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Tendências da exploração pesqueira na costa do Rio Grande do Norte

Ludmila de Melo Alves Damasio

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Dissertação apresentada ao Programa Regional de Pós-Graduação em Desenvolvimento e Meio Ambiente, da Universidade Federal do Rio Grande do Norte (PRODEMA/UFRN), como parte dos requisitos necessários à obtenção do título de Mestre.

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RESUMO

Tendências da exploração pesqueira na costa do Rio Grande do Norte

Apesar de toda importância, a pesca de pequena escala vive em uma condição de poucos dados. Para gerar conhecimento científico sobre estas pescarias, os pesquisadores têm usado, cada vez mais, o conhecimento ecológico local (CEL) dos pescadores. A grande vantagem no uso do CEL para avaliação da pesca de pequena escala é poder acessar informações do passado não relatadas pela literatura e que requereriam investimento considerável em tempo e recursos financeiros para serem amostradas, quando isto fosse possível. Nessa dissertação buscamos aumentar as informações disponíveis sobre a pesca de pequena escala no estado do Rio Grande do Norte. No primeiro artigo usamos as informações dos pescadores para estimar a Captura por Unidade de Esforço (CPUE) das capturas atuais, de 10 e de 20 anos atrás e identificar as espécies mais capturadas nesse mesmo período e comparamos essas informações com registros de desembarque e dados obtidos com os informantes – chave (pescadores mais velhos e reconhecidos pela comunidade). No segundo artigo analisamos as informações dos barcos utilizados na pesca artesanal para verificar se existe uma frota atuando sobre as mesmas espécies exploradas ou se são frotas diferentes atuando sobre espécies diferentes. No primeiro artigo tal como afirmado pelos pescadores, os resultados não sugerem qualquer alteração na CPUE entre 2003 e 2013. Além de serem bons informantes para estabelecer ordenações de abundância das espécies para as espécies alvo, os pescadores também forneceram estimativas acuradas para a CPUE das melhores capturas no período atual (2013). A abordagem usada nesse estudo mostrou, mais uma vez, que os pescadores possuem importantes e algumas vezes únicas informações. Entretanto, quando esse conhecimento foi comparado com dados formais, apareceram divergências importantes. Esta heterogeneidade de informantes e fontes de dados (dados dos pescadores e dados oficiais) pode ser a única e melhor fonte de informações para a pesca em áreas onde há falta de dados científicos e abundância de pescadores habilidosos. No segundo artigo, os resultados indicam que existem duas frotas diferentes atuando sobre as mesmas espécies. A divisão entre barcos pequenos e grandes mostrou que os barcos pequenos são a melhor opção para os pescadores de pequena escala. Isto se daria porque não foi observada diferença na quantidade capturada das espécies e nos rendimentos obtidos; além disso, as embarcações menores apresentam menores gastos, gerando mais lucros e menos impactos do que os barcos grandes.

Palavras – chave: Pesca de pequena escala; Série temporal; Reconstrução dados; Conhecimento ecológico dos pescadores; eficiência tecnológica barcos; vulnerabilidade espécies.

ABSTRACT

Trends in fisheries exploitation in Rio Grande do Norte coast

Despite all importance, the small-scale fisheries lives in a condition of limited data. To generate scientific knowledge of these fisheries, the researchers have used increasingly, the local ecological knowledge. The great advantage in using the LEC for evaluation of small-scale fishing is able to access past information not reported in the literature and require considerable investment in time and financial resources to be sampled. In this dissertation sought to increase information available on small-scale fishing in Rio Grande do Norte. In the first article we use information of the fishers to estimate the CPUE of current catches of 10 and 20 years ago and identify the species most captured in the same period and compare this information with landing records and data obtained from expert fishers. In the second article we analyze the information of the boats used in artisanal fisheries to check for a fleet operating on the same species exploited or are different fleets operating on different species. In the first article as stated by fishers, the results do not suggest any change in CPUE between 2003 and 2013. In addition to being good informants to establish ranks of species abundance for the target species, fishers also provided accurate estimates for the CPUE of the best catches in the current period (2013). The approach used in this study showed, once again, that fishers have an important and sometimes unique information. However, when this knowledge was compared with formal data, showed major differences. This heterogeneity of informants and data sources (data of fishermen and official data) may be the single best source of information for fishing in areas where there lack of scientific data and abundance of skilled fishers. In the second article, the results indicate that there are two different fleet acting on the same species. The division between small and large boats showed that small boats are the best option for small-scale fishers. Since there is no difference in the amount of captured species and obtained income and expenses of the vessels these categories are much smaller, generating more profits than the big boats.

Keywords: Small-scale fishery; Time series; Reconstruction data; Fisher's Ecological Knowledge; technological efficiency boats; vulnerability species.

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INTRODUÇÃO GERAL E REVISÃO DA LITERATURA

Pesca é a captura da vida selvagem aquática, assim como a caça nos ambientes terrestres (PAULY et al., 2002). A relação dos homens com a pesca é tão antiga quanto a própria história, antes mesmo de desenvolver técnicas de criação de animais e agricultura, o homem primitivo tinha a pesca como fonte de alimentos. A princípio, os peixes eram capturados com arpões, no final do paleolítico surgiu o anzol e o início do uso da rede é atribuído ao final do neolítico (DIEGUES, 1983).

No Egito e no Império Romano a pesca já era uma atividade importante e o consumo de pescado era considerável, a atividade era realizada por escravos e o comércio controlado por negociantes especializados. O surgimento do cristianismo impulsionou o consumo de peixe já que passou a ser considerado uma refeição nobre. Além disso, a forma de conservação do pescado também melhorou, enquanto que no Egito apena o sal era utilizado os romanos introduziram a conservação no azeite (DIEGUES, 1983).

Na Idade Média o uso do peixe e óleo de peixe como pagamento entre os camponeses e os senhores feudais e a confecção de redes nos mosteiros proporcionaram um grande avanço da atividade pesqueira, fazendo com que o peixe entrasse definitivamente na alimentação popular (DIEGUES, 1983).

No final do século XI surgiram as corporações de comerciantes empenhados no comércio de pescado, uma vez que o consumo só aumentava, devido principalmente à expansão do cristianismo. Com o aumento da escala de produção o poder de captura dos petrechos e das embarcações também aumentou, a princípio em quantidade. No fim do século XV os holandeses utilizavam redes com 300 pés de comprimento e nove pés de altura cada uma e depois os barcos de pesca acompanharam as inovações da engenharia naval (DIEGUES, 1983).

O processo de pesca se tornou industrializado com a operação dos barcos a vapor e com poderosos guinchos, no início do século XIX e posteriormente com os barcos à óleo após a 1ª Guerra Mundial. O freezer a bordo, radar acústico e localizadores de peixes foram acrescentados após a 2º Guerra dando mais autonomia ainda para as embarcações (PAULY et al., 2002).

Essas inovações tecnológicas provocaram um grande aumento na produção pesqueira que passou de quatro para 70 milhões de toneladas de pescado por ano (PAES e MARINHO, 2002). A produção foi aumentando até 1972 quando teve início uma queda da captura até estabilizar nos 85 milhões por ano desde 1900 (DULVY et al, 2004).

Em 2010 a captura de pescado foi de 88,6 milhões de toneladas e quando somados à produção da aquicultura, a pesca produziu 148 milhões de toneladas no mundo todo (com um valor total de US$ 217,5 bilhões). Destes, 128 milhões de toneladas foram utilizadas como alimento para pessoas, possibilitando o acesso a uma fonte de proteína animal de excelente qualidade. Além disso, essa atividade proporciona meios de subsistência e renda para aproximadamente 54,8 milhões de pessoas no mundo todo (FAO, 2012).

Deste total de pescado produzido, estima-se que metade é proveniente da pesca de pequena escala, que apesar de ocorrer no mundo todo é predominante nos trópicos em países subdesenvolvidos (FAO, 2004) (BERKES et al., 2006). A classificação da pesca de pequena escala, também chamada de pesca artesanal (FAO, 2008) depende do contexto de cada localidade (JOHNSON, 2006), mas geralmente é caracterizada como multi-espécies, multi-artes e com quase toda captura de peixe utilizada como alimento (BÉNÉ ET AL., 2007). Essa pesca é uma estratégia de sobrevivência essencial para milhões de famílias e possui uma contribuição significativa no sustento, bem estar e segurança alimentar em comunidades costeiras e rurais nos países mais pobres do mundo (FAO, 2004) (BÉNÉ et al., 2007).

Apesar de toda importância, a pesca de pequena escala vive em uma condição de poucos dados (ANDREW et al., 2007) (FAO, 2008) (TESFAMICHAEL ET AL., 2014) o que leva à desvalorização, falta de investimento, monitoramento e gestão, comprometendo a conservação e manutenção da pesca (GILLETT, R.; LIGHTFOOT, C, 2002) (ZELLER ET AL., 2006a). Em um provável cenário de esgotamento de recursos pesqueiros, já que é reconhecido que pescarias não regulamentadas são mais susceptíveis à sobrepesca (FAO, 2007), as consequências serão muito mais graves, pois, nessas localidades há poucas alternativas de subsistência (FAO, 2008).

Nestes casos, uma alternativa é realizar o manejo “com poucos dados”, usando todas as informações disponíveis (JOHANNES, 1998). Para gerar conhecimento científico sobre estas pescarias, os pesquisadores têm usado, cada vez mais, o conhecimento ecológico local (CEL) (JOHANNES ET AL., 2000) (ROCHET et al., 2008), coletando informações históricas ou atuais sobre processos ecológicos (CARVALHO, 2002), comportamentais (SILVANO, 2001), de tamanho e distribuição dos estoques ou de espécies (AINSWORTH ET AL., 2008) (BENDER et al., 2013) ou sobre regras locais de uso (AMARAL, 2004).

O conhecimento ecológico local pode ser definido com um conjunto de informações, habilidades e metodologias transmitidas oralmente nas comunidades. Esses conhecimentos incorporam a experiência de muitas gerações, aprendidos e transmitidos em atividades do cotidiano e através dos membros das comunidades (DIEGUES, 2005) (RAMIRES ET AL.,2007) (AINSWORTH ET AL., 2008).

Um dos primeiros estudos a analisar o conhecimento ecológico local dos pescadores sobre peixes marinhos é de MORRIL (1967). Este trabalho foca no conhecimento dos pescadores do Caribe sobre o comportamento dos peixes. O trabalho de (BEGOSSI E GARAVELLO, 1990), que aborda o conhecimento dos pescadores do rio Tocantins, foi o precursor dos estudos sobre conhecimento dos pescadores aqui no Brasil (COSTA-NETO ET AL., 2002) (COSTA-NETO E MARQUES, 2000). Até então, os trabalhos sobre comunidades pesqueiras no Brasil ressaltavam a homogeneidade social e a tradição (DIEGUES, 2005).

