collective self-esteem (BENÉ, 2006; FAO, 2015). In coral reef environments, where fishing is the most important human exploratory activity, effects of direct removal of species combined with habitat destruction may impair such beneficial possibilities by resulting in different levels of overfishing that affect from economical aspects to species size structure, recruitment and ecosystem composition and, in a final stage, may terminate in the indiscriminate destruction of resources, the Malthusian overfishing (MUNRO & WILLIAMS, 1985; PAULY, 1989). This level of overfishing occurs in a context where lack of livelihood alternatives and declining catches induce poor fishers to destroy the resources they heavily depend on by fishing more intensively and often with destructive gears in an attempt to maintain their income (PAULY, 1989). Along with overfishing, inadequate or inexistent management further threatens the perpetuation of small-scale fisheries tropical developing countries where fisheries degradation has been documented over the years (PAULY, 1997; TEH & SUMAILA, 2007; SALAS et al., 2011; BENDER et al., 2014)

To overcome this scenario and guarantee fishery sustainability, the creation of marine protected areas and fishing restriction measures (e.g. no-take zones, gear prohibition, temporal closures, size limits, etc.) have been widely encouraged based on scientific evidence that points to the recovery of target and non-target species and increases in biodiversity inside well-managed protected areas as well as increases in fishery productivity nearby these zones (FLOETER et al., 2006; WORM et al., 2006). This has been officially endorsed by the 2010 Convention on Biological Diversity where signing parties agreed on protecting 10% of the world's oceans by 2020 through effectively managed, ecologically representative and well connected systems of protected areas (CBD, 2010).

In this study, we take a case study approach to observe an attempt of maintaining the sustainability of a small-scale fishery through the establishment of a marine protected area and a no-take zone in a coastal community where fishing plays a significant role in Brazil, the municipality of Tamandaré. Tamandaré is inserted in a conservation unit mosaic built by four protected areas (UCs) with different categories and different administration levels: Saltinho Biological Reserve, Forte de Tamandaré Municipal Natural Park, Guadalupe Environmental

Protected Area and Costa dos Corais Environmental Protection Area (APACC), the federal level MPA we will focus on this study. The APACC was established by federal decree in October 23rd 1997 with the objective of regulating uses of the reef ecosystem and is the largest federal MPA in the country, extending for approximately 135 km of coast. The MPA extends from the southern coast of the state of Pernambuco – northernmost limit in Tamandaré – to the north of Alagoas, comprehending an area from the high tide line at 33 meters to 18 miles from the coast, thus encompassing the entire continental shelf up to the shelf break and totaling an area of approximately 413.563 hectares (FERREIRA et al., 2001). It is classified as a sustainable use conservation unit, aiming to coordinate the goals of environmental preservation and conservation with its natural resources uses (fishing, tourism and research) in a sustainable manner (ICMBIO, 2012). It was the first federal conservation unit to include coastal reefs, an ecosystem that, alongside with mangroves, is the basis for fisheries production in the region (FERREIRA et al., 2001). Following a tendency of marine reserve creation as an effective ecosystem management measure for preservation of environment integrity and as a buffer against unforeseen failures in traditional fishery management schemes (PISCO, 2008), Costa dos Corais' first no-take zone was created and implemented in Tamandaré in 1999. All types of fishing and exploration, visitation, tourism and nautical activities have been prohibited since April 1999 and only authorized research activities have been conducted in the 4km^2 area since then (FERREIRA et al., 2001). The no-take has served as an experimental demonstration of an effective management measure. Through visual underwater censuses that have monitored fish abundance, it was possible to observe increases in abundance of commercially relevant species inside the area already in the first years of its establishment (FERREIRA et al., 2001; FERREIRA et al., 2007). Since then, monitoring has continued, with significant higher abundances for many but not all species (FERREIRA et al., in prep.)[1].

In a context of intense transformations that included a central management measure that was the establishment of a no-take zone as well as socio-economic transformations, a historical database of effort and catch composition data allowed for the evaluation of the small-scale fishery of Tamandaré. Since the first decade of the 21st century, Brazil has experienced a rapid economic expansion driven by income increase and social mobility - 10%

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of the country's population has entered in the middle class in 2010, consequently boosting the population's acquisitive power (WWF-BRASIL, 2016). Moreover, Tamandaré has experienced intense population growth and consequent urban development over the past decades. Demographic censuses have revealed a population increase from 17.281 in 2000 to 20.715 in 2010 with a predicted population of 23.100 in 2017 (BRASIL, 2017). Although fishing and agriculture are traditionally the main activities of the region, tourism has suffered a great expansion of over the past decades as a result of expressive investments in infrastructure (PAIVA, 2014). Nowadays, tourism is responsible for greatly altering the city dynamics during the summer season due to elevated proportions of second homes and due to its contribution to the city's economy.

