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Shifting baselines among traditional fishers in São Tomé and Príncipe islands, Gulf of Guinea

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ABSTRACT

Local ecological knowledge has filled baseline gaps in conservation biology, providing important information that has contributed to resource management policies both on land and at sea. Marine ecosystems are globally threatened by overfishing, yet we know little on if and how fishers perceive changes in fisheries composition through time. This is particularly important in developing nations where people rely on fishery resources as their main source of food and income. We interviewed 178 artisanal fishers to collect information regarding their perceptions on the trends and composition of reef fisheries in São Tomé and Príncipe islands, a marine biodiversity hotspot. In addition, we investigated the relative contribution of the possible factors causing changes in these reef fish assemblages according to fishers' perceptions. Of six reef fish species assessed, five exhibited significant declining catch trends. We found a declining trend in individual body size for targeted species based on reports from older (mean ± S.E. = 43.3 ± 2.6 kg) and younger (21.0 ± 0.7 kg) fishers' generations. Generations also differed in their perceptions of declines over time, all of the very experienced fishers reported decline, while only one-third of inexperienced fishers did so. The main causes for fish catch changes identified by experienced fishers (> 40 years of fishing practice) were the increasing number of fishers (25%), destructive fishing practices (mainly blast fishing) (18%) and industrial fishing (29%). Our results suggest the occurrence of the shifting baseline syndrome phenomena among traditional fishers and provide baseline information for the conservation and management of São Tomé and Principe marine ecosystems.

1. Introduction

Ever since humans began collecting seafood along coastal areas, there have been impacts and changes on marine diversity (McCauley et al., 2015). Anthropogenic impacts have escalated through time and driven profound changes to marine systems, especially in the past few centuries (Jackson, 1997; Jackson et al., 2001; Halpern et al., 2008). The increase in human impacts is associated with population growth, and the augmented need for space and a multitude of resources, including marine ones. The industrialization era marked the expansion of fishing activities across the oceans, upscaling the impacts of human exploitation from local to global (Jackson et al., 2001; Roberts, 2007). Consequently, few marine environments have been left as pristine, i.e. locations that maintain relatively untouched biodiversity. Most of these pristine environments are located in remote, unpopulated and/or strictly protected areas (Edgar et al., 2014; Maire et al., 2016). While the majority of marine environments are heavily impacted by human activities (e.g. Jackson et al., 2001; Bellwood et al., 2004) there is still the need for a proper baseline knowledge of the past natural conditions of the oceans to better assess the magnitude of these impacts.

Fisheries have direct effects on fish populations, causing declines in overall abundance and reductions in average fish body size (Jennings and Kaiser, 1998; Myers and Worm, 2003; Jennings and Blanchard, 2004). Additionally, fisheries can have indirect effects that include impacts on marine habitats from destructive fishing practices such as bottom trawling and blast fishing (Roberts, 2007). While bottom trawling is mostly practiced in temperate zones (Dayton et al., 1995), blast fishing (using dynamite, grenades or other explosive mixtures) is

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often employed on tropical reefs (Ruddle, 1996; Jennings and Kaiser, 1998; DeMartini and Mundy, 1999). This activity has been particularly prevalent in low-income countries with declining fish catches, especially in Southeast Asia and Africa (Alcala and Gomez, 1987; Edinger et al., 1998; Ruddle, 1996; Pet-Soede and Erdman, 1998; Fox et al., 2003; Wells, 2009; Morais and Maia, 2016). Although blast fishing causes and consequences are well known (Alcala and Gomez, 1987; Fox et al., 2003; Wells, 2009), we still have a poor knowledge on how pervasive is this practice among artisanal fisheries.

Ethnographic methods are used in several scientific domains (e.g. medicine, anthropology, agriculture) and have also been applied in conservation biology to expand knowledge on past environmental conditions (Shackeroff and Campbell, 2007; Ternes et al., 2016; Braga et al., 2017; Lima et al., 2017; Turvey et al., 2017). The use of ethnographic methods such as interviews and participant observation enables the collection of data about local ecological knowledge (LEK) (Gadgil et al., 1993; Colding, 1998; Johannes, 1998; Berkes, 1999). The LEK of individuals and communities can reveal important insights regarding marine ecosystems (Ruddle, 1994a, 1994b; and 1994c; Silvano and Begossi, 2010). For example, at a local scale, the assessment of LEK from fishers can reveal valuable information about life history characteristics of fish species (Ruddle, 1993). In addition, LEK can provide important information for local resources management and policy design.