A grande vantagem no uso do CEL para avaliação da pesca de pequena escala é poder acessar informações do passado não relatadas pela literatura e que requereriam investimento considerável em tempo e recursos financeiros para serem amostradas (BEGOSSI, 1993) (DIEGUES, 2005) (JOHANNES ET AL., 2000) além de permitir que se avalie o potencial dos pescadores para reportar o passado ecológico da pesca local (HALLWASS et al., 2013).

Os objetivos principais deste estudo são: (1) reconstruir o cenário de explotação de 10 e de 20 anos atrás utilizando informações etnoictiológicas fornecidas pelos pescadores e validar esses dados com dados formais de desembarque; (2) verificar se existe uma frota atuando sobre as mesmas espécies exploradas ou se são frotas diferentes atuando sobre espécies diferentes.

Em atendimento aos objetivos e conforme padronização estabelecida pelo Programa, esta Dissertação se encontra composta por esta Introdução geral, uma Caracterização geral da Área de estudo, Metodologia geral empregada para o conjunto da obra (dissertação) e por dois capítulos que correspondem a artigos científicos a serem submetidos à publicação. O Capítulo 1, intitulado “Matching reconstructed and landing data to overcome data missing in small-scale fisheries”, está submetido ao periódico Plos One e, portanto, está formatado conforme este periódico. O Capítulo 2, intitulado “É possível subdividir a pesca de pequena escala?”, será submetido ao periódico Fisheries Research e, portanto, está formatado conforme este periódico.

CARACTERIZAÇÃO GERAL DA ÁREA DE ESTUDO

Locais de estudo

O litoral do Rio Grande do Norte (RN) ocupa o extremo nordeste do Brasil (4o49’53”S, 35o58’03”W e 6o58’57” e 38o36’12”W), estendendo-se por 410km, ocupados por 25 municípios e 93 comunidades pesqueiras. O estado como um todo tem temperatura média elevada (25.5oC), assim como os mais altos níveis de insolação do país (2600h/ano) e umidade relativa em torno de 70%.

O litoral do RN divide-se em setentrional e oriental, tendo Touros como o município divisório. Esta separação é baseada em aspectos climáticos, geomorfológicos, fitogeográficos e tectônicos que afetam a direção dos ventos e padrão de circulação oceânicos.

1) Litoral setentrional (Touros e Macau)

Nos últimos anos, estes dois municípios são os que mais se destacam, aparte de Natal, na produção da pesca artesanal. Touros, por exemplo, detinha em 2006, a maior frota pesqueira potiguar somando 403 embarcações (10,7%) (IBAMA, 2007). Touros destaca-se pela produção de lagosta, enquanto Macau destaca-se pela maior produção de sardinhas (Clupeidae) e voador (*Hirundichthys affinis*) do estado. Estudos recentes mostram uma certa discrepância nas espécies alvos entre os municípios, com a região de Macau destacando-se com a captura de tainha (*Mugil curema*) e voador (*H. affinis*), principalmente, e a região de Touros destacando-se com a produção de serra (*Scomberomus brasiliensis*) e ariocó (*Lutjanus synagris*) (SILVA, 2010).

2) Região central (Natal - Canto do Mangue)

De fato, esta região enquadra-se no litoral oriental, mas está separada aqui por diferir grandemente em termos de atividade pesqueira e por estar em uma posição intermediaria entre as outras duas regiões de estudo. O município de Natal responde pela maior parte da captura da pesca artesanal do estado (34% entre 1996 e 2006) (SILVA ET AL., 2009). Apesar da existência de vilas espalhadas pelo município que também praticam a pesca artesanal, boa parte do desembarque dá-se na região do Canto do Mangue, um bairro à beira do Rio Potengi e próximo à estrutura portuária a qual atende especialmente a pesca industrial. Destacam-se a produção de tainhas (*Mugil curema*) e vermelhos (Lutjanidae).

3) Litoral oriental (Tibau do Sul e Baia Formosa)

Tibau do Sul e Baía Formosa são os dois municípios que mais se destacam no litoral oriental em termos de produção pesqueira, cada um tendo capturado 3.6% e 2.3% da produção pesqueira artesanal estadual entre 1996 e 2006 (SILVA ET AL., 2009). Embora com uma produção menor que as outras regiões descritas, este litoral destaca-se na captura da albacorinha (*Thunnus atlanticus*) especialmente em Baía Formosa e de tainha em Tibau do Sul (SILVA ET AL., 2009).

Foram escolhidas duas comunidades pesqueiras, que são importantes portos de desembarques do estado, para o estudo: Baía Formosa localizada no litoral sul, e no litoral norte a comunidade de Caiçara do Norte.

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Matching fishers' knowledge and landing data to overcome data missing in small-scale fisheries

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Abstract

Background: In small-scale fishery, information provided by fishers has been useful to complement current and past lack of knowledge on species and environment.

Methodology: Through interviews, 82 fishers from the largest fishing communities on the north and south borders of a Brazilian northeastern coastal state provided estimates of the catch per unit effort (CPUE) and rank of species abundance of their main target fishes for three time points: current day (2013 at the time of the research), 10, and 20 years past. This information was contrasted to other available data sources, respectively: scientific sampling of fish landing (2013), governmental statistics (2003), and information provided by expert fishers (1993).

Principal findings: Fishers were more accurate when reporting information about their maximum CPUE for 2013, but their maximum CPUE differed than the highest landing records in the governmental data (2003). Fishers were also accurate at establishing ranks of abundance of their main target species for all periods. Fishers' beliefs that fish abundance has not changed over the last 10 years (2003–2013) was corroborated by governmental and scientific landing data. Except for three species, fishers overestimated their mean CPUE per species.

Conclusions: The comparison between official and formal landing records and fishers' perceptions revealed that fishers are accurate when reporting maximum CPUE, but not when reporting mean CPUE.

Introduction

Small-scale fisheries (SSFs) provide food security, welfare, and livelihood sustenance for many coastal communities in the poorest countries in the world [1]. Despite and also due to their relevance, fishing resources have been intensively exploited, causing large effects on marine ecosystems worldwide [2].

Fisheries, including marine, continental fishing, and aquaculture, are estimated to have produced 154 million tons of fish worldwide in 2011 [3]. About 55 million direct jobs are generated by these activities, of which up to 90% are occupied by small-scale fishers who end up supplying half of the world's fish [4]. Brazil produced 1.4 million tons of fish in 2011, including aquaculture, marine, and continental fishing. Following the world trend, an estimated 45% of the continental and marine fish in Brazil are caught by small-scale fishers. Most of these fisheries are located at the northeastern coast, which alone provides 32% of the Brazilian production. The Brazilian small-scale fishing sector employs 957,000 people, showing its social and economic relevance [5].

Nevertheless, the Brazilian SSFs are highly overlooked, which also seems to be a tendency worldwide for SSFs [6] [7]. The lack of public policies for the sector results in unreported and unregulated activity around the world, for which there are barely any financial resources, staff, logistics, or skills in management agencies to collect fishery data [8]. What is known usually comes from a few independent, usually short-term, and research-based endeavors [9]. In the absence of reliable information, we can only obtain a partial picture of what is happening to fish stocks and what could be the best management actions to avoid resource and subsequent societal collapse, as the SSFs are mostly concentrated in the poorest segments of societies [10].

Therefore, in the absence of data, researchers have increasingly used information provided by fishers [11] [12] to fulfill both long- and short-term data gaps [13] [14] [15] [16]

[17]. However, although fishers' knowledge can provide detailed information and helpful material to management, especially when there is no other data available [18], it is often difficult to contrast such information with official data. Such comparisons could identify if all or parts of the information provided by fishers were comparable to what would be obtained through formal methods. Fishers hold facts and memories that may not be registered elsewhere [13]; therefore, an understanding of the precision of this information could define what can and cannot be applied to management in the absence of better data or as a complement to it. Further, this understanding could avoid costly data sampling procedures [19] and could complement information over temporal scales [20] [21].

Here, we contrasted two formal datasets (governmental and scientific) with data provided by fishers to assess the agreement between the different sources. Specifically, we tested if fishers' perception of past and current catches per unit effort (CPUE) (mean and maximum catches) and rank of species abundance matched the formal landing data. Understanding the aspects where information agrees and disagrees could show that not all information provided by fishers is the same, which could direct future research addressing unreported but sometimes valuable past and present information to direct management.

Materials and Methods

Sampling site

The coastal fishing area assessed is located on the Brazilian northeast in the Rio Grande do Norte state (4°49'53"S, 35°58'03"W, and 6°58"57", 38°36"12"W; Figure 1). This coastline has 25 towns and 93 fishing communities along 399 km. Most of the fish landings of this state are done in the capital, Natal (34% of the total landings of the state, mostly industrial). However, the origin of this fishing is difficult to trace, as Natal harbors boats with more autonomy, allowing fishing essentially anywhere on the coast and offshore. For these reasons and the impossibility of disaggregating small from large-scale data in Natal, interviews were conducted at two of the main small-scale fishing ports in their respective regions: one in the north (Caiçara do Norte—6.9% of all the state landings, herein *North*) and one in the south (Baía Formosa—2.3% of all landings, herein *South*) [22]. Current (scientific sampling) and past official fish landing data were also registered in these two villages (Fig. 1).

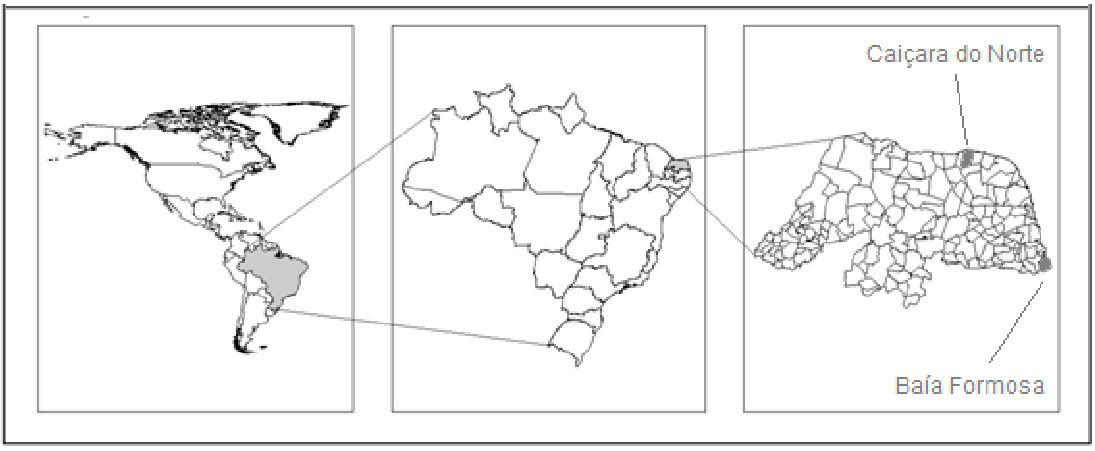

Fig. 1. Study area. Fishing communities sampled in the north (Caiçara do Norte) and in the south (Baía Formosa) of the Rio Grande do Norte State, Brazilian northeast.