The objective of this work was to compare the small-scale artisanal reef fishery of Tamandaré occurring in two distinct periods separated by important transformations. In order to do that we observed changes in: (i) fisher profile; (ii) catch per unit effort (CPUE); (iii) catch composition; (iv) fishery yield. Considering a context of environmental and anthropogenic transformations, it is expected that the fishery profile has somehow changed between the studied periods and that management measures have been minimally sufficient to prevent degradation of the fishing activity in Tamandaré.

Methodology

Study area

The municipality of Tamandaré is located in the northeastern coast of Brazil (8°47'20" S, 35°06'45''W), 110km south of Recife, state of Pernambuco, and extends for approximately 14 km of coast forming an open ocean embayment (figure 1). The area has a hot and humid coastal tropical climate, with seasons marked by two distinct periods: a rainy season from March to August and a dry season from September to February (FERREIRA & MAIDA, 2007). Abiotic parameters generally vary following a cycle: higher temperatures, higher salinity and greater water transparency are observed in the summer months, from December to January, when winds are predominantly from the northeaster quadrant; from March to May (Fall) a transition period is observed with increasing values; highest precipitation values and lowest temperatures, salinity and average water transparency are observed in the winter, from June to August, when winds are predominantly from southeast; the Spring marks another transition period with an increase in mentioned values (FERREIRA & MAIDA, 2007).

The waters of Tamandaré are influenced by the Formoso River in the north portion, by the Una River in the south and by the Mamucabas River that flows directly into the studied area, a biodiversity hotspot that encompasses Atlantic rainforest, mangroves, sandbanks, estuaries, seagrass beds, and coral reefs (BARBOSA et al., 2016). The coral reef formations are arranged in three groups running parallel to the coast (MAIDA & FERREIRA, 1997). The region between the coastline and third reef line has exposed reefs during low tide, with maximum depth of roughly 10 meters, and is locally known as "inward sea" ("*mar de dentro*") (GASPAR, 2006). Beyond the third reef line, depth increases gradually towards the sea, becoming the "outward sea" ("*mar de fora*") (GASPAR, 2006).

Tamandaré holds a small-scale artisanal reef fishery characterized, as it is typical of such fishing communities, by its great diversity of gears and fishing strategies and by its great relevance to the area economy. Fishing is the most important exploratory activity occurring in coral reefs in Tamandaré as its products represent the main income source of nearby fisher communities and its yield is absolute (FERREIRA et al., 1998). The fishery is predominantly of subsistence, being typically practiced by very low-income population and, whether fish is sold or consumed, it provides a mean of living instead of exclusively having lucrative ends, (MACINCKO & SCHUMANN, 2007). Fishing grounds are near the coast and are reached by swim, by foot primarily during spring tides, or by small artisanal vessels (*jangadas*) in fishing trips that last no longer than a day. Landings do not go through any trading site and, although they are composed of very small individual captures (mainly fish, octopus and lobster), the total fishery production in Tamandaré is considerably significant (FERREIRA et al., 2001; FERREIRA & MAIDA, 2007).