The assessment of local ecological knowledge has also been critical for the investigation of the shifting baseline syndrome (SBS; Pauly, 1995). This phenomenon describes how the baseline information of past conditions biases the characterization of present environmental states. In fisheries science, detecting the SBS depends on comparisons of present day conditions with the most pristine state as possible (i.e. before human expansion) (Pauly, 1995; Pandolfi et al., 2003). In the last 20 years, marine scientists have conducted several studies to demonstrate how our baseline shifted and its implications for conservation. Those studies have reported declines in the number of fished species, associated with declines in fish abundance (McClanahan et al., 2007; Mora et al., 2011; Sandin et al., 2008), fish sizes (DeMartini et al., 2008; Kittinger et al., 2011; McClenachan, 2009) and biomass (Friedlander and DeMartini, 2002; Graham and McClanahan, 2013; McClanahan et al., 2007). Additionally, some studies reported changes in species' reproductive potential (DeMartini and Smith, 2015) and in food web structure (Sandin et al., 2008; Sandin and Zgliczynski, 2014; Sala and Sugihara, 2005; Trebilco et al., 2013; Williams et al., 2011) as well as declines in reef resilience (Sandin et al., 2008; McClanahan, 2014). The perception of different fishers generations has also been used to describe changes in fisheries through time and to assess the occurrence of the SBS (e.g. Turvey et al., 2010; Baisre, 2013; Hanazaki et al., 2013; Bender et al., 2014; Plumeridge and Roberts, 2017; Sáenz-Arroyo et al., 2005a,b). These studies allow us to make comparisons to better understand how fisheries have changed through time and how fishers perceived these gradual changes throughout generations.

Despite being a marine hotspot (Roberts et al., 2002), São Tomé and Príncipe (STP), located in the Gulf of Guinea, Western Africa, has been understudied in many aspects of marine ecology, including the local trends in artisanal fisheries. Yet, its reef fish diversity has been relatively well studied in STP in the last decade, with 234 recorded species, 3% being endemic (Wirtz et al., 2007; Floeter et al., 2008). In the present study, we assessed the LEK of fishing communities to describe local fisheries composition and catch trends through time in STP. We also investigated the drivers of the detected trends in local fisheries and mapped the distribution of one of these drivers. Specifically, we intended to: (1) investigate changes in fisheries species composition, maximum catches and maximum body size of fish caught in STP in the past decades; (2) investigate the main causes of changes according to the LEK of fishers; and (3) to spatialize the prevalence of destructive fishing (blast fishing) in STP. Results from this work will contribute to establish a baseline for future management strategies for marine ecosystems in STP.

2. Material and methods

2.1. Study area description

São Tomé and Principe is an archipelago with two main islands (São Tomé island – ST and Príncipe island - PR) located in the Gulf of Guinea, West Africa (Fig. 1). The Democratic Republic of São Tomé and Príncipe is a Small Island Developing State (SIDS) (Frynas et al., 2003; Briguglio, 1995; Monnereau and Failler, 2014) that regained independence in 1975, after five centuries of Portuguese colonization. Presently, São Tomé and Príncipe has a population of approximately 190,000 people (RGPH, 2012). Fishing contribute with more than 80% of animal protein consumed by the population (RDSTP, 2009). Attempts to order local fisheries were first implemented by Portugal, through the *Serviço de Capitania dos Portos* (literally, port captaincy service) in the 1950s. At that time, a *Chefe de Praia* (literally, chief of the beach) was appointed to supervise fishing activities on each district (São Tomé and Príncipe has six districts, five in ST and one in PR) along the 30 fishing communities that existed in the two main islands (Hodges and Mewitt, 1988). Today, both industrial and artisanal fishing occur in São Tomé and Príncipe. Industrial fishing is practiced in the Exclusive Economic Zone (EEZ) of São Tomé and Príncipe, mainly by the European Union, Japan, Taiwan and China (vessels ranging from 160 to 290 feet) (Frynas et al., 2003; Krakstad et al., 2010; Carneiro, 2011; Serigstad et al., 2012). The present work focuses on artisanal fishing, which takes place mainly in traditional fishing villages (Fig. 1C–D). These villages hosted 2428 active fishers in 2010 (88% in ST and 12% in PR) (DGAP-RDSTP, 2010).