Caiçara do Norte is the largest fishing community in the north state, housing 800 active fishers. Since there is no pier or harbor, fishers land anywhere along the only beach (8 km long) in the village. Because there is no communal landing site and because of the extent of the beach and the history of drug-associated violence in parts of it, the formal sampling effort was concentrated on a third of the area, where roughly 250 fishers land their catches. Fortunately, based on what was observed during fieldwork and talks with fishers, this apparently happens to be the place where most fish landings take place. In Caiçara do Norte, the main target fishes are *Coryphaena hippurus* (dolphinfish, locally named *dourado*) and *Hirundichthys affinis* (flying fish, locally named *peixe voador*) [23].

Baía Formosa has a landing site, the Harbor Beach, where all the formal landings were sampled. Baía Formosa's main catches are *Thunnus atlanticus* (blackfin tuna, locally known as *albacora*) and *Lutjanus analis* (mutton snapper, locally known as *cioba*) [23]. In 2014, the local fishers' organization estimated 188 active fishers in Baía Formosa.

As it is common in Brazil, the number of registered fishers considered active by the local fishers' association does not accurately represent the number of fishers really engaged in fishing. Although some of these fishers will fish only sporadically, they will make sure they are permanently registered to have access to social benefits, such as retirement and/or a minimum wage during specific fish closed season.

Scientific, governmental, and informal data assessed

Scientific and governmental data

A research team recorded fish landing (hereafter referred to as scientific data) from January 2013 to March 2014, an interval chosen for including a full fishing cycle, from the blackfin tuna period to black grouper (*Mycteroperca bonaci*) migration period. Both ports (in the north and south) were visited simultaneously on two days each month. All landings from 6 am to 6 pm were registered. Information on the amount of species caught, fishing effort, and fishing gear (types and quantities) were recorded. Fishing effort was measured as hours at sea and crew size.

The nation's environmental agency, the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA), provided past landing data for the two studied areas only for 2003, because neither IBAMA nor any other governmental body did not sample any data for 1993 or 2013. The governmental data included the same type of information as the scientific data, as these official samples were done to inform the Food and Agriculture Organization of the United Nations (FAO). However, the quality of these data has been questioned before, as have data provided by multiple countries [24].

Informal data to reconstruct catches and fish abundance

The research team also gathered informal data through face-to-face interviews with 82 fishers (North=50; South=32) and nine expert fishers (North=5; South=4). As explained earlier, although many fishers are considered officially active, they are in fact "registered" fishers, fishing rarely. These sporadic fishers were not interviewed, as it was expected that they would not be able to provide detailed past information. After providing personal information, such as name, age, and fishing experience, fishers were asked questions that would allow the reconstruction of catches and the establishment of a rank of abundance of fish species currently (at the time of the interview: 2013), 10 (2003), and 20 (1993) years ago. Only fishers older than 18 years and with more than five years of fishing experience were approached. If the fisher had less than 20 years of experience, he was interviewed only for the reconstruction of CPUE and to inform the rank of species abundance for the fishery in 2013. The interviewees' fishing experience ranged from eight years (in the South) to 48 years (in the North), and the average age was 43 (range 20–62 y).

Data sampling was approved according to the guidelines of the Committee of Ethics at the Federal University of Rio Grande do Norte (Protocol of approval No.19685113.3.0000.5537). Before each interview, fishers were approached and informed about the research purpose. Only those who gave verbal consent were included in the study. The ethical committees’ guidelines allow oral consent due to the likelihood of illiterate interviewees and/or traditional communities not willing to tape recording. Here the verbal consent was indeed necessary due to the high proportion of illiteracy among fishers and was always witnessed by a third person from the university but not involved in the research.

Data sampling to reconstruct catches

The interviewed fishers provided information on crew sizes, hours at sea, catches, and types and quantities of gear used. As in other studies recording fishers' memories (e.g., [7]), a few questions were adapted to guarantee better understanding by fishers and to elicit their memories. Accordingly, for each of the three years (2013, 2003, and 1993), fishers were asked about the fish species they caught (a free list of species) and the species and amounts of fish caught (kg) in their best catches. For each of the species cited, they were asked to estimate the average catches for each given year. However, at first the fishers did not understand that a mean catch meant their regular catches. Thus, they were asked about those catches they considered neither good enough to be called great catches nor bad enough to be considered among the worst. The fishers understood this concept and were able to estimate mean catches informing species and amount caught.

To avoid the tendency of fishers to believe that past catches were always better than current catches (called retrospective bias by [25]), the fishers were not asked to provide information chronologically, but were asked first about 2003, then 1993, and, finally, 2013.

Data sampling to reconstruct fish abundance

The abundance of species (in kg) in 2003 was extracted from the governmental data supplied by IBAMA for comparison with a rank of species abundance established by the fishers themselves. These species from the governmental data were categorized as high, average, and low abundance, and the intervals for each of the categories varied according to village. This was necessary because the villages tend to focus on different species with very discrepant abundances.

In the southern community, the intervals were coded following a logarithmic scale [26]: species that represented more than 7t in the official records for 2003 were considered highly abundant; species with total catches between 0.3t and 2t were classified as of average abundance (there were no species between 2.1 and 6.9t); and any species below that level were classified as low abundance. A random choice of 20 species was made from the final list, containing high-, average-, and low-abundance species. Then, four species of high-, three species of average-, and four species of low-abundance were chosen randomly to be discussed in interviews. Fishers were presented pictures of these 11 species and asked to rank them from the highest to the lowest abundances in current catches and in catches from 10 and 20 years past.

However, this approach did not work in the North. Fishers simply did not understand how to rank the species shown in the pictures. Therefore, they were asked to cite species of high-, average-, and low-abundance currently, for 10 years, and 20 years past, regardless of the pictures. In both areas (North and South) the fishers spontaneously informed when the low abundance species became scarce or completely disappeared.

Fish species abundance reconstructed by expert fishers

Nine fishers (five in the South and four in the North) were approached as expert fishers (hereafter EFs), after multiple suggestions of currently active fishers. When summed up, their fishing experience represented more than 427 years of observations.

Through face-to-face interviews, the EFs were assessed to contrast information provided by regular fishers regarding the fishing status of 20 years ago (target species, abundance, and CPUE) because this information was not available elsewhere. EFs are older and more experienced fishers who are expected to have specific and detailed knowledge on local fishery issues. Here, EFs included those older than 40 years and who had lived their entire lives in the same communities; all of the EFs had stopped fishing but still visited the landing sites daily, mainly because of their influential status as knowledgeable fishers.

The EFs were asked which species were most abundant when they began to fish, which species decreased or disappeared from the catches since then, and whether any other species had become fishing targets since they started fishing.

CPUE estimates

The CPUE was defined as catches (kg)/number of fishers × hours fishing; and was calculated for the best catches (maximum CPUE) and for average catches (mean CPUE) using official and informal (interviews) datasets. The fishers' data provided information to calculate CPUE for 1993, 2003, and 2013. However, because the EFs, the only source of information for 1993, could not provide CPUE data for 1993, the fishers’ CPUE could only be compared to: 1) governmental data for 2003 (fish landing sampled by IBAMA); and 2) scientific data (fish landing sampled by researchers) for 2013. Therefore, the CPUE estimated by fishers for 1993 is not shown here.

The CPUE was estimated per species and per fishing gear. Only species registered in at least two landing samplings and mentioned by at least two fishers during the interviews were used to calculate the estimates. The modal value for the variable hours at sea and crew size, per gear, was used to fill in the occasional lack of information in the governmental data for 2003.

Questions

Two different questions related to catches were statistically tested, as detailed in Fig. 2.

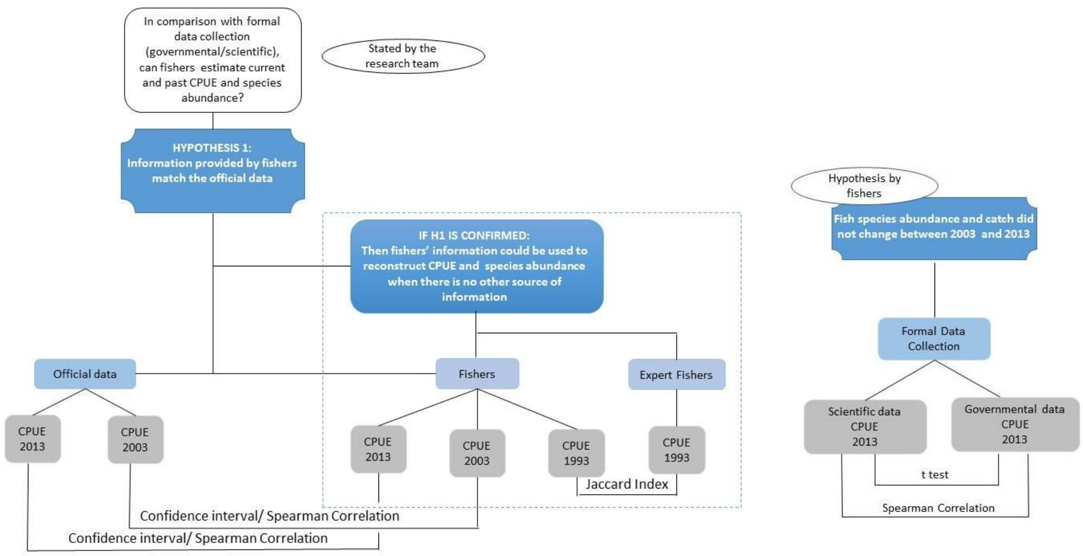

Fig. 2. Research outline. Questions and hypotheses raised by the research team and fishers that guided the statistical analyses performed regarding the CPUE for 1993, 2003, and 2013. (See text for details.)

1. Did the fisheries change between 2003 and 2013?

In the interviews, fishers claimed that the CPUE and rank of species abundance did not change between 2003 and 2013. To investigate if fishers were correct in their collective belief, the CPUE from governmental data (2003) and the CPUE from scientific data (2013) were compared by t-test using GraphPad Prism Version 6.01 for Windows. The data from the South had to be bootstrapped due to data heteroscedasticity. To test the fishers' perceptions about the lack of change in the rank of species abundance, all the species were first ranked for both years using the official data sources (governmental – 2003, and scientific - 2013), from most to least abundant. The two official ranks were then compared by the Spearman's rank correlation coefficient. This non-parametric test measured the strength of the association between two ordinal variables using the order in which the species appeared rather than the observed values.

2. Can fishers provide accurate estimates for past, present, and maximum CPUE and for changes in the rank of species abundance?

A confidence interval analysis was performed to assess the difference between the CPUE by species reconstructed by fishers and the CPUE estimated from the governmental data (2003) and the scientific landing sampling (2013). The difference between the CPUE estimated using the data provided by fishers and the governmental/scientific data were bootstrapped using Microsoft Excel and the supplement Pop Tools [27]. Negative confidence interval values meant that fishers underestimated the CPUE for a given species, while values higher than zero meant that fishers overestimated the species' CPUE. Values crossing the zero line showed no difference between the CPUE estimated by fishers and that provided by governmental/scientific data.

