Tourism as a driver of conflicts and changes in fisheries value chains in Marine Protected Areas

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A B S T R A C T

Although critical tools for protecting ocean habitats, Marine Protected Areas (MPAs) are sometimes challenged for social impacts and conflicts they may generate. Some conflicts have an economic base, which, once understood, can be used to resolve associated socioenvironmental problems. We addressed how the fish trade in an MPA that combines no-take zones and tourist or resident zones creates incentives for increased fisheries. We performed a value chain analysis following the fish supply and trade through interviews that assessed consumer demand and preference. The results showed a simple and closed value chain driven by tourism (70% of the consumption). Both tourists and local consumers preferred high trophic level species (predators), but the former preferred large pelagics (tuna and dolphin) and the latter preferred reef species (barracuda and snapper). Pelagic predators are caught with fresh sardines, which are sometimes located only in the no-take zone. Pelagic species are mainly served as fillet, and the leftover fish parts end up as waste, an issue that, if properly addressed, can help reduce fishing pressure. Whereas some of the target species may be sustainable (e.g., dolphin fish), others are more vulnerable (e.g., wahoo) and should not be intensively fished. We advise setting stricter limits to the number of tourists visiting MPAs, according to their own capacity and peculiarities, in order to avoid conflicts with conservation goals through incentives for increased resource use.

1. Introduction

Establishing and maintaining Marine Protected Areas (MPAs) should be a priority for all countries, especially those that have committed to protecting at least 10% of their marine habitats by signing the United Nations Convention on Biological Diversity (Coad et al., 2009). Yet, this goal has been hard to reach on a global scale. While advances towards conservation initiatives have been considerable in some countries (Halpern, 2014), they have been delayed in others, such as Brazil (Schiavetti et al., 2013). There are various reasons for that, many associated to some economic interest (Cheung and Sumaila, 2008; Di Dario et al., 2015; Soares-Filho et al., 2014). Commercial fisheries are one such example that tends to see conservation as an obstacle (Di Dario et al., 2015), despite the growing evidence for the positive effects of conservation on fishery catches (Garcia et al., 2015).

Fisheries have removed fish biomass from the oceans at alarming rates (Pauly and Zeller, 2016). This has resulted in many collapsed and collapsing stocks, including those exploited by small-scale fisheries (Costello et al., 2012). Although some of these stocks have been giving signs of recovery after proper management (Costello et al., 2016), this mostly happens in developed countries able to afford long term funding (Worm et al., 2009). All this makes it vital to explore how to better manage fisheries. MPAs are typically proposed by conservationists as a suitable candidate (Costello and Ballantine, 2015; Edgar et al., 2014), based on evidence suggesting that well planned and enforced MPAs can result in significant improvements in fish biomass and ecosystem health (Bonaldo et al., 2017; Mumby et al., 2006).

On the other hand, conservation efforts should consider the...
and Worm, 2003). Besides, some presence and abundance of other species (Cheal et al., 2010; Myers, 2004), destroy the seabed (Brennan et al., 2015) or demand un-sustainable water use, sewage, and waste produced (Pagano, 2001). For the management of the archipelago, the control of fishing methods is a state responsibility. The state charges tourists a daily fee, benefiting directly from tourism through tax collection. The entrance of visitors and tourists in the archipelago is limited by the number of flights per day, which has been growing regularly in the last decade, due to the state political pressure and interests to promote tourism in the area.

Such interests conflict with the MPA interests. According to recent reports and studies, the archipelago has reached its carrying capacity and has a large tourism ecological footprint (Feitosa and Gómez, 2013), giving signs that it cannot deal with the increasing number of visitors, sewage, and waste produced (Pagano, 2001). For the most part, the MPA warnings regarding the carrying capacity have been ignored or dismissed, except for the no-take area where the MPA has full control and enforces visitation limits (Falcão, 2010). There are additional charges to enter the no-take zone, which is directed to the institute in charge of managing federal protected areas in Brazil (ICMBio). Some areas do not allow any tourist visitation.