Figure 1. Map of study area showing (a) Brazil, (b) Costa dos Corais, (c) Tamandaré coastal zone with no-take area outlined in white.
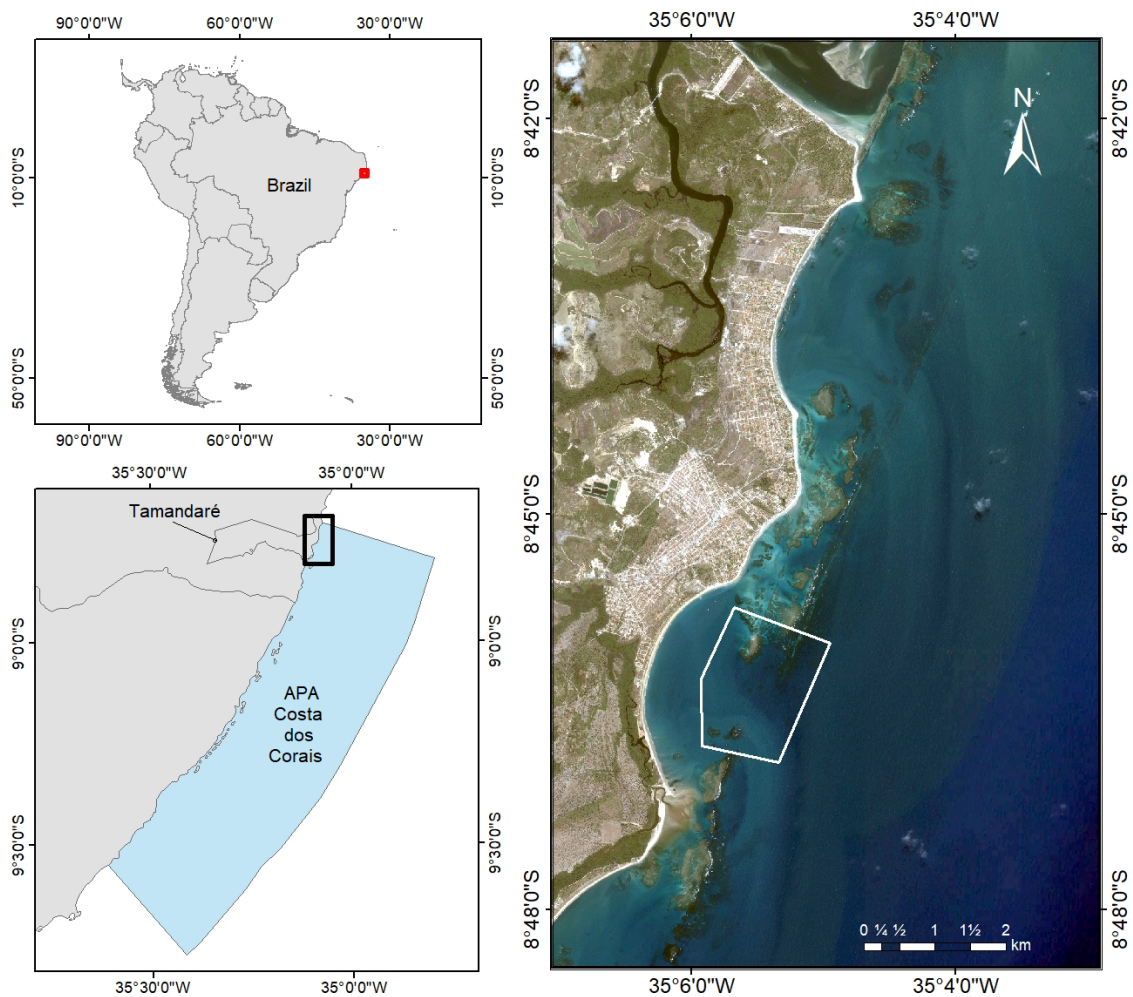
Source: author

Data Collection

Data collection and fisher interviews were initially conducted by the Recifes Costeiros Project (PRC) from 1998 until 2004, when effort data by gear and catches were analyzed, and same data returned to be collected in 2005 and have been collected until present date due to a multi-institutional collaboration of the Projeto SOS Mata Atlântica to the Instituto Recifes Costeiros for the maintenance and effectiveness evaluation of the Zona de Preservação da Vida Marinha do Parque Municipal de Tamandaré through funding from Fundação SOS Mata Atlântica and Fundação Toyota.

Two 12-months periods of reliable data were selected from the historical database in order to compare and evaluate the two distinct scenarios: the period of July 1999 – June 2000, when no-take zone was just implemented but measures where not yet effective, and July 2016 – June 2017, when pilot studies had been concluded. In both periods researchers and members

of the fishing community who were trained to become field agents performed data collection.

Data was collected on average two day per week, on random days. Information recorded included count of fishers, fishing craft and propulsion type and individual fisher information (occupation, years of fishing experience, time of entry and exit at sea as well as species captured and total catch weight). Counting of fishers was done primarily during low tide, when most fishers were at sea, and data on fisher effort by gear, fishing craft and propulsion by region and specific reef was registered. At landing sites or at sea, fishers were interviewed for individual information and catch was weighed.

Due to personnel limitation and logistics, data collection effort differed slightly in 1999/2000 vs. 2016/2017. While in 1999/2000 4 field agents were each designated one subarea and covered that subarea in one day, in 2016/2017 2 field agents/researchers traveled by motorboat. In both periods, fishers were first accounted for in the entire subarea and then interviews were performed. In order to resolve possible biases and balance fishing effort results, fishing effort data was standardized on a surveys per week basis with same amount of field days each corresponding week, totaling 87 days of effort data each period. Interview and fish length data was not standardized; all the information collected was used in analysis.