Fishers provided information that allowed the estimation of 1,075 individual CPUE for 43 species caught in 2003 or in 2013. However, for better accuracy, only species quoted by two fishers and also recorded in the governmental and in the scientific sampling had their CPUE taken into account, which resulted in 763 individual CPUE for 22 species. A list of species registered in the landing samplings and mentioned by the interviewees is provided in S1 Appendix.

For 1993, the information on the rank of species abundance provided by fishers was compared to information provided by EFs on species that they considered abundant and species they thought had decreased or disappeared, which was used as a control, assuming that the experts had better knowledge. In this case, as there was number of citations per species, the comparison was done using the Jaccard similarity coefficient (Fig. 2).

The Spearman's rank correlation coefficient was used to verify whether the rank of species abundance reported by fishers for 2003 and 2013 in the South and North areas corresponded to the species that comprised most of landings (in kg), in the same order, in the governmental and scientific data for the same years respectively.

Results

Reconstructing catches

1. Did the fisheries change between 2003 and 2013?

All fishers said that their fisheries did not change between 2003 and 2013. Confirming their claim, the CPUE estimated from the governmental landing data (for 2003) did not differ from the CPUE estimated from the scientific landing data (2013) in both villages (south: $t=0.1$, $p= 0.202$; north: $t = 1.6$, $p = 0.118$).

Conversely, the species abundance rank differed between 2003 (governmental data) and 2013 (scientific data) for the South (Spearman's $r=0.38$, $p= 0.15$), but not for the North (Spearman's $r=0.6$, $p=0.003$).

2. Can fishers provide accurate estimates for mean past, mean present, and maximum CPUE and for changes in the rank of species abundance?

The fishers tended to overestimate the mean CPUE for roughly all species, regardless of the year or gear used to exploit each species. The fishers' information only matched official data significantly for three fish species caught by gillnets: Atlantic little tunny (Fig. 3A), sharks, and coco sea catfish (Fig. 3D). For the other 13 species, fishers' information was close but not statistically equal to official data (Fig.3).

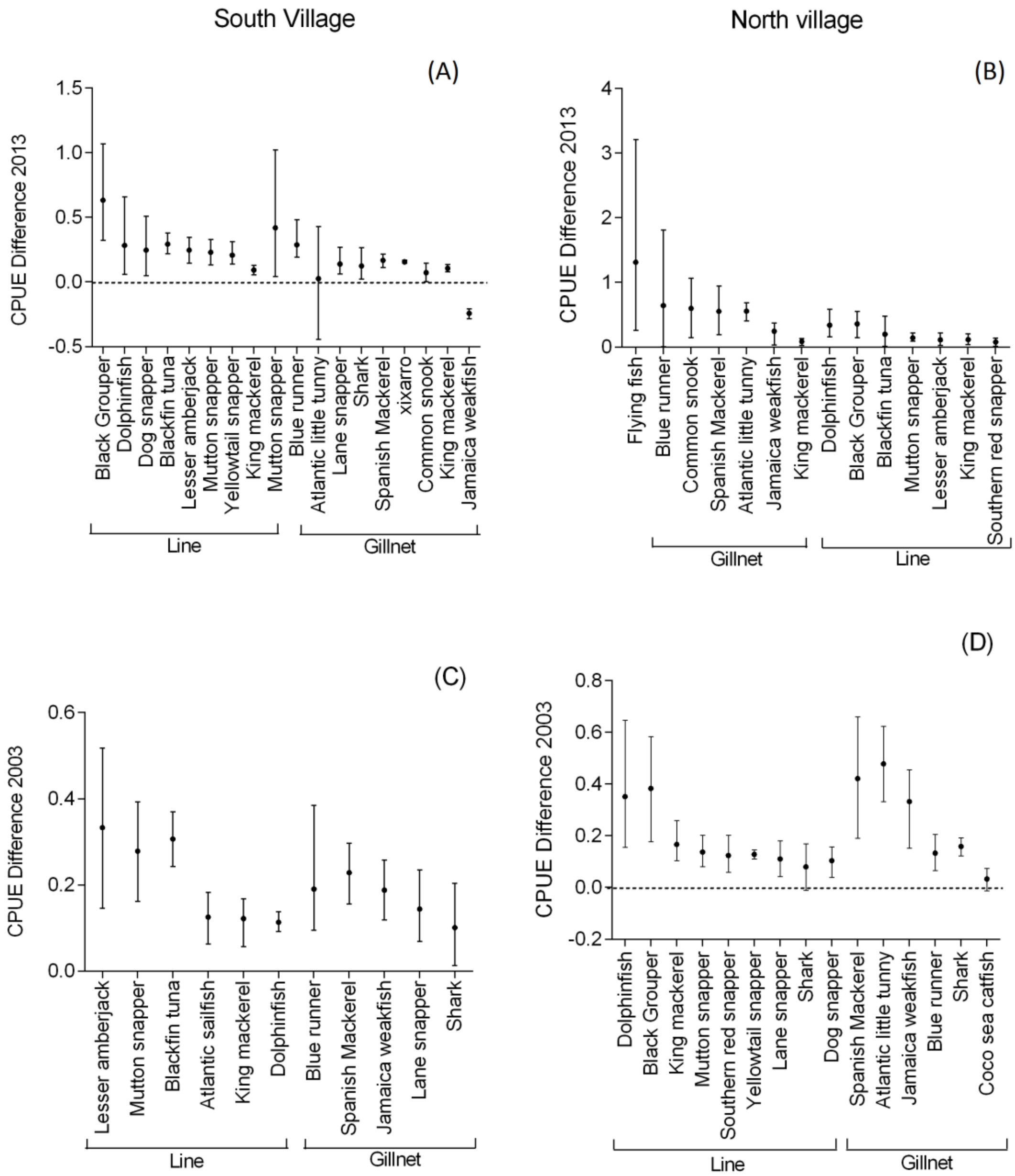

Fig. 3. Difference between mean CPUE informed by fishers and mean CPUE of formal data. Mean value and confidence interval of the difference between the CPUE provided by fishers (2003 and 2013) and the CPUE calculated from governmental data (2003) and from scientific data (2013). Fig. A: South village in 2013; Fig. B: North village in 2013; Fig. C: South village in 2003, and Fig. D: North village in 2003. Flying fish was not included due to its large confidence interval (CI—upper: 2.64; lower: 0.23). Dotted line is not shown when the difference between the values was not negative (as in Figs. 3B, 3C).

The information provided by fishers on their maximum CPUE allowed the calculation of 55 CPUE estimated for the years 2003 and 2013 to 18 species caught by handline or gillnet. These were compared to the maximum CPUE registered in the governmental (2003) and scientific (2013) data. Of the 55 compared CPUE, 18 were not statistically different (the significant measures are identified by arrows in Fig. 4). However, of these 18, 16 (eight in each region) referred to 2013 fishing events, mostly using handlines. The remaining measures were usually overestimates of the fishers' maximum CPUE.

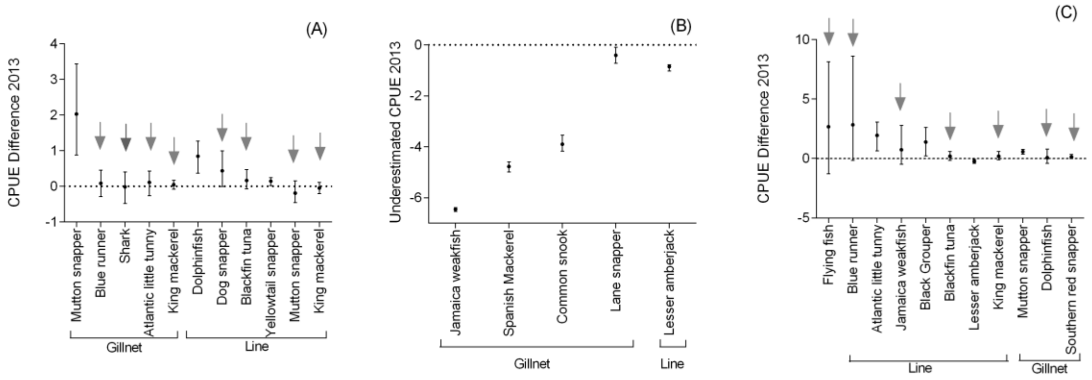

Fig. 4. Difference between maximum CPUE informed by fishers and maximum CPUE of scientific data. Mean value and confidence interval of the difference between maximum CPUE according to fishers and according to scientific landing data (records for 2013). (A) CPUE overestimated (vertical dotted line) by fishers or similar to the official data (see arrows) in the South village; (B) CPUE underestimated by fishers in the South village. Black Grouper (underestimated) is not shown due to its large confidence interval (mean: -10.489; upper: -9.954; lower: -10.934); (C) CPUE overestimated or similar (arrows) to the CPUE of official data in the North village.

For 2003, fishers' information on their maximum CPUE only matched the maximum CPUE registered in the governmental data for dog snapper (Fig. 5A) and flying fish (Fig. 5B).

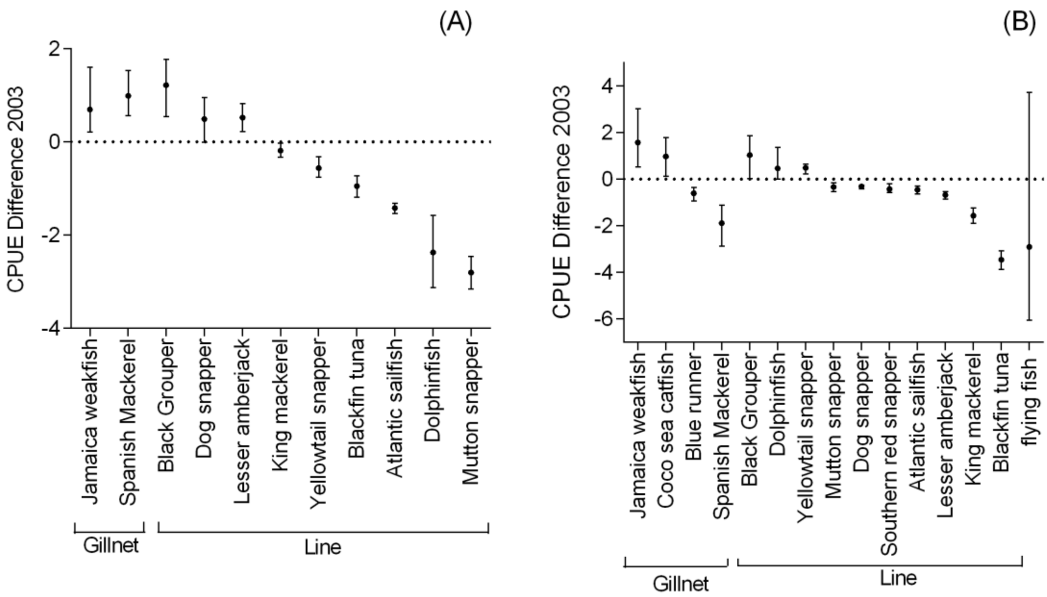

Fig. 5. Difference between maximum CPUE informed by fishers and maximum CPUE of governmental data. Mean value and confidence interval of the difference between the maximum CPUE estimated using fishers' information and the maximum CPUE according to the governmental data (landing records for 2003) in the South village (A) and the North village (B).