The fishing of pelagic and reef fish is done with powerboats, using fishing rods, outside the no-take zone, and, for the most part, outside the outer limits of the MPA. However, fishers want to access the no-take zone during part of the year, due to the arrival of swells that limit the catching of baitfish in the 30% allowed area. This demand has generated escalating conflicts in the last six years. However, the roots of the conflict go back to 1988, when the park was created. At the time, the advocates of the MPA and the fishers reached an understanding that allowed some level of extraction even within the no-take area. Sardines, for instance, could be caught inside the no-take zone, under adversary conditions (swell) or caught inside the no-take zone, under adversary conditions (swell) or pressure (Aertsen et al., 2009; Hoogland et al., 2007; Vermeir and Verbeke, 2006). Even when geared towards more sustainable behavior, consumers could be misled into believing that eating local and unprocessed food may have no or few consequences on the ecosystem (Edwards-Jones, 2010). However, the recommendations for sustainable consumption should consider fish species, their life history, as well as fishing methods. That is so because some fish species have longer lifespans with low fecundity, which make them more vulnerable to exploitation (Begossi et al., 2012). Other species play key roles in the ecosystem, controlling the presence and abundance of other species (Cheal et al., 2010; Myers and Worm, 2003). Besides, some fishing methods are more detrimental to the environment, either because they present low selectivity (Arellano-Torres et al., 2006; McClanahan and Mangi, 2004), destroy the seabed (Brennan et al., 2015) or demand unsustainable baitfish (Rahel, 2016).

In this context, the main goal of this study was to evaluate the role of economic forces underlying the cause of management conflict in a tropical oceanic island MPA. We used the archipelago of Fernando de Noronha (Brazil) as a case study, which includes no-take zones and areas that allow tourism and residency. While the possibility of a near future re-categorization of this MPA and its no-take zones added weight for choosing Fernando de Noronha, many protected areas currently face similar risks of losing their legal conservation status (Bernard et al., 2014; Mascia and Paillet, 2011). Specifically, we investigated how the fish value chain, including the supply and trade pathway from the boat to the plate, can be an important driver of conflicts and how different types of consumers (locals and tourists) have different indirect impacts on fish exploitation. We expected to identify economic aspects along the fish value chain that could be addressed in order to avoid or decrease socio-environmental conflicts that threaten the effectiveness of conservation. We believe that it is important to understand if the same invisible hand of the market that hampers conservation initiatives could also hold the solution for more effective MPAs.

2. Material and methods

2.1. The case study

Fernando de Noronha is a volcanic archipelago formed by 21 islands, islets and rock outcrops, located about 345 km offshore the Brazilian northeastern (Fig. 1). The archipelago is home to multiple reef and rock fishes (e.g., snappers, jacks and parrotfishes), a nursery spot for others (e.g., lemon and nurse sharks), and it is on the migratory route of large pelagic species (e.g., tunas, rainbow runner, wahoo and dolphin fish) (Table S1).

The Fernando de Noronha MPA is divided into two management categories: 70% of its area is a no-take zone (controlled tourism is allowed) and 30% is a sustainable use zone (dwelling, fisheries and tourism are permitted). Following the Brazilian protected area system, known as “conservation units”, the no-take zone is called “Park”, while the remaining is called “Environmental Protection Area”. The archipelago holds an estimated resident population of over 5000, plus the average flow of almost 6000 tourists per month (ICMBio, personal communication). The administration of the island and its infrastructure (roads, hospital, school, etc.) is a state responsibility. The state charges tourists a daily fee, benefiting directly from tourism through tax collection. The entrance of visitors and tourists in the archipelago is limited by the number of flights per day, which has been growing regularly in the last decade, due to the state political pressure and interests to promote tourism in the area.
area. Some of these managers were locals or knew that the MPA had been initially established on this trust that the fishers would have kept some of their old fishing traditions. More recent management, who came from other parts of Brazil after 2010 or so, was more prone to follow the legislation to the book. In 2012, the implementation of resolute management ignited ongoing conflicts and non-compliance events that have resulted in fees and arrests. Such conflicts now represent a threat to the integrity of the park, regardless of the manager in place, because fishers have questioned its legitimacy at higher political levels, lobbying a possible change of status in parts of the no-take area. The re-categorization of protected areas has happened in Brazil before for similar reasons, some of them towards less restrictive categories (Payes et al., 2013), which is worrisome in a country with so few no-take MPAs (Schiavetti et al., 2013). In conflicting cases, such as Fernando de Noronha, alternatives that improve the efficiency of an MPA without compromising livelihoods would be a win-win solution.

2.2. Value chain

We investigated the fish value chain of the archipelago of Fernando de Noronha as a possible disruptor of the MPA success. A value chain describes the activities, step by step, to bring a product to the consumer, from its conception through its production phases (Kaplinsky and Morris, 2001). When the value chain is not firm specific and follows through different nodes and different actors (e.g.: extractor, processor, intermediary and consumer), it is generally known as a macro value chain (for a review, see Song et al., 2013). The value chain can be complex or very simple, the latter being the case of a raw product, such as fish, that undergoes no or very little transformation before it gets to the consumer (Fig. 2a). The fish value chain studied here encompasses the steps in the supply and fish trade (boat-to-market approach), from the catching of the fish, including the preceding catching of baitfish, to the consumer.
Fernando de Noronha presents a fully closed value chain, meaning that virtually no fish caught by commercial fishers leave the island, due to the constant high demand generated by tourism. However, some fish is brought from the mainland, which we traced only after it enters the island value chain. The value chain is formed by links or nodes: fishers, traders (fishers that also sell their own fish), middlemen, restaurateurs (independent or inside hotels), and consumers (tourists and locals).