Data Analysis

Fisher profile

Fisher profile proportions of amateur vs. professional using all fishing gears were compared through fishers in the activity calculated from interview data, using the χ^2 contingency test (ZAR, 2010). As described in the *APACC's Management Plan*, professional fishers are defined as ones who have fishing as primary activity and should be licensed to commercialize their catch while non-professional/amateur fishers generally have other occupations, do not have commercial purposes and fish for recreation or even resort to this activity for food security and household livelihoods (ICMBIO, 2012).

CPUE

To investigate capture pattern variations and compare fishing gears between periods, daily rates of capture were considered. Due to the fishery's multi-specific nature, analysis of catch-per-unit-effort (CPUE) used directed fishery data for fish and octopus separately to calculate the mean catch in kilograms per fisher in a day (kg/ fisher day). CPUE data was tested for normality and data did not show a normal distribution even after Box-Cox

transformation so differences between periods were tested using Mann-Whitney U-tests. Fish CPUE data for the dominant gears line and spear were compared taking into consideration the appearance of a new gear – the spear gun – in the latter period (Silveira et al. in prep.) so paired tests of spear pole between the two periods and then a test between spear pole and spear gun in the more recent period to investigate gear innovation efficiency were conducted. Octopus CPUE of spear and octopus hook fishing were conducted separately and finally the overall CPUE (fish, octopus and lobster considered) of amateur and professional fishers between periods were tested.

Catch composition

Fish catch analysis of the most used gears line and spear were conducted in PRIMER following methods described by Clarke and Warwick (2001). Species that never constituted more than 1% of the total abundance in either period were removed from analysis. Since one species was particularly abundant in catches, data were square root transformed to increase sensitivity to detect differences driven by species of intermediate abundance. Non-metric multidimensional scaling (MDS) based on Bray-Curtis similarity measures was used to observe variability of catches between periods. An analysis of similarity test (ANOSIM) was conducted to test whether the catch composition was significantly different between the periods of 1999/2000 and 2016/2017. A similarity percentages analysis (SIMPER) identified the species important in driving trends. All analysis used a significance level of p=0.05.

Estimation of fishery yield

Annual fishery yield (Y, tons km^{-2} $year^{-1}$) was estimated for both periods based on the following formula:

$$Y = \frac{FCD}{A}$$

where F is the mean number of fishers per day, C is the mean daily catch per fisher in kilograms, D is the number of days in a year (365 days) and A is the estimated reef area (12 km^2).

All analyses considered a significance level of $p= 0.05$

Results

A total of 1192 fisher interviews in 1999/2000 and 888 interviews in 2016/2017 were conducted, with 8000 and 4505 fish, octopus and lobster individuals measured, respectively.

Fisher profile

There was a significant shift in fisher profile: in 1999/2000 the fishery consisted dominantly of professional fishers (69%) whereas in 2016/2017 it was primarily composed of non-professional/amateur fishers (72%) (Chi-squared; $p < 0.01$).

CPUE

CPUE of fish from the line fishery did not vary significantly between periods (Mann-U; $p > 0.05$) as fish CPUE of the rudimentary spear pole did not vary significantly as well (Mann-U; $p > 0.05$). However, a significantly higher fish CPUE was observed for the spear gun when compared to the rudimentary spear pole CPUE during the same period (Mann-U; $p < 0.05$) Values of octopus CPUE of octopus hook did not reveal significant differences between years (Mann-U; $p > 0.05$). While within each period the CPUE of amateur fishers was significantly lower than that of professional fishers, as it would be expected, the CPUE of amateur fishers did not vary significantly between periods (Mann-U; $p > 0.05$) but professional fishers CPUE showed a significant increase (Mann-U; $p < 0.05$) in 2016/2017. Table 1 summarizes all the CPUE values calculated and the significance levels of change.

Table 1. Results of CPUE calculations and the significance level of change (Mann-Whitney U-test)

|	Mean CPUE	Stand. Error	Median CPUE	U-Test
Line (fish)				
1999/2000	2,288	0,107	1,6	
2016/2017	2,706	0,211	2	NS
Spear pole (fish)				
1999/2000	1,747	0,158	1,2	
2016/2017	1,3	0,286	1	NS
Spear pole vs. gun (fish)				
spear pole 2016/2017	1,185	0,284	0,5	
spear gun 2016/2017	3,608	0,615	2	**
Spear (octopus)				
1999/2000	0,448	0,062	0	
2016/2017	0,053	0,023	0	**
Octopus hook (octopus)				
1999/2000	1,254	0,114	0,9	
2016/2017	1,411	0,179	1,2	NS
Amateur fishers (overall)				
1999/2000	1,453	0,185	0,875	
2016/2017	2,201	0,274	1	NS
Professional fishers (overall)				
1999/2000	2,483	0,222	1,5	
2016/2017	3,702	0,385	2,5	**