Most artisanal fishers of São Tomé and Príncipe are descendants of the *Angolar* people that occupy especially the western and eastern portions of São Tomé island (Ceita, 1991). Fishing is mainly practiced by men using wooden canoes while the fish is marketed by women called *palayês* (literally, saleswomen) (Ceita, 1991). The traditional Santomean canoes (or *Dongos*, Figueiredo, 1966) are made from a single trunk of local trees (normally *Ceiba pentandra*, but also other species). Large *Dongos* can reach 30 feet long, but on average measure 15–20 feet (Horemans et al., 1994) and are operated with paddles by one to three men. Only more recently (after the decades of 1970 or 1980), did *Dongos* start to be equipped with outboard motors of four to 40 Hp. Motors, lines, hooks and the *Dongos* themselves, which rarely last more than five years, constitute a heavy money investment for the fishers (Costa, 1959; Hodges and Mewitt, 1988). The eight main types of fishing gear used by artisanal fishers in São Tomé and Príncipe are described in Table 1.

São Tomé and Príncipe has a warm equatorial oceanic climate that receives seasonally the influence of dry and cool southern winds (Horemans et al., 1994). This results in two main seasons in the country: a dry season, from June to August, and a rainy season that occurs in the remaining months.

2.2. Data collection

We interviewed fishers in both São Tomé and Príncipe islands (Fig. 1C and D) from December 2015 to March 2016 using a structured questionnaire. Fishers were intentionally approached at the beach (Silvano et al., 2006; Bender et al., 2013) as they were leaving for fishing or repairing *Dongos* or nets. Before each interview, we informed fishers about the objectives of the study and asked for their consent to take part on the research. Interviews were recorded only after verbal consent since many fishers are unable to write or sign their own names. Interviews were mostly conducted in Portuguese but in some cases were held in local languages (*Santome* and *Angolar*) by the first author. To maximize the expression of personal experiences, each fisher was interviewed individually. Retired fishers indicated by other peers were visited in their households.