We interviewed fishers, traders, middlemen, tourists, and restaurateurs or chefs in order to understand the local value chain and its probable impact on conservation. Although each link of the chain was subject to a different set of questions, to fit their characteristics, the standardized semi-structured questionnaires (Appendix 1, Supplementary Material) used were all set up to elicit information on the topics: (i) description of the trade of large pelagic (migratory) and reef fish (resident) or more sedentary fish, representing two distinct functional groups; (ii) market preferences and reasons for that; and (iii) amount traded of each functional fish group, its seasonality, preferences and reasons for such preferences (Table 1). All the interviews were performed between November 2015 and September 2016.

2.2.1. Fishers

Of the 40 fishers identified in the island, we interviewed 35 (87.5%). We asked the fishers about their main target species and their seasonality, how they are caught, and their regular yield in a good and in a bad day with and without fresh sardines as bait.

2.2.2. Restaurants

We actively sought every single restaurant and cater in the island, including those inside hotels. This resulted in 36 face-to-face interviews with owners and managers, corresponding to 41 establishments. These were all the restaurants selling fish in the island at the time of the research. During this phase, we also identified four hotels that owned boats and fished for their own restaurants. We computed their catches together with those of fishers. Whenever these four hotels could not meet their demand,
they also bought fish from the regular traders, and therefore, provided the same information described below as the other restaurants.

We asked the 36 restaurateurs about their most demanded fish species and why, if they bought fish in the island and/or from mainland suppliers and from whom, the amounts per species, if they processed the fish themselves and, if so, their estimated loss of fish meat. Whenever possible, cooks, chefs and kitchen assistants provided estimates for fish waste. We were interested in knowing about the waste because we assumed that a better use of fish could result in less fishing. We also asked if restaurants preferred fish landed in the island or coming from companies in the mainland, if they thought that tourists cared about eating locally caught fish and about the species they were eating, and if they thought it possible to adapt their menu to serve other species when there is shortage of pelagic species (the species that demand baitfish from the no-take zone during part of the year).

Whenever the interviewees provided an interval for the amount of fish they bought during a period (day, week or month), we used the lowest and most conservative value. If they provided values for the high and low season, we used the lowest value for each season and then calculated the average. Whenever informants reported purchases of fish per month, we divided the values by four, whereas values per day were multiplied by six, as most places tend to be closed one day per week.

2.2.3. Fish traders and middlemen

A total of 21 fish traders were mentioned by restaurant owners and managers. Two of these traders worked exclusively as middlemen and 19 were fishers, who sold their catch without an intermediary. We interviewed those who were cited by more than one restaurateur (n = 12). The remaining nine traders were either fishing sporadically or were fishing and selling their catches together with one of the interviewed fisher-traders at the time of the study.

We asked all the traders, even if they were interviewed previously as a fisher, to estimate the amount of fish they caught per day or per month (according to what they felt more comfortable estimating) in a good and in a bad month. We compared such values with the previous information provided by fishers to calculate the average. Traders also estimated the proportion of their catch and the species that are sold to the local population and to restaurants. We used such proportion and the individual catch estimates to calculate the amount of fish consumed by tourists and by residents, besides evaluating differences in preferences for given species.

We used both the values estimated by restaurants and by traders to calculate the weekly demand of fish in the island. Surprisingly, the data provided by restaurants and by traders differed by less than 2%, suggesting that the estimates were probably close to real figures.

2.2.4. Tourists

We interviewed tourists at the airport, their main exit route, when they were waiting to board. We interviewed one person per family (family average size = 2.5 people ± 1.26), who was older than 18 (average = 39.2 years ± 12.2). In total, 238 tourists, of which 135 were women, were asked about the length of their stay in the island and if they liked fish. If their answer was positive, we asked if they had eaten fish in the island, how many times and if they could cite the species they ate. Tourists were also asked whether they would mind eating alternative fish species other than the ones they had (we provided examples, such as jacks) and whether they minded if their fish was locally caught or not.