NS = not significant, **p< 0.05

Source: author

Catch composition

A total of 24 species in the line fishery and 15 species in the spear fishery were recorded occurring at a total abundance greater than 1% (Fig. 2). Considering subareas as replicates, MDS plots suggested some degree of differentiation between catches from 1999/2000 and 2016/2017 for line and a clearer differentiation for spear fishing. ANOSIM results revealed no significant variations for the line fishery ($R= 0.083$, $p= 0.20$) but showed significant variations for the spear fishery ($R= 0.438$, $p= 0.029$). SIMPER results indicated that any dissimilarity that did occur between compositions of line fishery catches was driven mainly by the higher abundance of the grey parrotfish *Sparisoma axillare* in catches while in the spear fishery *Sparisoma axillare, Mugil spp.* and *Acanthurus coeruleus* contributed in approximately 50% for changes in catch composition between periods (Table 2).

Table 2. Results of SIMPER analysis for species captured in the line and spear fishery, showing which species best explained differences in catch composition between periods (average dissimilarity: line = 46,49; spear = 40,56).

Species	Average Abundance		Average dissimilarity	Contribution (%)	Cumulative contribution (%)
	1999/2000	2016/2017			
Line fishing					
Sparisoma axillare	18,86	9,31	5,17	11,13	11,13
Lutjanus synagris	5,25	4,72	3,47	7,47	18,60
Pomadaysys corvinaeformis	6,61	2,18	3,10	6,68	25,27
Haemulon aurolineatum	4,48	7,26	2,44	5,24	30,52
Sphyraena guachancho	3,73	2,89	2,35	5,05	35,56
Cephalopholis fulva	3,20	5,25	2,32	5,00	40,56
Cynoscion spp.	0,50	3,61	2,25	4,85	45,40
Epinephelus adscensionis	5,98	7,85	2,04	4,39	49,80
Haemulon squamipinna	4,44	2,99	1,94	4,18	53,98
Eugerres brasilianus	3,99	0,83	1,92	4,12	58,10
Holocentrus adscencionis	5,41	6,71	1,86	4,00	62,10
Opisthonema oglinum	2,05	2,54	1,80	3,88	65,98
Halichoeres spp.	6,59	6,10	1,75	3,77	69,75
Conodon nobilis	3,22	2,12	1,73	3,72	73,48
Haemulon plumieri	2,68	2,10	1,61	3,47	76,94
Ophioblennius trinitatis	0,00	2,35	1,57	3,39	80,33
Abudefduf saxatilis	2,73	1,29	1,43	3,08	83,41
Myripritis jacobus	2,68	0,50	1,38	2,97	86,38
Netuma barba	2,06	2,27	1,26	2,71	89,09
Haemulon parra	2,31	1,62	1,25	2,69	91,77
Spear fishing					
Sparisoma axillare	10,33	10,21	9,09	22,41	22,41
Mugil spp.	2,93	0,00	5,36	13,22	35,63
Acanthurus coeruleus	1,78	3,61	5,03	12,40	48,03
Lutjanus alexandrei	0,00	2,26	3,88	9,56	57,59
Epinephelus adscensionis	5,30	4,00	3,18	7,85	65,44
Haemulon parra	1,72	0,25	2,94	7,26	72,70
Cephalopholis fulva	0,00	1,41	2,41	5,95	78,66
Holocentrus adscensionis	2,09	1,91	2,36	5,83	84,49
Halichoeres spp.	1,82	1,55	2,31	5,69	90,17