The rank of species abundance provided by fishers from the South was highly correlated with the rank of species abundance estimated from the governmental data for 2003 (r=0.75; p=0.009) and with the rank of species abundance estimated from the scientific data for 2013 (r=0.88; p=0.000; Fig. 6). Although significant, the correlations for the North showed worse results (2003: r=0.4, p=0.01; 2013: r=0.3, p= 0.05).

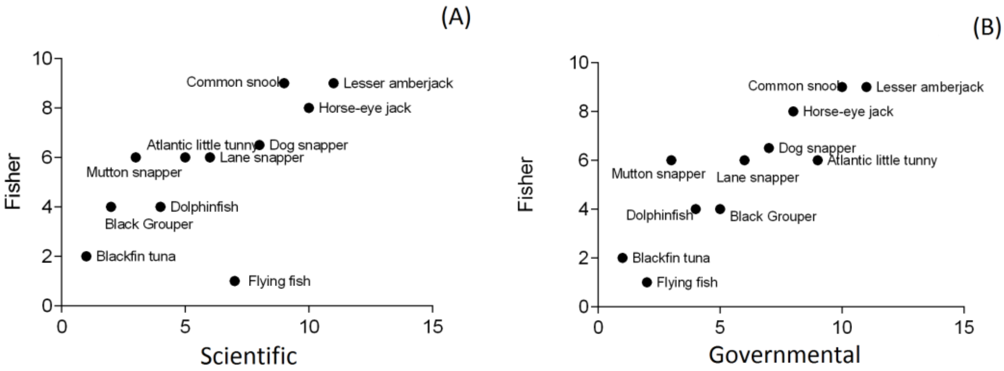

Fig. 6. Correlation of the rank of species abundance according to fishers from the South with the rank of species abundance according to formal data. (A) scientific landing data for 2013 (2013 r=0.88, p=0.000) and (B)) governmental landing data for 2003 (r=0.75, p=0.009).

The EFs reported the decrease or disappearance of 10 species from the fish landings in the last 40 years. In fact, four species mentioned by the EFs were not recorded in the landings for 2013 or 2003 (northern red snapper, Atlantic goliath grouper, and two species of Atlantic bumper). For the other four species (lesser amberjack, black salmon, great hammerhead, and queen triggerfish), the EFs reported low catches since 2003. Even though the EFs pointed out decreased catches of dolphinfish and Spanish mackerel, these species are still among those most caught in the southern and northern coastal areas. According to the EFs, catches were higher in the past.

Fishers were able to provide more information on their maximum CPUE than on their mean CPUE for 1993, which allowed estimates of 77 CPUE of maximum CPUE and 45 mean

CPUE of average catches. However, this information could not be compared to other measures due to lack of any source of official data and the difficulties the EFs had reporting quantitative data.

Both in the South (Jaccard index: 0.33) and North (Jaccard index: 0.37), there were high similarities in the species composition for 1993 between the information provided by fishers and the information provided by EFs.

Discussion

Since Johannes' seminal paper in 1981 [28], which suggested the importance of using fisher's knowledge, different studies have supported his claims, showing the consistency of data provided by fishers with direct use in fishery management [7] [21] [11]. Recently, some researches have shown that fishers' knowledge, if combined with scientific data, could also be useful in filling the gaps required to understand fisheries [17] [13]. Here, official data was compared to information provided by fishers regarding CPUE and target species. Additionally, one hypothesis raised by the fishers themselves (i.e., that the CPUE did not change in the last decade) was tested using only official data. If proved correct, this last hypothesis could also give support to fishers' knowledge. Indeed, as claimed by fishers, the findings did not show any change in the CPUE from 2003 to 2013. In addition to being good informants to establish ranks of abundance for their target species, the fishers also provided accurate estimates of their maximum CPUE in the most recent period (2013).

However, the fishers tended to overestimate mean CPUE. Some research has suggested that fishers can have trouble perceiving trends in catch variability along time series [29], which could make it difficult to measure this variability in relation to fishing effort. This could explain the difficulties fishers had when informing CPUE. On the other hand, some researches have suggested that official data, mostly governmental data provided to FAO, usually underestimates catches, mainly in small-scale fisheries [30] [31] [32]. Therefore, at least in 2003, the fishers' information cannot be completely disregarded. Such discrepancies between the data sources has yet another implication. While management will be based on official data sources, fishers will keep believing in their perceptions of higher values of CPUE, threatening the success of any management actions due to lack of compliance [33]. Thus, assessing the agreement between governmental and scientific CPUE with the CPUE perceived by fishers can guide managers on how to address the lack of acceptance among fishers, who do not understand why such measures are necessary if fisheries, according to their beliefs, have not changed.

The fact that the CPUE did not change between 2003 and 2013 does not necessarily imply no changes in the fish stock, as fishers probably changed the proportions and sizes (for nets) of gears used. This can also be a source of confusion for the fishers, as they may not perceive changes in their catches or even time spent fishing due to the adoption of more efficient gears. This also means that for some fishers, especially the younger ones, this may suggest safe and productive stocks, which disagrees with the opinion of expert fishers. The experts indicated lower catches for multiple species, including those more commonly caught currently, such as dolphinfish and Spanish mackerel. The different views between older and younger fishers qualify for what the literature refers to as the shifting baseline syndrome [34].

The good precision of fishers when reporting their maximum CPUE has been registered recently in other studies (e.g., [7]). Fishers may better remember their best catches because such memories are associated with uncommon and pleasant fishing events [35] and are likely the recollections fishers talk about most. However, it is worth noting that, here, their memories of maximum CPUE and the most abundant species referred mainly to migratory target fishes. Therefore, when attempting to reconstruct data from fishers' recollections, it may be important to notice if a species is a main target. Fishers may be less precise the less important a species is for their economy.

The approach used is this study showed, once again, that fishers hold important and sometimes unique information. However, different than other studies, when such knowledge was compared to more formal data, it also showed important divergences, mainly suggesting that fishers tend to overestimate their CPUE and are more accurate in reporting CPUE on recent best catches. This should be seen as a caution sign when using fishers' information: not everything can be taken for granted, as fishers, just like the rest of us, may forget or mix information. Finally, the use of official data combined with information provided by expert fishers allowed the reconstruction of CPUE for two periods using two different sources of data. This heterogeneity of informants and data sources may be the only and best source of information for fisheries in areas where there is shortage of scientific data but abundance of skillful fishers.

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S1. Appendix.

List of the species registered in landings and/or mentioned by the interviewees.

Common name - Portuguese	Scientific name	Common name - English
Agulha	*Hemirhamphus brasiliensis*	Ballyhoo
Agulhão chato		
Agulhão de vela/Agulhão	*Istiophorus albicans*	Atlantic sailfish
Albacora	*Thunnus atlanticus*	Blackfin tuna
Arabaiana	*Seriola fasciata*	Lesser amberjack
Arabaiana chata	*Seriola rivoliana*	Longfin yellowtail
Ariacó	*Lutjanus synagris*	Lane snapper
Bagre	*Bagre bagre*	Coco sea catfish
Bejupirá	*Rachycentron canadum*	Black salmon
Boca mole	*Larimus breviceps*	Silver snapper
Bonito	*Euthynnus alletteratus*	Atlantic little tunny
Cação	Many sharks species from different families	Shark
Cação cavala	*Isurus oxyrinchus*	Shortfin mako shark
Cambuba	*Haemulon parra*	Sailor's grunt
Camurim	*Centropomus undecimalis*	Common snook
Camurupim	*Megalops atlanticus*	Tarpon

Cavala branca/Cavala	*Scomberomorus cavalla*	King mackerel
Cavala preta/Cavala	*Acanthocybium solandri*	Wahoo
Cioba	*Lutjanus analis*	Mutton snapper
Corá	Lutjanus campechanus	Northern red snapper
Cururuca	*Micropogonias furnieri*	Whitemouth croaker
Curvina	*Pareques acuminatus*	High-hat
Dentão	*Lutjanus jocu*	Dog snapper
Dorminhoco	*Lobotes surinamensis*	Tripletail
Dourado	*Coryphaena hippurus*	Dolphinfish
Espada	*Trichiurus lepturus*	Largehead hairtail
Galo do alto	*Alectis ciliaris*	African pompano
Garacimbora	*Caranx latus*	Horse-eye jack
Garajuba/ Garaxumba	*Caranx crysos*	Blue runner
Guaiuba	*Ocyurus chrysurus*	Yellowtail snapper
Judeu	*Menticirrhus americanus*	Southern kingcroaker
Mero	*Epinephelus itajara*	Atlantic goliath grouper
Palombeta açu/Palombeta chata	Chloroscombrus sp	Atlantic bumper
Pargo	*Lutjanus purpureus*	Southern red snapper
Pescada	*Cynoscion jamaicensis*	Jamaica weakfish
Salema	*Anisotremus virginicus*	Porkfish
Sardinha	*Opisthonema oglinun*	Atlantic thread herring
Serra	*Scomberomorus brasiliensis*	Spanish Mackerel

Sirigado	*Mycteroperca bonaci*	Black Grouper
Tainha	*Mugil curema*	White mullet
Voador	*Hirundichthys affins*	Flying fish
Xaréu	*Caranx lugrubis*	Black Jack
Xixarro	*Decapterus punctatus*	Round scad

Size matters: fishing less and yielding more in smaller-scale fisheries.

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Abstract
Several factors influence catches and the sustainability of fisheries, and such factors might be different depending on the scale such fisheries work. Small-scale fisheries (SSF) are usually regarded as more sustainable and more relevant for food security and maintenance of livelihoods than large or industrial scale ones, which by no means have assured SSF more attention from science or policies. Here we investigated the existence of possible variations and sub-divisions within small-scale fisheries themselves, regarding their economic performance and relative social and environmental impacts in order to understand which categories of the fleet are best positioned to ensure sustainability. By doing so, we intended to investigate if it is worth in the first place for the small-scale fisheries to aim to grow towards larger scales. We sampled economic and ecological data from small-scale fish landings and information on technological efficiency of this fleet, using a northeastern Brazilian state as a case study. We defined a cut-off point to separate the small-scale fisheries in two categories of boats, according to their size and gear. We then compared their CPUE and the factors affecting it within each category; we also compared economic (number of boats, number of registered landings, jobs created, gears used, data of fishery operations (average capture, travel time and total time of the fishery), revenues, costs, profits, revenue per unit of effort (RPUE) and profit per unit of effort (PPUE) and ecological factors (vulnerability of species caught)) between the two categories. Small boats spent less time fishing and employed comparatively fewer people as crew, however the CPUE and profits of small boats was higher and the both categories explore species with the same vulnerability. Therefore being smaller, even within the SSF category, seems to be a more advantageous strategy, because growing does not guarantee neither better catches nor higher profits. These findings should be taken into account when defining new policies, such as the distribution of subsidies.