We did not interview local consumers, first because they are a minority in terms of fish consumption, which we knew from the interviews with traders and restaurateurs/chefs, and also because they virtually eat only locally caught fish. Their preference for only local fish was clearly and repeatedly stated by fishers and traders and also directly observed by us during informal talks.

2.3. Analysis

We ran Spearman correlations to test if the demand, here specified as the fish most preferred by restaurants, correlates with the supply, which was measured as the fish most commonly available to commerce, according to the traders. A second Spearman correlation was run between what traders specified as the fish most sought by restaurants and the fish most sought by local consumers, in order to see if there is a different market demand between the two groups. All the variables were measured as frequency of citation of each fish species.

We also developed a pressure index to be applied to value chains to indicate the fish that would be more intensively sought by fishers due to restaurants’ and local consumers’ demands. The reasoning behind such index is that if a fish is highly demanded by restaurants and by the local consumers, it is under higher fishing pressure, which can be worrisome depending on its biological status. The index can be easily expanded to accommodate other nodes of more complex value chains. The pressure index was calculated as follows:

\[ Sp_i = (P_{ei}^*_D_i) + (P_{ri}^*_D_r) \]  

where \( S_i \) represents the pressure index for species \( i \), \( P \) represents the preference of local consumers \( c \) or restaurants \( r \), and \( D \) represents the demand by consumers \( c \) or restaurants \( r \). \( P \) was measured as the percentage of the total citations attributed to a given species by the trader as a species sought by the local consumer or by the restaurants. \( D \) were constants extracted from the value chain analysis, as the sum of all the fish (in %) that get to the local consumers or to the restaurants. Specifically, \( D_i \) was calculated as 0.325 and \( D_r \) as 0.675 (see Fig. 2b for the percentages).

The index was rescaled to vary from 0 (lowest pressure) to 1 (highest pressure).

This index was used to rank the most demanded species and relate them to the IUCN Red List of Threatened Species and to three ecological indexes (vulnerability, resilience, and trophic level) extracted from FishBase (Froese and Pauly, 2011). By doing that, we intend to show if the value chain had a direct ecological effect on the ecosystem, for example, by focusing on species that are important to assure the ecosystem and trophic chain functioning or species that could not stand high fishing pressure. The vulnerability index takes into account the maximum size a fish reaches at first maturity age, its longevity, the growth parameter K von Bertalanffy, natural mortality, fertility, energy spatial behavior and geographic reach of a species. The vulnerability index varies from 1 to 100, where 1–35: low vulnerability; 36–55: moderate; 56–75: high; 76–100: very high vulnerability. The resilience index is similar to the vulnerability one as it also integrates biological parameters, but it is presented on a categorical scale that varies from high to very low resilience. The trophic level of a species is obtained from its diet, and also readily available on Fishbase (Froese and Pauly, 2011). The trophic level partitions species according to their diet, depending on their ingestion of mostly producers or of other consumers (Ricklefs, 2008). Species with high trophic levels, i.e., those that consume mostly other consumers, play a determining role in shaping the ecosystem structure and functioning. However, they tend to be the first to go due to their lower biomass and larger body size (Duffy, 2002), which is appreciated for human consumption (Jackson et al., 2001).
3. Results

Fishing in Fernando de Noronha is a one-day activity that begins with bait fishing, around 6 a.m., and ends between 4 and 6 pm. Nocturnal fishing is sporadic and done with frozen sardines (Harengula jaguana) or with a small jack (Bigeye scad - Selar crumenophthalmus). Most fishers dislike nocturnal fishing because, according to them, it results in smaller fish (e.g.: jacks and dog snapper) not so demanded by restaurants. Most fishers (80% out of 35) stated that nocturnal fishing depended on the market demand or that it took place when the diurnal fishing was unproductive, due to shortage of large pelagic or difficulties in catching baitfish on the shore. Both factors are probably related: the demand for jacks and snappers is likely to peak when there is no pelagic fish available, either due to natural seasonality of fish or due to the difficulties in catching sardines when the sea is rough.

3.1. The value chain

Fernando de Noronha has a simple value chain, with few links (Fig. 2). Only about 19% of the fish comes from outside fisheries and are bought from the mainland, the remaining (81%) is fully supplied by the local fishers. The fish brought from the mainland costs about the same as the island fish, once their transportation cost is included; therefore their prices are not presented. Restaurant informants estimated an average internal demand of 4288.00 kg of fish per week and an external demand of 1014.65 kg of fish per week. Traders (fishers and middlemen) estimated that they provide 4202.35 kg of internal fish per week, i.e., very similar figures.