Figure 2. Catch composition distribution of gears (A) line and (B) spear.
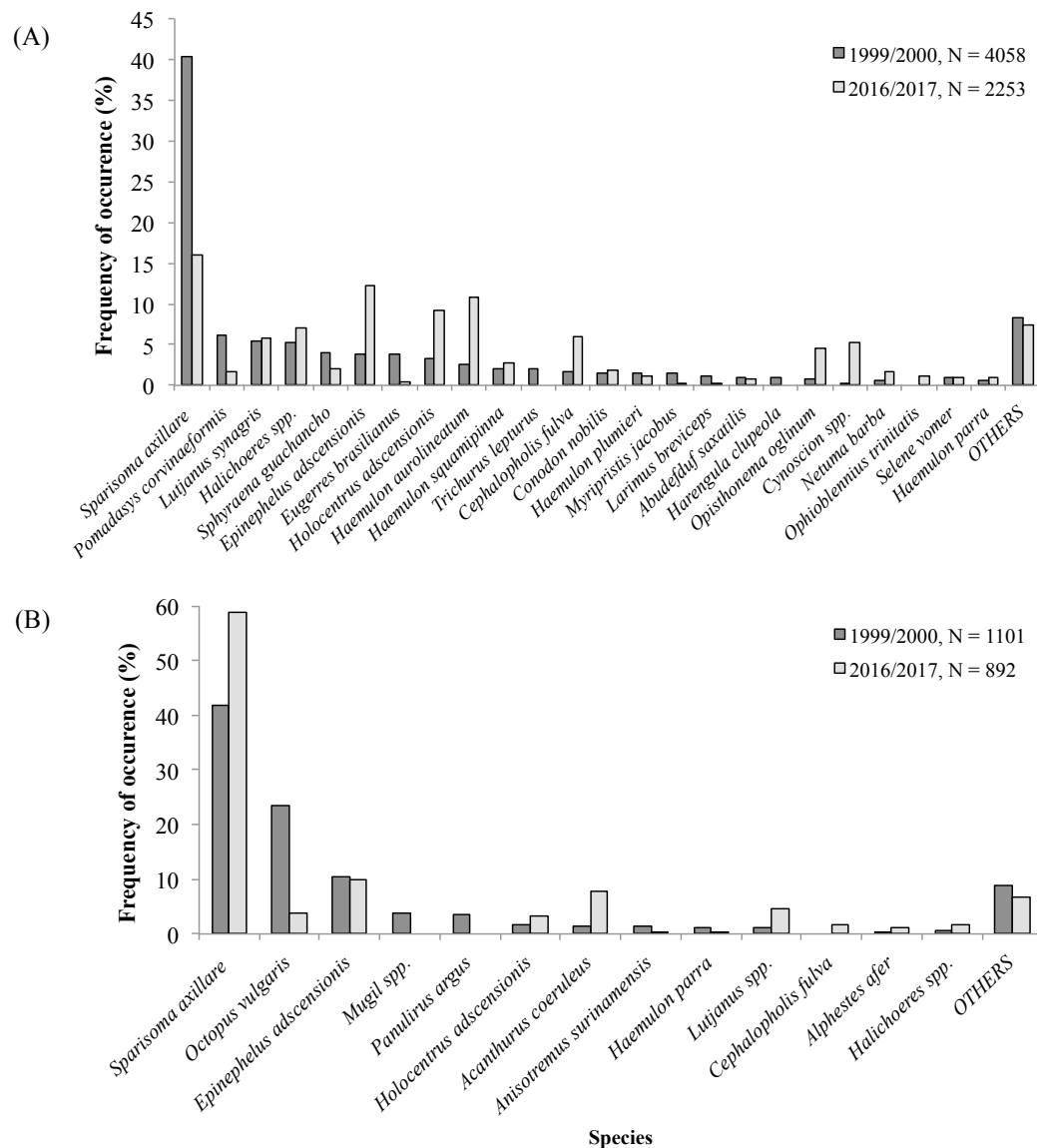
Source: author

Fishery yield estimation

   In 1999/2000 there was an average of 36 fishers per day at sea with mean daily catch of 2,24 kg per day thus estimated yield in the period was 2,4 tons km^{-2}. In 2016/2017, an average of 22 fishers with mean daily catch of 3,08 kg produced an estimated yield of 2,1 tons km^{-2}.

4. Discussion

Overall, results indicate consequences of an increase in opportunistic fishing associated with growing coastal population and easy accessibility to reefs, but also of fishery innovation and management measures. The shift that occurred over the years for a fishery made up mostly of amateur fishers is also indicative of relevant socio-economic transformations that include the vanishing of fishing as a culture passed on throughout generations. During full and new moon phases, a significant and positive correlation was found for line and non-vessel based fisher effort, a consequence of reef exposure. During spring tides, people can easily walk or wade to the reefs, with no need for vessels, further reinforcing how amateur/opportunistic fishers take advantage of the accessibility of the activity in the region. This both agrees with the theory that small-scale fisheries, primarily due to overall low entry costs, have contributed tremendously as a buffer and labor safety net by substituting and/or complementing other economic activities for increasing rural and unskilled population over the past decades, especially in developing countries (BÉNÉ, 2006) but also shows that even with better economic conditions and presence of alternatives, opportunistic fishing effort continues to increase.

For spear fisher effort, a greater influence of period studied points to the innovation represented by the introduction of the spear gun in the more recent period. Professional fisher CPUE has actually significantly increased, suggesting consequences of gear efficiency associated to greater fisher expertise and positive effects of the no-take area. Moreover, while mean CPUE of spear gun shows a significant increase indicating a greater power of capture for the innovative gear when compared to the rudimentary spear pole, CPUE of most gears and amateur fisher catches results reveal a stability in catch, that is further confirmed by relatively stable estimated fishery yields among the periods studied.