The structured questionnaire consisted of closed and open

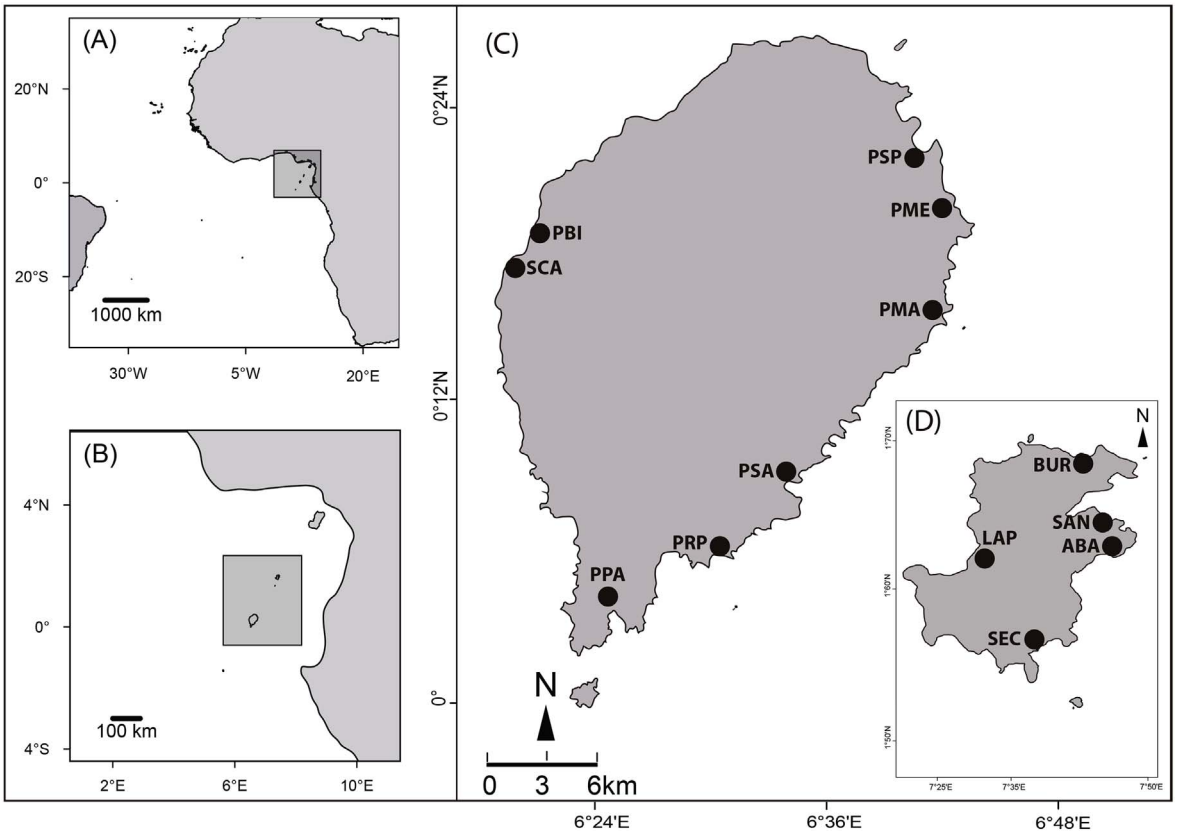

Fig. 1. Location of São Tomé and Príncipe islands (STPI) in the Atlantic Ocean: (A) Gulf of Guinea highlighted in the grey box; (B) STPI; (C) São Tomé island; and (D) Príncipe island. (● = Traditional fishing communities). ST: SCA – Santa Catarina; PBI – Praia Brita; PSP – Praia de São Pedro; PME – Praia Melão; PMA – Praia Messias Alves; PSA – Praia de Angolares; PRP – Praia de Ribeira Peixe; PPA – Praia de Porto Alegre. PR: LAP - Praia da Lapa; BUR – Praia das Burras; SAN – Santo António; ABA – Praia de Abade; SEC – Praia Seca.

questions, where the interviewees had the opportunity to elaborate on answers as desired (see questions in Appendix). The first part of the questionnaire was used to determine the sociological characteristics of fishers (name, birth place, age, fishing gear and fishing experience in years). The second part consisted of displaying fish species images to the interviewees and requesting them to assign the name of those they recognized (based on Silvano et al., 2006). Following each fish species identification, they were questioned on: 1) The average size of individuals caught in the present; 2) the largest individual ever caught (in kilograms); 3) when and where those largest fish were caught; 4) fishing gear used; and 5) the best day's catch, i.e., the greatest catch, in kilograms, that they remembered landing for each species. These questions were repeated for every species identified by fishers. The last part of the questionnaire comprised questions on their environmental perceptions: 1) past and present catch composition, 2) trends in catch over time, and 3) impacts on fish abundance in the region. To assess catch trends over time, interviewees were asked specifically to compare the current fisheries situation with that when they started fishing and to define potential trends over time.

We used photographic images from six commercially targeted fish species in STP islands (Costa, 1959; EST, 1980): the Dungat grouper, *Epinephelus goreensis* (Valenciennes, 1830); the Great barracuda, *Sphyraena barracuda* (Edwards, 1771); the White grouper, *Epinephelus aeneus* (Geoffroy St. Hilaire 1817); the African red snapper, *Lutjanus agennes* (Bleeker, 1863); the Gorean snapper, *Lutjanus goreensis* (Valenciennes, 1830); and the Bluespotted seabream, *Pagrus caeruleostictus* (Valenciennes, 1830). We also questioned fishers on other large-sized fish species caught during their fishing practice.

Table 1
The eight main types of fishing gear used by artisanal fishers in São Tomé and Príncipe.