Fishers trade more than half of their fish (56.4%) without a middleman and they provide the local population a slightly higher proportion of their fish (17%) than the middlemen themselves (15.5%). However, tourists get most of the fish caught by local fishers (64.1%) and consume basically all the outside fish as well (95% of the outside fish; 70.1% of all fish), since they are mostly sold in restaurants.

3.2. The external fish acquired by restaurants

Of the 41 restaurants, four were not buying or never bought fish from the island. Three of these argued that the island fish was temporally or hygienically unreliable, whereas one only serves Acoupa weakfish (Cynoscion acoupa), a species that does not occur around oceanic islands. Still, 21 restaurants clearly stated they prefer to buy fish from the island, but also have to import fish regularly or sporadically, when they cannot find enough local fish. The most commonly imported species (in kg and in frequency) are the same species usually locally caught (dolphin fish, yellowfin tuna and wahoo) (Fig. 3). Other than those species, there is also a preference for Acoupa weakfish and salmon, the first for having an easy tender fillet to prepare and the latter to be served in sushi places. These five most demanded fish are purchased in larger amounts and also cited by a higher number of restaurants (Fig. 3).

3.3. Preferences and conservation

Restaurants and local consumers differed regarding their fish preferences, according to the information provided by traders (\(\rho = -0.36; p > 0.05\)) (Fig. 4a). However, traders seem to focus their offer on what the restaurants demand (or vice-versa), because there is a strong correlation between the species being more commonly offered and those being demanded. (Spearman
rho = 0.84; p = 0.0007) (Fig. 4b). Restaurateurs said to prefer the larger pelagic species because they provide more boneless meat, which is easier to turn into presentable dishes. Except for tunas, which can be made into ceviche and sushi, both well accepted by clients, the others are also demanded for having white meat.

Restaurants and hotels estimated that they use on average 63.5% of the fish they buy. The loss is due to the processing and it is higher (35–50%) when the fish is processed into fillets. Such estimates, provided by managers and chefs of the interviewed places, represent the loss on top of gutted fish. Of the 37 restaurants that were buying locally caught fish, 17 (46%) buy the fillet from the trader, whereas others do the processing in their own facilities.

According to the pressure index, yellowfin tuna, wahoo and dolphinfish are the most demanded fish in the island (Table 2). These species would be those most subjected to fishing. When such species are compared to their biological features and conservation status, dolphinfish stands out as a possible sustainable alternative, in relation to the others, because it is a resilient species of least
concern, according to the IUCN Red List of Threatened Species. Wahoo is in an intermediary situation, whereas the yellowfin tuna is a near threatened species. On the other hand, it is positive to observe that species that are in a more delicate situation, due to their high vulnerability, low resilience and high trophic level (e.g., such as barracuda, black jacks and the marbled group), do not show a high pressure index. It is also worth noticing that the island’s demand focuses exclusively on high trophic level species (Table 2). Therefore, the relation between the pressure and the ecological indexes brings a not so negative portrait, although it flashes some warning signals, especially regarding the overall preference for high trophic level species and the more delicate ecological situation of some species.

Not all restaurants informed the percentage of tourists asking if the fish are locally caught or the species being served, mostly because these restaurants make a point in advertising their fish as locally caught and of informing the species. Still, according to the restaurant and hotel interviewees, on average 59% of the overall consumers ask if they are being served a locally caught fish (n = 25 restaurants), whereas 64.7% (n = 26) inquire about the species available (Fig. 5a).

On the other hand, most tourists (69.2%, n = 212 who eat fish) reported that they would prefer to eat locally caught fish rather than fish brought from the outside. Also, most (89.1%) of them indicated they had eaten fish at least once while in Noronha, although 83% of all the tourists had eaten it more often. Of these, 63% remembered the species they had eaten, and these were mostly, again, barracuda, tuna and wahoo (Fig. 5). Tourists also said they would accept eating other species in season (83%), and although not quantified, a few tourists expressed some reticence in

Table 2
Qualitative assessment of the conservation status of the most demanded fish species caught in Fernando de Noronha archipelago. The pressure index was calculated as described in the methods, while the remaining data were extracted from Fishbase. The color classification system was randomly used to represent the aspects that make a species subjected to conservation concern, with green suggesting least concern, yellow intermediate, and red high concern.