Keywords: fishing scale; policy objectives; socioeconomic variables.

Introduction

All fisheries consist in a variety of vessel type that differ greatly in terms of vessel size, gears used, technology implemented, fishing grounds reached and degree of expertise of the fishermen. All these factors are also highly dependent on the market characteristics, on the conditions of the targeted fish stocks, and on a range of social aspects such as local culture and availability of investment capital [1].

Unfortunately studies assessing trends in catches especially using vulnerability indicators and their relation with fleet technological efficiency are only common in industrial fisheries. Small-scale fisheries (SSF) are usually ignored when compared to industrial fisheries, not only by governmental and political measures, but also by science [2–4]. Such neglect is worrisome due to the role SSF play in food security and poverty alleviation, especially in coastal and rural communities in developing countries [5]. Currently this type of fishery is estimated to harvest half of the fish of the world and to employ nearly 51 million fishers worldwide [6].

One common governmental policy adopted worldwide for fisheries are the subsidies. However, subsidies tend to be biased, as they are usually directed to the large-scale fishing sector, which end up influencing the structure of the fishing fleet [7]. Changes in the fleet structure, on its turn, can have important implications for the viability of fisheries and consequently on the marine resources [8]. However, although much speculated, it is not clear yet what fleet structures are best positioned to ensure ecosystem sustainability, while generating the higher benefit from the limited fish resources [1]. To answer such question, a study of the different fishing sectors regarding their economic and environmental impacts is needed.

Many different criteria exist to divide fleets into sectors to be compared and analyzed. Nevertheless, there is still no single or widely accepted definition of what should be classified into small or large scale fisheries, with most studies being highly context dependent: what is considered small scale in one location could be understood as large somewhere else [9,10].

One important and more logical attempt to do so adopted a relative rather than an absolute scale to categorize small and large-scale fisheries [11]. In that study, the authors used catch per vessel per year, reasoning that low catches are associated with smaller boats that travel shorter distances and employ a less numerous crew, thus capturing the essence of “smallness” with just one figure. While these authors also compared the economic performance of the two sectors, they did not, however, took into account social and environmental parameters, issues that are also fundamental to regulate fisheries. Further studies addressed such shortcomings by including a number of socioeconomic and environmental impact parameters [12]. More recently, other studies also applied the model developed by Ruttan et al.[11] to examine how small and large-scale fishing operations differ in a number of policy-relevant parameters in the New England and Azore archipelago fishing fleet, respectively [1,13].

Here we adapted this methodology to investigate the existence of possible variations and sub-divisions within SSF themselves, regarding their economic performance and relative social and environmental impacts. We understand that any division is arbitrary, even the broad categories of small and large-scale fisheries, as there is possibly a continuous from the smallest to the largest profile. However arbitrary, such divisions have guided the adoption of subsidy policies, among other initiatives [7], raising concerns about the fairness and sustainability of such measures [14]. By investigating the non-homogeneity of a sector that has been treated so clear-cutly, we hope to show that large is not necessarily better, and that subsidies, bad, ugly, and good ones [15], need to be reconsidered according to the impact a given fleet has on its social-ecological environment.

Methodology

Study area

In order to assess the divergent impact of what is currently considered small-scale fisheries on social, economic and environmental aspects, we used data from Brazil, specifically from Rio Grande do Norte State. This northeastern state covers 410 *km*. of coastline divided into eastern and northern coast, which are subjected to different environmental influences [16] that consequently affected the development of each fleet and their target species.

We chose this state because fishery has been for a long time one of its main economic activities, both performed as small and as large-scale. While in the past lobster fishery (now overfished) led the exports records for the region, nowadays the main market is dominated by tuna and tuna-like fishes caught by industrial fishing, which lands the vast majority of its catch in the capital (Natal). On the other hand, small-scale fishery focuses on the catch of sardines, flying fish, the scarce but still profitable lobsters, groupers, snappers and blackfin tuna, with major landing ports distributed along the coast [17].

Here specifically, we chose two of the main landing ports of SSF on Rio Grande do Norte coast, one in the eastern (Baía Formosa) and another on the northern coast (Caiçara do Norte). By doing so, we hoped to represent the geographical variability in the region, which may have some effect on the fleet development (*Figure 1*).

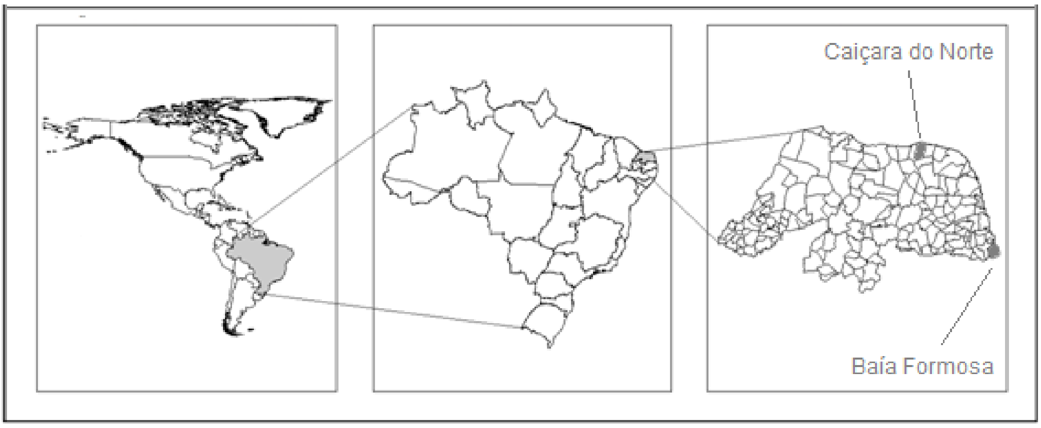

Figure 1. Fishing communities sampled in the north (Caiçara do Norte) and in the eastern (Baía Formosa) of the Rio Grande do Norte State, Brazilian northeast.

Data collection

We monitored landings of the two fishing communities simultaneously from January 2013 to March 2014. The sampling was performed during two consecutive days (from 6:00 am to 6:00 pm, approximately) in each place every month. Harbor observers recorded information directly from interviews with fishermen about fishing gear used, date, duration of the fishing operation herein total time of the fishery (in *h.*), time round trip to fishing grounds herein travel time (in *h.*), species caught (in *kg.*), fishing grounds, ex-vessel price (in the Brazilian currency Real - R$). In addition, in order to determine the technological potential of each vessel, information about the presence/absence of an engine, engine power (in cubic centimeter - *cc*), ice and fish storage capacity (in *kg.*) were collected for all the sampled vessels.

We aggregated the gears used in four different groups. The first group includes handline (hereafter "Line"). The second group is formed by longlines. Gillnets represent the third group, and includes nets that are generally made of monofilament nylon and could be fixed to the bottom or drift. The fourth group (hereafter "Mixed") included fishery operations that are done with more than one type of these gears.

For statistical purpose, we created a unique data matrix was created merging the information of the vessels to the landing data to related the characteristics of the vessel and the information of each fishery operation were related. Since the catch statistics varied markedly between the vessels, we computed the catch per unit effort (CPUE) as the total catch in a fishing operation (in *kg.*), standardized per number of fishermen and per haul duration (in *h*).

Statistical Analysis

The analysis strategy we adopted here involved 5 steps: (1) the definition of a cut-off point to separate landings of what has been originally treated as small-scale fisheries; this allowed us to investigate if such fisheries are really homogeneous; (2) a Wilcoxon Rank-Sum test to explore if the total CPUE of the two categories differed; (3) a Bayesian General Linear Model (GLM) to evaluate if different factors influence the CPUE of the two categories; (4) an analysis of the similarity (ANOSIM) of the fish assemblages of the two categories regarding species composition and vulnerability; and (5) a Wilcoxon Rank-Sum test to compare if economic and production factors differed between the two groups.

1) Step one: finding the cut-off point of the fleet

Aiming to achieve this goal we used the method developed by Ruttan et al.[11]. The methodology is based on a division of the fishing fleet into a series of gear type/vessel size combinations, as follows: (1) vessel classes were defined by length in meters; (2) gear type/vessel size combinations were ranked according to annual landings and landed value (for each boat size, we recovered the catches associated to a given gear); and (3) the cut-off point between the two categories was set at 50% cumulative landed weight and landed value. For this case study, vessel size was accounted for in terms of length rather than tonnage (GRT), as done in previous studies (see [12]). Length classes were assumed to be more appropriate due to great variability in tonnage values for vessels with very similar characteristics, such as maximum crew size, autonomy at sea, and ice storage capacity.

2) Comparison of CPUE between the two categories

After detecting the non-normality of the data with a Shapiro-Wilk test, we compared the CPUE of the two categories using a Wilcoxon Rank-Sum test using R software (R Development Team 2015).

3) Understanding which factor affect the CPUE in the two categories

To understand if different factors explain the CPUE of each of the two categories, we first log transformed the CPUE values to downweight extreme values and to ensure a normal distribution and homocedasticity for both categories.

To model the CPUE, we opted for mixed models using a Bayesian approach, as it allows both the observed data and model parameters to be considered as random variables, resulting in a more realistic and accurate estimation of uncertainty [18].

The expected values of CPUE in each fishery operation and for each category were related to the independent variables: type of gear, fishing grounds, landing harbors (the two sampled sites), month, engine power, presence/absence of an engine, and ice storage capacity (*kg*), according to the general formulation,

$$\text{CPUE}_i = \alpha + X\beta + Z_i$$

where X is the vector of covariates for each survey i, α is the intercept, β is the vector of the model parameters and Z_i is a random factor that represents the vessel or fishermen’s effect.

Indeed, the remaining potential source of variation on CPUE data could be due to the fishermen themselves. These differences can be caused by fishermen's behavior (caused by random aspects, experience, age, social needs, etc.) or unobserved gear characteristics. Ignoring such non-independence of the data may lead to invalid statistical inference. Then, in order to remove this bias a random vessel effect was included.

Following the Bayesian reasoning, once the model has been determined, the next step is to estimate its parameters and assign to them a prior distribution. For the parameters involved in the fixed effects, we use non-informative Gaussian distributions N(0, 100).

We started with a complete model, with all the variables just described (random and fixed), and we then proceeded with the model selection, using both backward and forward approaches to select relevant variables. Specifically, we used the Deviance Information Criterion (DIC), a well-known Bayesian model-choice criterion for comparing complex hierarchical models [19]. DIC is inversely related to the compromise between fit and parsimony.

To fit Bayesian models we used the integrated nested Laplace approximation (INLA) methodology and software (http://www.r-inla.org).