Although *Sparisoma axillare* remained as the main resource of the line fishery there was a clear decline in its percent frequency between periods. This is most likely related to the vanishing of the species traditional directed line fishery ("bobozeiros"), who were older, very experienced fishers commonly seen in the outer reefs in the earlier period studied. In the spear fishery, variations in frequency of species that mostly explain changes between periods may be related to different aspects of the fishery of Tamandaré. Firstly, a relative increase in *Sparisoma axillare* in the spear catch indicates an increase in efficiency of the spear fishery promoted by the innovative/more efficient spear gun. Then, a relative decline in the percent abundance of *Mugil spp.* could be explained by increase in boat movement especially during

summer months that pushes fish away as well as vanishing of the traditional mullet net seining (see SILVEIRA et al., chapter 1). A relative increase in the abundances of snappers and medium sized groupers (albeit not significant, see fig. 2) indicate a positive effect of the protected area, since these groups have presented greater biomass increase inside the no-take according to past and current studies (FERREIRA et al., 2007; FERREIRA et al., in prep.). The increase of *Acanthurus coeruleus* in the catches, by the other hand, may both reflect their increase in the no-take area as detected by the above studies and a new trend of exploitation of this species for a market for their fillets that has been developed in the last decade (Fishers Association pers. comm.)

Final Considerations

Even though the no-take zone represents approximately 10% of Tamandaré's coastal zone, there are no indicatives of negative impacts to the local fishery presented by the indicators we analyzed but rather that the management measure was minimally effective in order to maintain catches stable throughout the period. In fact some evidences indicate that the fishery has possibly benefited from biomass spillover, as observed in other regions of the world (MAYPA et al., 2002).

Globally, studies have shown a shift in trophic level of catches from higher to lower levels where groupers used to be the major targets but in more recent times parrotfishes and surgeonfishes have assumed this position (BENDER et al., 2014). In Tamandaré, the continued dominance of parrotfishes in the catch in both periods may suggest that the top predator demise might have occurred even before the establishment of the marine protected area. In fact, much of the decline of trophic level around the world has occurred before the 1990s (PAULY, 1989). Therefore, the positive aspect is that, for the past 20 years, the established scenario remained stable and therefore sustainable.

In a typical scenario of Malthusian overfishing, evidences of declining catches, ecological overfishing, non-enforcement of management regulations, entry of new fishers with no fishing tradition, and increasing use of destructive gears, among other characteristics are expected (PAULY, 1993 apud TEH & SUMAILA, 2007). However, even with the entry of opportunistic fishers in the fishery of Tamandaré, evidences for declining catches were not found, as well as no major change in catch composition indicating a shift to a new phase and to ecological overfishing.

Nevertheless, the situation in Tamandaré configures a unique situation of fragile equilibrium. To what extent this management measure and enforcement is able to buffer the unregulated entry of people in the activity in the common area, and lack of control over gear efficiency and fishing strategy evolution in order to maintain this fragile equilibrium is questionable. Fisheries management agencies should highly take into consideration opportunistic fishers role when developing management measures in order to properly register, control, and minimally educate these and all other fishers about the environment and the impacts they might cause on it. The success of a management tool is often enhanced when it is paired with other measures such as controlling fishing effort with quotas in combination with limited entry or marine protected areas with effort restrictions (SELIG et al., 2017).

In Brazil, the usual is to have a lack of social capital restraining communities to launch initiatives of their own and, in addition, low literacy levels and poor organization, impairing communication and their ability to understand problems and make connections (LOPES et al., 2015). In Tamandaré the situation seems not follow the "Brazilian norm", probably due to a combination of local conservation measures promoted by multiple MPAs, job inclusion in the tourism industry (see SILVEIRA et al., chapter 1), partnerships between multiple institutions and fisher engagement through local initiatives that promote co-management such as the local councils (FERREIRA et al., 2006; GLASER et al., in press). In conclusion, in any setting where there is lack of national fishery monitoring programs, lack of data, and institutional instability, local initiatives should be strongly encouraged and implemented by a variety of local institutions such as universities, non-governmental organizations, local councils, and mostly definitely by the community involved in order to guarantee local empowering and to ensure fishery sustainability.