<table>
<thead>
<tr>
<th>Species scientific name</th>
<th>Species popular name</th>
<th>Pressure index</th>
<th>Trophic level</th>
<th>Resilience</th>
<th>Vulnerability</th>
<th>IUCN status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caranx bartholomei</td>
<td>Yellow jack</td>
<td>0.13</td>
<td>4.5 ± 0.2</td>
<td>High</td>
<td>Moderate to high (51)</td>
<td>Not evaluated</td>
</tr>
<tr>
<td>Caranx cryssos</td>
<td>Blue runner</td>
<td>0.19</td>
<td>4.1 ± 0.4</td>
<td>Medium</td>
<td>Low to moderate (34)</td>
<td>Least concern</td>
</tr>
<tr>
<td>Caranx lugubris</td>
<td>Black jack</td>
<td>0.36</td>
<td>4.5 ± 0.8</td>
<td>Low</td>
<td>High (60)</td>
<td>Not evaluated</td>
</tr>
<tr>
<td>Cephalopholis fulva</td>
<td>Coney</td>
<td>0.07</td>
<td>4.1 ± 0.4</td>
<td>Low</td>
<td>Moderate to high (52)</td>
<td>Least concern</td>
</tr>
<tr>
<td>Coryphaena hippurus</td>
<td>Dolphinfish</td>
<td>0.69</td>
<td>4.4 ± 0.0</td>
<td>High</td>
<td>Moderate (40)</td>
<td>Least concern</td>
</tr>
<tr>
<td>Dermatolepis inermis</td>
<td>Marbled grouper</td>
<td>0.07</td>
<td>4.5 ± 0.8</td>
<td>Low</td>
<td>High (61)</td>
<td>Near threatened</td>
</tr>
<tr>
<td>Lutjanus jocu</td>
<td>Dog snapper</td>
<td>0.19</td>
<td>4.4 ± 0.0</td>
<td>Low</td>
<td>High to very high (66)</td>
<td>Not evaluated</td>
</tr>
<tr>
<td>Elopogon bicirrulata</td>
<td>Rainbow runner</td>
<td>0.33</td>
<td>4.5 ± 0.3</td>
<td>Medium</td>
<td>High (63)</td>
<td>Not evaluated</td>
</tr>
<tr>
<td>Acanthocybium solandri</td>
<td>Wahoo</td>
<td>0.84</td>
<td>4.3 ± 0.2</td>
<td>Medium</td>
<td>Moderate to high (46)</td>
<td>Least concern</td>
</tr>
<tr>
<td>Seriola lalandi</td>
<td>Yellowtail amberjack</td>
<td>0.07</td>
<td>4.2 ± 0.1</td>
<td>Low</td>
<td>High to very high (69)</td>
<td>Not evaluated</td>
</tr>
<tr>
<td>Sphyraena barracuda</td>
<td>Great barracuda</td>
<td>0.59</td>
<td>4.5 ± 0.6</td>
<td>Low</td>
<td>Very high (79)</td>
<td>Not evaluated</td>
</tr>
<tr>
<td>Thunnus albacares</td>
<td>Yellowfin tuna</td>
<td>1</td>
<td>4.4 ± 0.4</td>
<td>Medium</td>
<td>Moderate to high</td>
<td>Near threatened</td>
</tr>
</tbody>
</table>

Fig. 5. Species consumed by the tourists, according to themselves. The species are divided in species highly likely to have been bought in the mainland, resident species in Fernando de Noronha archipelago and pelagic species usually caught in the archipelago. Barracuda and sardines are debatable.
replacing the species: they would replace it for others as long as the alternative ones were not bony and had white meat.

4. Discussion

The interference of conservation initiatives on fisheries was the kick-start to challenge the protection status of the Fernando de Noronha MPA, one of the few MPAs in Brazil that includes a strict no-take zone. Here we assessed how the commerce of fish in the archipelago, with its specific demand and links among different actors (fishers, traders and consumers), could offer insights for reducing conservation threats. We disentangled the value chain, showing that it is relatively simple, which technically should be easier to manage, but might require some complex changes, such as changes in people's preferences.

The peculiarities of this chain could hold the key to minimize conflicts. Local fisheries are tailored to meet the demand created by restaurants to satisfy the tourists' preferences for fillets of large pelagic species. When local fisheries cannot reach the demand, the same large species are purchased in the mainland. Local consumers, on the other hand, buy mostly reef fishes, which are smaller-sized fish to be cooked or baked whole, or which are given alternative culinary uses to the remaining parts. Few species are ranked high on overall consumers' preferences. In general such species do not nurse or grow in the MPA or in its surroundings, but still might changes in people's preferences. In general such species do not

Furthermore, it has been pointed out that tourism and its associated value chain in general is not under any incentive to voluntarily avoid natural resource overexploitation (Beritelli, 2011), mostly due to the public nature of the resources it depends upon (e.g., nature sites) (Hardin, 1968). The present study complements such knowledge by showing the direct consequences of having tourism affecting other value chains (e.g.: fish). Through such chains, tourism influences the dynamics of MPAs or of resource exploitation in general.