(4) Analyzing the impacts on vulnerability of species between the two categories

In order to ensure species with no catch significance would not compromise the results, we just included species which catches were above 100*kg.*/year were considered in the analyses.

To check the vulnerability of the species sampled in landings, we used the vulnerability index available in FishBase [20]. This index integrates ecological characteristics (maximum size at first maturity age, longevity, growth parameter K von Bertalanfly, natural mortality, fertility, energy spatial behavior and geographic reach) of a species with its life history, using the "*Fuzzy Expert System"* software [21]. The vulnerability of a species is expressed on a scale that varies from 1 to 100. Values up to 35 are considered low vulnerability; 36 to 55 are considered moderate; 56 to 75 are considered high vulnerability, and values above 76 species are classified as very high vulnerability. With these values we compared if our two pre-defined small-scale fisheries categories were targeting species of different vulnerabilities.

In order to assess if there are differences in the quantity (in *kg*.) of the vulnerable species caught between the two categories of vessels an analyses of similarity (ANOSIM) was performed. For this purpose the "*anosim*" function of the "*vegan*" package [22] of the R software was used.

(5) Comparing the economic factors between categories

To determine whether there was any difference between the two categories of small-scale fisheries, we compared: number of boats, number of registered landings, jobs created, gears used, data of fishery operations (average capture, travel time and total time of the fishery), revenues, costs, profits, revenue per unit of effort (RPUE) and profit per unit of effort (PPUE). The RPUE was computed as the total revenue for a fishing operation (in R$), standardized per number of fishermen and per haul duration (in *h*). Similar, the PPUE was calculated as total profit for a fishing operation (in R$) standardized per number of fishermen and per haul duration (in *h*), while the PPUE followed the same logic but excluded the costs from the revenue.

We compared all of these variables between the two categories through a.Wilcoxon test, because the data showed non-normal distributions (Shapiro-Wilk was used to test data normality).

Results

Among the 542 landings sampled, 183 landings could be related to the technological information of the vessels in the two communities. The 59 vessels examined were evenly distributed in the eastern and in the north part of the State (26 in Baía Formosa; 33 in Caiçara do Norte).

Table 1. Data on volume (kg) and value of landings. Values are shown in Brazilian currency (BRL). The average dollar conversion rate for the period is 1USD = 2.30 BRL. Gear type "mixed": various types of fishing gear used in the same fishery.

Vessel size in meters (Gear type)	Cumulative Proportion of catch (in %)	Proportion of catch (in %)	Total catch	Profit	Proportion value (in %)	Cumulative value (in %)	Number of landings
7.5 (Gillnet)	0.08	0.08	11.4	961.8	1.28	13.53	1
6.2 (Gillnet)	0.18	0.11	16	0	0.00	0.00	2
5.1 (Line)	0.36	0.17	26	543.5	0.73	7.90	4
6.1(Gillnet)	0.59	0.23	35	398.5	0.53	3.88	3
7.7 (Longline)	0.85	0.27	40	230	0.31	0.69	2
5.1 (Gillnet)	1.17	0.31	46.9	822	1.10	10.99	1
7.25 (Longline)	1.48	0.31	47	283	0.38	1.07	1
5 (Gillnet)	1.79	0.32	47.5	7274.52	9.71	77.95	5
7.25 (Line)	2.11	0.32	47.8	20.5	0.03	0.03	1
5.9 (Gillnet)	2.44	0.32	48.8	345.75	0.46	2.35	5
9.6 (Longline)	2.79	0.36	53.5	537.5	0.72	7.18	1
6.4 (Gillnet)	3.17	0.38	57	300.25	0.40	1.47	6
9 (Mixed)	3.62	0.45	67.9	2263.5	3.02	29.04	3
6.5 (Line)	4.13	0.51	76.1	106.5	0.14	0.17	1
7 (Mixed)	4.71	0.58	87.9	314.43	0.42	1.89	1
10 (Longline)	5.83	1.12	168	0	0.00	0.00	1
8.1 (Mixed)	7.29	1.46	218.8	454.5	0.61	4.48	1
8.2 (Gillnet)	8.94	1.65	247.7	1383.9	1.85	18.09	5
6.8 (Line)	10.63	1.70	255.2	745.3	0.99	9.89	3
7.25 (Mixed)	12.47	1.84	276.4	376	0.50	3.34	1
8.2 (Line)	14.35	1.88	283	482	0.64	5.13	2
8.75 (Gillnet)	16.25	1.90	285	0	0.00	0.00	5
4.5 (Gillnet)	18.25	2.00	301	2062.85	2.75	26.02	7
9.3 (Gillnet)	20.29	2.04	307	982.5	1.31	14.84	2
8 (Mixed)	22.43	2.13	321	504.5	0.67	6.46	4
8.4 (Mixed)	24.99	2.56	385.4	742.5	0.99	8.89	3
6 (Gillnet)	27.56	2.57	386.1	2755.65	3.68	32.72	13
8 (Longline)	30.20	2.64	396.7	941.5	1.26	12.24	3
7.2 (Line)	32.92	2.73	410.3	3853	5.14	47.13	6
8.1 (Longline)	35.68	2.75	414	3219.5	4.30	37.02	3
7.4 (Line)	38.70	3.02	454.5	5175.8	6.91	60.39	5
7.77 (Gillnet)	42.03	3.33	500.7	162.5	0.22	0.39	2
7 (Line)	45.43	3.40	510,6	7502.7	10.01	87.97	9
9.6 (Gillnet)	48.84	3.41	513	1048.5	1.40	16.24	5
9 (Line)	52.60	3.76	565.2	3726.6	4.97	41.99	13
10 (Gillnet)	56.99	4.39	660.5	1987.2	2.65	23.26	4
7.8 (Line)	61.43	4.44	668.2	495	0.66	5.79	3
9.5 (Gillnet)	65.90	4.46	671	1893	2.53	20.61	3
8.5 (Line)	72.15	6.26	941	366	0.49	2.84	3
9 (Gillnet)	78.70	6.54	983.9	475.8	6.35	53.48	11
8 (Gillnet)	85.47	6.77	1018	9012.94	12.03	100.00	15
8 (Line)	100.00	14.53	2185.3	5883.39	7.85	68.24	13

The small-scale fishing sector assessed here had a cut-off point for boats at 9 *m* length both in terms of landed (R$) and weight (*kg*) values (*Figure 2*).

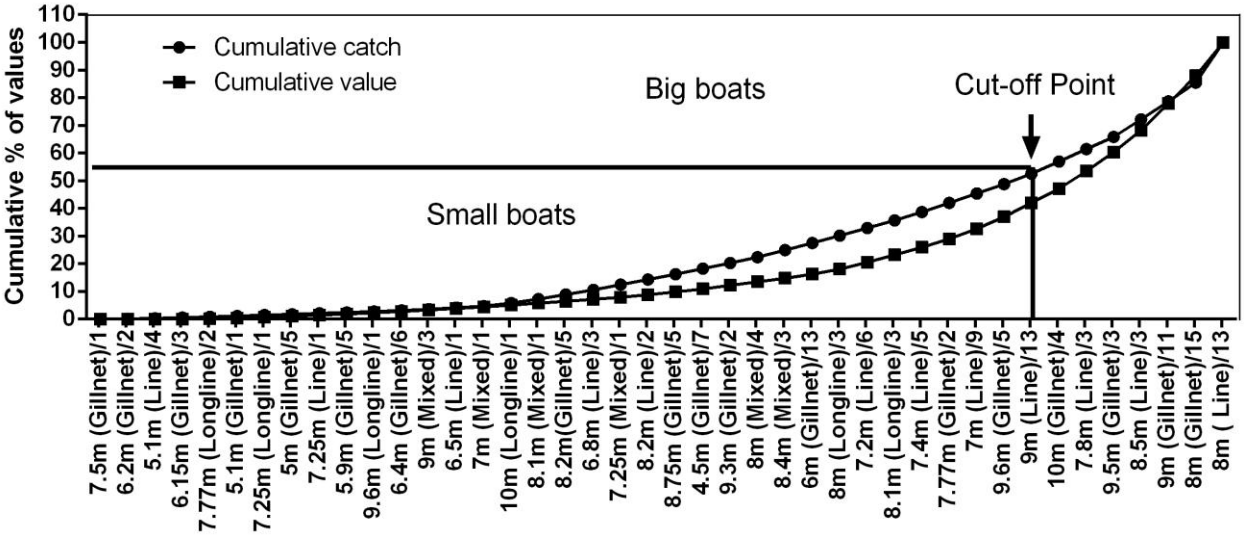

Figure 2. Gear type/vessel size against cumulative percentage of landed value (line with squares) and landed weight (line with circles). The cut-off point between the two categories is shown at 52.60% cumulative weight (to ensure that all vessels of the same size were in the same category). The corresponding cumulative percentage in landed value is shown at 53.48%.

Following this cut-point, 141 landings were analysed for the small boats category (vessels < 9 *m.*) and 42 were evaluated for the large boats category (vessels > 9 *m.*). The studied sites had about three times more small boats (N = 59) than large ones (N = 17). However, as the number of jobs position directly generated by larger boats is proportionally higher (3,6) than the job positions generated by small boats (2,8), is reasonable to assume one more fisher employed by each larger boat if compared to the small boats.

The mean CPUE (in *kg*/effort unit) among small boats (mean CPUE =1.48) and large boats (mean CPUE = 0.73) was different (Wilcoxon test; p = 0.00008).

After selection of the best Bayesian model, the CPUE of the smaller boats was explained by the variables landing harbours, type of gear and presence/absence of an engine as covariates. Specifically, the northern village ("Caiçara") showed higher estimated CPUE (posterior mean = 0.87; 95% CI = [0.26, 1.48]) than the eastern one (Baía Formosa). Longlines had lower estimated CPUE (posterior mean = -0.05; 95% CI = [-0.11, -0.00]) than the mixed gears. Finally, having an engine on the boat also contributed to a higher estimated CPUE (posterior mean 2.16; 95% CI = [0.94, 2.56]).

For the larger boat category (vessel >9 *m*.) the final models included the engine power and the ice storage capacity, with both contributing directly to increasing CPUE: (engine posterior mean = 1.07; 95% CI = [0.75, 1.99]; ice storage capacity posterior mean = 1.80; 95% CI = [0.79, 2.75]).

Then, as expected, larger boats carried more powerful engines (3.0 cylinders) than the smaller ones (1.4; p = 0.0001). Further, larger boats also had greater ice tonnage (332.59 kg × 249.5 kg; p = 0.01).

Around 20 different species were identified as the most commonly caught by both categories of fleet (> 100 *kg*/year). All species were exploited by both fleets, in exception of the exploitation of one species of medium vulnerability and one of high vulnerability by large boats, (*Table 2*). Although there is difference in the CPUE of species caught between the two categories, there is no difference in the vulnerability index.

Table 2. Low (L), Medium (M) and High (H) vulnerability and catch of species exploited by small and large boats. (1 – Catches below 100 kg / year are not considered).