Acknowledgements

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5 CONCLUSÃO GERAL

A abordagem temporal comparativa do presente estudo em dois períodos separados por desenvolvimentos de infraestrutura, crescimento populacional e turístico, e transformações socioeconômicas, revelou importantes transformações na pesca artesanal de pequena escala em Tamandaré. No geral, as tipologias de pesca que sofreram um aumento na frequência de uso relacionam-se com o crescimento da população e com a acessibilidade aos pontos de pesca, ou com inovações tecnológicas e o aumento da renda da população. Sendo assim, os resultados indicam consequências de um aumento na pesca de oportunismo associado ao crescimento da população costeira e fácil acesso aos recifes, mas também de inovação tecnológica e medida de manejo. Por outro lado, tipologias de pesca que apresentaram redução na frequência de uso indicam o desaparecimento de práticas que geralmente necessitam ou são mais eficientes quando executadas por pescadores com maior experiência, tradição ou por múltiplos pescadores atuando em colaboração. Em relação a interação da atividade pesqueira com o turismo na região, os resultados revelaram que existe uma interação entre esforço de pesca e CPUE em Tamandaré que é influenciada por uma combinação de fatores e disponibilidade de emprego relacionada à temporada de turismo. O potencial da troca da atividade pesqueira por atividade turística é influenciada por inúmeros fatores sociais e geográficos e, como evidenciado ao redor do mundo, está muitas vezes ligado a intensificação da atividade pesqueira e não a migração para atividades sustentáveis (FABINYI, 2010). Em Tamandaré, essa migração dependeria de oportunidade de empregos além dos meses de verão uma vez que, depois de janeiro e fevereiro, casas, condomínios, restaurantes, lojas e hotéis fecham, assim removendo muitas pessoas de empregos relacionados ao turismo (LIMA, 2006). Desta forma, é essencial que as interações entre os usos diretos de consumo (pesca) e usos de não-consumo (turismo) sejam sempre reconhecidas e incorporadas em estratégias de manejo integradas que utilizem uma abordagem ecossistêmica que identifique a conectividade das espécies e as estruturas sociais e políticas presentes no ambiente recifal (MANGI et al., 2007). Estratégias devem reunir todos usuários dos serviços de forma que encontrem maneiras sustentáveis de utiliza-los (LOPES et al., 2015).

O cenário da pesca em Tamandaré encontra-se em um estado de equilíbrio frágil, onde embora a zona de exclusão represente aproximadamente 10% da zona costeira de Tamandaré, não há indicativos de impactos negativos para a pesca apresentados pelos indicadores analisados, mas que a medida de manejo foi minimamente eficaz para manter a

sustentabilidade da pesca ao longo de todo período estudado. Entretanto, até que ponto esta medida de gestão e fiscalização é capaz de amortecer a entrada não regulamentada de pessoas na atividade na área comum, e a falta de controle sobre a eficiência das artes e a evolução da estratégia de pesca para manter este equilíbrio frágil é questionável. Em um cenário típico de Sobrepesca Malthusiana, evidências de declínio de capturas, sobrepesca ecológica, falta de aplicação de regulamentações de manejo, entrada de novos pescadores sem tradição de pesca, e aumento do uso de artes destrutivas, entre outras características, são esperadas (PAULY, 1993 apud TEH & SUMAILA, 2007). No entanto, mesmo com a entrada de pescadores oportunistas na pescaria de Tamandaré, não foram encontradas evidências de declínio de capturas, bem como nenhuma mudança significativa na composição das capturas, indicando uma mudança para uma nova fase e para a sobrepesca ecológica.

As agências de manejo pesqueiro devem levar em consideração o papel dos pescadores oportunistas no desenvolvimento de medidas de manejo, a fim de registrar, controlar e educar minimamente esses e todos os outros pescadores sobre o meio ambiente e os impactos que podem causar sobre ele. No Brasil, o costume é a falta de capital social que restrinja as comunidades a lançar iniciativas próprias e, além disso, baixos níveis de alfabetização e má organização, dificultando a comunicação e sua capacidade de entender problemas e fazer conexões (LOPES et al., 2015). Em Tamandaré a situação parece não seguir a "norma brasileira" provavelmente devido a uma combinação de medidas de conservação locais promovidas por áreas protegidas, ofertas de emprego na indústria do turismo (ver SILVEIRA et al., pg. 5), parcerias entre instituições e engajamento de pescadores por meio de iniciativas locais que promovem a co-gestão como os conselhos municipais (FERREIRA et al., 2006; GLASER et al., no prelo). Em conclusão, em qualquer cenário onde há falta de programas nacionais de monitoramento da pesca, falta de dados e instabilidade institucional, iniciativas locais devem ser fortemente encorajadas e implementadas por uma variedade de instituições locais como universidades, organizações não-governamentais, conselhos locais, e principalmente pela comunidade envolvida, a fim de garantir o empoderamento local e garantir a sustentabilidade da pesca.

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