Previous studies have presented tourism as an alternative to diversify fishers' livelihoods (Cinner and Bodin, 2010), even if through secondary and low-skill jobs (Sobhee, 2006). Such diversification could decrease the pressure on fishing stocks or would at least work as an incentive for fishers to exit the fishery if necessary (Cinner et al., 2009). However, in the current study, most fishers are not a direct part of the tourism industry, except for the fact that they provide the protein for the visitors, and instead of diversifying they might become even more specialized in fishing. Even though specialization can increase income, it also increases social vulnerability in situations where the source of income is lost (Hahn et al., 2009). Increased pressure on fishing resources with possibly increased social vulnerability are side effects of unplanned tourism that needs to be addressed in MPAs that allow visitation.

Such issues may be especially important where conservation, tourism and fisheries planning are decoupled, because instead of working synergistically, such activities might create trade-offs that negatively affect each other (Lopes et al., 2015). In this specific case, multiple management institutions and actors (the local administration, the MPA, and the fishers) have different and conflicting interests with possible negative consequences to all. Trying to achieve win-win solutions for economic, social and environmental problems is not easy, and may require short-term compromises to one or to all interests (Cheung and Sumaila, 2008). Here, the best solution would possibly be to curtail tourism to sustainable levels, making up for the loss of income from fisheries through better and fairer prices. Fair prices for the fish could be achieved through some certification that attests its sustainability for considering how fisheries are practiced, the species exploited, and its destination (Roheim, 2003).

Moreover, the results of the value chain analyses showed at least three other points that could be addressed to improve fisheries sustainability and ameliorate the local conflict. These include i) a wasteful preparation of fish, ii) the focus on large-bodied species, and iii) the preference for few species. Restaurateurs argued that tourists demand boneless fish, served as fillets of large body-size species, which results in considerable waste of good food. In other non-isolated places, fish waste could at least be given alternative uses (e.g., animal feed) (Stuart, 2009). Such unnecessary waste has been reported to cause economic and environmental problems around the globe (Papargyropoulou et al., 2014). Some estimates suggest that only 10% of the world fish that is killed by fisheries end up being used as food. The remaining is discarded (thrown overboard for having no economic interest), spoiled, turned into fishmeal or wasted in inedible portions (Lopes, 2008). Waste disposal is also worrisome (Papargyropoulou et al., 2014), especially in isolated places with limited infrastructure, such as the studied MPA where waste is shipped back to the mainland.

On the other hand, the overall preference for large fish is not entirely negative, as long as the species being caught are not endangered or of low resilience (see Table 2). The catch of large individuals agrees with a widely advertised strategy for fisheries sustainability, known as the “spawn-at-least-once” principle (Vasilakopoulos et al., 2011). This states that the removal of large individuals through fisheries gives fish a chance to reproduce at least once. Dolphinfish, for instance, would benefit from such fishing strategy, probably without major consequences to its stocks due to its biological characteristics (e.g., fast growth and moderate vulnerability). However, caution is still recommended if indeed the largest individuals of each population are being intensely removed, because it could induce the selection of individuals that show earlier maturation, with lower egg production, and smaller adult body size (Law, 2000). This can happen through the removal of genes from the gene pool that are responsible for large size and plentiful spawning (Jusufovski and Kuparin, 2014).

Finally, the third point regards the preference and pressure on some pelagic species and top predators (high trophic level). The significant removal of top predators is associated to changes in the structuring and functioning of ecosystems (Jackson et al., 2001), especially haroshened by the fact that we might have already lost 90% of large predators (Myers and Worm, 2003). Overfishing top predators can also negatively affect coastal economies by making some fisheries economically unviable (Myers et al., 2007). The management of the studied MPA should therefore anticipate and possibly work to divert the focus of fisheries from high trophic level species, especially from those least resilient, in order to keep the local ecosystem and economy healthy. Tourists seemed to be willing to cooperate by trying different species. The consumption of lower level trophic species is usually more advisable due to their larger population sizes, although their fishing can also have undesirable consequences (Smith et al., 2011), but that is especially true when they are harvested for fishmeal (Alder et al., 2008).