Common name	Scientific name	Vulnerability	Total catch in kg per species	
			Small	Larger
Flying fish	*Hirundichthys affins*	L	2975.00	41.43[1]
Blue runner	*Caranx crysos*	L	89.00[1]	100.00
Dolphinfish	*Coryphaena hippurus*	M	1196.25	120.50
Mutton snapper	*Lutjanus analis*	M	904.75	226.50
Lesser amberjack	*Seriola fasciata*	M	576.30	25.50[1]
Blackfin tuna	*Thunnus atlanticus*	M	540.70	226.50
Lane snapper	*Lutjanus synagris*	M	291.70	18.00[1]
Common snook	*Centropomus undecimalis*	M	161.00	13.00[1]
Coney	*Cephalopholis fulva*	M	150.00	0.00[1]
Coco sea catfish	*Bagre bagre*	M	65.00[1]	304.00
Black grouper	*Mycteroperca bonaci*	H	1996.50	13.00[1]
Spanish mackerel	*Scomberomorus brasiliensis*	H	1007.50	1414.60
King mackerel	*Scomberomorus cavalla*	H	313.10	82.90[1]
Atlantic little tunny	*Euthynnus alletteratus*	H	295.00	260.00
Shark	*Galeocerdo cuvieri*	H	285.20	476.00
Southern red snapper	*Lutjanus purpureus*	H	219.00	22.00[1]
Whitemouth croaker	*Micropogonias furnieri*	H	126.00	0.00[1]
Atlantic sailfish	*Istiophorus albicans*	H	89.00[1]	190.00
Yellowtail snapper	*Ocyurus chrysurus*	H	55.00[1]	179.50
White grunt	*Haemulon plumieri*	H	35.00[1]	121.00

Despite the slightly difference in the number of species in the classes of vulnerability (high and moderate) for the two vessel categories, there is not difference in their abundance indicating that larger boats caught fewer species, but in larger amounts (*Figure 3*).

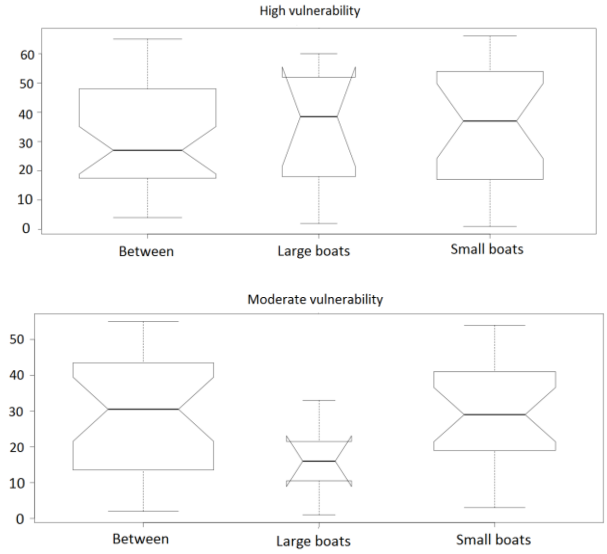

Figure 3. Anosim results for each categories of vulnerability between vessel categories. Values presented refer to high vulnerability (R=-0.106; p= 0.817) and moderate vulnerability (R=0.042; p=0.282).

There was little variation in the type of gear used by both boat categories. The use of handlines, for example, is almost the same (Small = 39%; Large = 31%), while larger boats tended to use gillnets slightly more often (Small = 43.5%; Large = 57%).

Even though larger boats stay for longer periods fishing in the sea, their landings and revenues are not different than those of small boats (*Table 3*). In addition, larger boats have higher average costs with ice, fuel and food than small boats, although the average profits of both categories are not statistically different (*Table 3*).

Table 3. Information on fishery features, production and the economy of the two categories of boats operating in the two communities assessed. The CPUE was estimated by: catch × (nº fishermen × fishing hours) $^{-1}$. *P* value refers to the Wilcoxon test. Values are shown in Brazilian currency (BRL). The average dollar conversion rate for the period is 1USD = 2.30 BRL. RPUE = Revenue per unit of effort; PPUE = Profit per unit of effort.

Variables	Small boats		Larger boats		*P*
	Average	SD	Average	SD	
Time trip (hours)	5.79	3.31	5.72	2.06	0.91
Time fishery (hours)	31.32	26.46	51.25	29.70	**<0.01**
Crew size	2.51	0.63	3	0.38	**<0.01**
Catch (Kg)	85.60	94.58	94.47	74.42	0.17
CPUE	1.47	2.18	0.76	0.75	**0.0008**
Revenue (BRL)	550.32	779.70	546.66	472.23	0.16

Cost (BRL)	100.17	129.10	181.50	154.40	**0.0003**
Ice cost (BRL)	29.30	51.14	36.23	15.24	**0.0009**
Fuel cost (BRL)	47.70	48.50	118.90	109.23	**<0.01**
Food cost (BRL)	46	40.4	55.80	34.15	**0.04**
Profit (BRL)	453	782.56	373	476	0.82
RPUE (BRL)	15.61	32.27	7.00	8.77	0.17
PPUE (BRL)	14.21	32.06	5.62	8.24	0.16

Discussion

In this study we examined how homogeneous the small-scale fisheries are in relation to their economic performance, relative social and ecological impacts, using a northeastern state in Brazil as a case study. Similar studies have evaluated the economic difference between small and large-scale fisheries in different areas [1,11,13,23]. Here, this approach was used to investigate the possible variations and sub-divisions within small-scale fisheries themselves. This assessment is valuable for management purposes since through the world, mainly in developing countries, governments are subsiding and stimulating the improvement in fisheries by the increasing in the fleet size and technology instead of assuring the supply of sustainable fish stocks [25] .

Overall, the results showed that smaller boats spend less time at sea per fishing trip and employ a smaller crew size, which is balanced by the fact that there are usually more of the smaller boats. Further, smaller boats have low costs in general and have higher CPUE. Conversely, larger boats spend longer periods at sea since their more powerful propulsion enable them to reach more distant grounds, likely searching for sites with greater abundance of fish, as the large boats have higher expenses is necessary to capture a larger quantity of fish to cover the expenses.

In opposition to common sense and expectations, the CPUE achieved by smaller boats was higher than the CPUE estimated to the larger boats. The reasons affecting such differences also varied between the categories of vessels. Concerning to the small boats, for instance, social (numbers of jobs created), cultural factors (harbor of landing) and the presence or absence of an engine seem to be important predictors for the CPUE. The gear used also affected the variability of the CPUE, which is an expected outcome whenever there are different gears being used [24]. This gear effect can be attributed to many interacting factors, such as the ability of certain species to avoid or escape certain gears due to morphological and behavioral characteristics and the fact that gears are not equally effective in all habitats.

Despite the higher CPUE achieved by smaller boats, among the larger boats category technological characteristics, such as more engine power and higher ice storage capacity, guarantee higher CPUE indeed. This is probably one of the reasons why fishers tend to think that larger boats are always better than smaller ones. In addition, since the performance of smaller boats are often disregarded, both fishers or government authorities are not aware on the potential social and economics differences and benefits provided by which size of boats and what kind of technology.

While the number of jobs per boats is higher in larger boats, the total number of jobs generated within a category is higher for smaller boats, simply because there are more of them. This is a well-known common fact around the world when SSF are considered as a whole, as it is known that they generate many more jobs than industrial ones. In fact, it is estimated that SSF provides over 90% of all fisheries jobs [4]. What is interesting here is that this pattern is repeated even within what is commonly seen as a homogeneous group of SSF boats. Although well-known in general and repeated here under a zooming lens inside the SSF sector, managers and policy-makers do not seem to grasp the meaning of having more jobs in a sector than in other, because the common tactic is to always stimulate growth and improve fleet as a way to increase catches and profits [25]. By such policies, not only overfishing becomes a closer threat, but also the distribution of income becomes more unequal, by concentrating wealth in fewer hands of the ones who can afford larger boats.

Regardless of the size category a boat is in, the pressure on highly vulnerable species is the same. Although there was some difference in relation to the target species of smaller and larger boats, both groups targeted an important proportion of high vulnerable species (small boats - 53.3%; large boats – 54.6%). Another relevant point to consider is the fact that if only larger boats are present in a system, less economic and social benefits will be generated under the same fishing pressure upon the most threatened species. Consequently, any subsidies allocated to improve the SSF fleet may be fatefully financing overfishing on highly vulnerable species while disregarding the economic and social benefits generated by small size boats practicing SSF.

Worldwide, are estimated that USD 26 billions were assigned to 11 types of fishing subsidies (excluding fuel subsidies). Most of it (51%) was provided by 103 developing countries, while 38 developed countries provided the remaining amount (49%). However, little more than half (US$16 billion) are subsidies that contributed towards an increase in fishing capacity globally while only US$7 billion contributed to fisheries management and conservation programs. The remaining US$3 billion may lead either to fisheries conservation or to overcapacity depending on the context [25].

Currently in Brazil there are three types of subsidies available for SSF: (i) a fuel subsidy, which can represent from 25 to 80% of a boat operational cost; (ii) a boat construction, renewal and modernization subsidy, (the so called 'Revitaliza Program'); and (iii) fishery and aquaculture subsidy, which is direct towards fisheries enterprise development (Plano Safra) [26]. Specifically in the Brazilian case, most poor fishers will not have access to such subsidies, even if they are categorized as small-scale fishers. That is because most of these initiatives will require a minimum level of organization through fisher's associations or through a fisher becoming a legal person [26]. In some instances, institutions and non-profits have taken the initiative of doing the bureaucratic job for the fishers especially regarding a possible transition to aquaculture, the third kind of subsidy mentioned here [26]. Except for a few cases, such initiatives have collapsed after a certain time, again for lack of organization or understanding of the cultural background [26]. Additionally, when having access to the second type of subsidies, fishers always decide for a larger boat and more powerful engine, to expand fishing grounds and time spent fishing, due to their untrue feeling (shared with governmental managers) of getting higher catches with larger boats. Hence, in the social imaginary subsidies remain as something positive, worth finding the means to get to them [27,28].

In addition to keeping their cultural value [5,10], the SSF with moderate fishing fleet can generate a social benefit greater than what is generated by the fishing fleet that can benefit from the official subsidies. The higher expenses of these latter vessels decrease the fishers' profits, showing that having a small boat can be more advantageous than having a larger one. Hence, choosing to subsidize the growth of SSF can backfire. Environmentally, overfishing is more easily achieved under a bad subsidy policy. Socially and economically, fishers will incur in more costs, not always balanced by better profits, besides the fact that wealth distribution tends to become more unfair, with less jobs being generated overall and therefore fewer opportunities in the sectors, with the few wealthier fishers benefitting from subsidies. This is not to say subsidies should be disregarded altogether in SSF, but they should be directed to more positive improvements, for example, through financing local fish processing, fisheries management and fish certification, which can add value to their product and improve wealth distribution without compromising fish stocks even further.

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