Many of the high trophic level fish targeted in the present study (e.g., tunas) are also migrating pelagic species that cover long distances (Silbert and Hampton, 2003), before they reach the MPA waters. These species usually form very few stocks (Kramer and
Chapman, 1999) and are exploited by multiple fishing fleets, sometimes from different countries. When restaurants import pelagic species that they would have been bought from the local fishers, chances are that this fish came from the same stock that locals exploit. However, whereas the MPA fishers are artisanal and only use rods, the mainland fleet fishing outside the protected area of the archipelago uses industrial scale longlines (Zagaglia et al., 2004), setting hundreds of hooks simultaneously, with considerably more impact on the ecosystem (Lewison et al., 2004). Nevertheless, the studied MPA, similar to most MPAs around the world, has little impact on the protection of the migrating species themselves (Guentette et al., 2000). The MPA protection is limited to resident species or to the ones that spawn or at least grow within its limits, which is hypothesized of sardines (Mendes, personal communication) – the baitfish for pelagic species – and of many rock/reef species (Almany et al., 2007). Sardines specifically are attributed as the cause of conflicts in the MPA, although the value chain analysis showed that sardines are just one side of a more complex problem. The demand for fish to attend mostly tourists would be at the root of the problem. Therefore, simply allowing the catch of sardines within the no-take zone will only postpone resolution of the conflict and increase the possibility of unforeseen impacts on the ecosystem, such as having direct effects on coastal sharks.

Particularly, the no-take zone is a nursing site for the locally abundant but near endangered lemon shark (Negaprion brevirostris), which also feeds on sardines (Garla et al., 2009). Other initial conservation measures that do not compromise the MPA, especially its no-take zone, have to be sought while the growing demand of tourism itself is not addressed. The literature suggests that the use of lures to catch pelagic fish and the development of Fish Lighting Attractors specific for sardines and outside the no-take zone could be alternative options. Lures, for instance, may be more effective than live baitfish to catch tunas (Lowry et al., 2006), although one has to contrast the costs of both alternatives to fishers. If lures are more expensive, this extra cost could be either slightly subsidized by the park fee or recovered by a higher price of the final product. On the other hand, many species of sardines are well studied regarding their aggregating behavior around artificial light (Giannouli et al., 1999), which could be an alternative pursued by the MPA itself, outside the limits of the no-take zone, to ameliorate the conflict.

5. Conclusions

We showed that addressing the problems identified in this value chain could open the dialogue for improved sustainability in the MPA of Fernando de Noronha while also identifying dynamics that may affect other MPAs allowing tourism. MPAs that allow visitation may exacerbate the pressure on natural resources to attend the demands created by tourists. In the studied case, the demand considered was fish for food, but it could as well be the impacts on biodiversity caused by recreation, for instance (Rouphael and Inglis, 2001). Furthermore, if an MPA interacts with divergent institutional and economic interests, the different institutions should find an integrative mid-ground to improve the synergies in the use of local ecosystem services (food and biodiversity provisioning and recreation). Here such mid-ground may be to establish limits to tourism and to seek better prices and reduced waste in order to avoid fishermen’s losses in the long run. Also it would be important to divert the focus from some of the most vulnerable and least resilience top predators.

Whereas conservation is usually not a top priority for developing countries, it is still important to make the existent initiatives viable and worth maintaining. This is a permanent effort and a battle that has been usually lost by conservationists in Brazil and elsewhere (Bernard et al., 2014; Mascia and Pailler, 2011). Losing sight of the underlying causes of conflicts in conservation areas is likely an important factor for failure. Economic tools, such as value chain analysis, can be cost-effective methods to evaluate and propose alternatives to otherwise unforeseen knots challenging the conservation or management status of an area.

Role of each author

PFML planned the study, collected and analyzed data and wrote the manuscript.

LM helped with the logistics, collected data and wrote the manuscript.

VF collected and analyzed data.

SV planned the study and wrote the manuscript.

Role of the funding source

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.jenvman.2017.05.080.

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Before the project, the global catch of the sardine Sardina pilchardus was an average of 1.2 million tons per year, but in 2002, it dropped to 900,000 tons. This reduction is due to the overfishing of the species, which has led to a decrease in the size of the population and a shift in the recruitment of cohorts.

The decline in the sardine population is a result of the overfishing of its predators, particularly the bluefin tuna Thunnus thynnus and the Atlantic mackerel Scomber scombrus. These species, which are important for the sardine population, have been overfished and are no longer able to regulate the population of sardines.

In addition to the overfishing of predators, other factors contribute to the decline in the sardine population. These include habitat destruction, pollution, climate change, and the introduction of non-native species. These factors have all contributed to the decline in the sardine population, and it is clear that urgent action is needed to prevent this species from becoming extinct.

The sardine is an important species for the global seafood market, and its decline has significant implications for the economies of countries that rely on this resource. It is clear that urgent action is needed to prevent the decline of this species, and this will require a coordinated effort among governments, scientists, and the seafood industry.

References