Fishing gear	Description
Line	This technique is applied to four types of fishing in the São Tomé and Príncipe islands: *Corrico, palangre de fundo*, and bolo [the fishermen pull the lines with their hands, it is usually practiced on top of the canoe, but sometimes it is observed that it is practiced by women and children from the coast]. The diameters of the lines vary according to the target species.
Fishing net	In the São Tomé and Príncipe islands there are three main variants of fishing nets: Surrounding net (length between 100 and 2000 m, height from two to 25 m and 13/29 mm mesh), drift net (length between 1000 and 1500 m, height ~870 m and 210/6 mm mesh) and bottom set gill net (length ~300 m, height ~4 m and 13 mm mesh).
Voador panhan	Is the most widespread fishing gear, and consists in capturing flying-fish (family Exocoetidae) with the use of floating traps made of herbs or grass (Costa, 1959; Horemans et al., 1994).
Spearfishing	Is practiced by the younger fishers and involves the capture of mainly reef organisms (e.g. octopuses, cuttlefish, morays and rays).
Casting net	Is an almost extinct fishing gear, being practiced almost exclusively by fishers over 70 years old.
Pingue/palangre de fundo	Is a composite of hundreds of hooks hanging over the seabed that targets bottom species such as the Bluespotted seabream (*Pagrus caeruleostictus*) and the flying gurnard (*Dactylopterus volitans*).
Corrico	The *Corrico* gear uses bait (e.g. *Euthynnus* spp. and *Decapterus* spp.) towed by a motorized canoe and targets mainly sharks.
Candieiro	*Candieiro* is practiced at night, with the use of light to attract and capture fish.

2.3. Data analysis

Fishers were categorized into four groups according to their time devoted to fishing activities: inexperienced (≤15 years of practice, 53 fishers); intermediate (16–30 years of practice, 48 fishers); experienced (31–40 years of practice, 37 fishers); and very experienced (> 40 years of practice, 40 fishers). It is important to highlight that this classification is solely based on time devoted to fishing, in years, and brings no qualitative judgement about the real experience of each fishers. We acknowledge that this classification assumes that all fishers spend the same proportion of their year devoted to fishing, and that all fishers are able to acquire experience (in the sense of "knowledge") at the same rates. Nevertheless, this classification allowed us to quantify trends in fish catches, as well as the differences in overall perceptions of these trends across fishers' generations. A simple linear regression was used to evaluate how the best day's catch reported by each respondent varied according to the time of that fishing event (in years before present), for each species.

To assess whether maximum body size of fish caught in STP in the past decades varied with fishers' experience (inexperienced, intermediate, experienced and very experienced), we applied a generalized linear model – GLM – with a Gamma distribution. To assess whether possibly detected changes were due to changes in target species that attained different sizes rather than changes in size per se, we modelled how maximum body size of captured fish responded to both experience level and fish species. To detect differences among groups, we used a post-hoc Tukey test built upon the GLM, with the function "glht" within the package *multcomp* (Hothorn et al., 2008).

Those fishers who described changes in catches over time were also questioned regarding the possible cause of changes. We further quantified and grouped the main causes of change mentioned in categories of problems, or drivers of change. The analyses of the fishing impact were conducted by island. Given the repetitive accounts on the use of blast fishing in the region (Morais and Maia, 2016), we included this topic in our interviews. Specifically, we asked if 1) they had ever heard about blast fishing occurring in their region and, if so, 2) if they had ever witnessed blast fishing and, if so 3) if they had ever practiced blast fishing. To uncover the most affected sites from blast fishing, we further asked interviewees the fishing grounds in which blast fishing has been used and spatialized this distribution in a map for each island.

3. Results

3.1. Changes in targeted fish species

We interviewed 178 (~7.3% of 2428) active fishers (see Table 1, supplementary material). All were men, with ages ranging from 16 to 92 years old (average = 43 years). In Príncipe island we interviewed fishers from five traditional villages: Praia da Lapa (n = 3), Praia das Burras (n = 25), Santo António (n = 1), Praia de Abade (n = 12) and Praia Seca (n = 1) (Fig. 1D); and in São Tomé island we interviewed fishers from eight villages: Santa Catarina (n = 35), Praia Brita (n = 7), Praia de São Pedro (n = 3), Praia Melão (n = 7), Praia Messias Alves (n = 25), Praia de Angolares (n = 12), Praia de Ribeira Peixe (including the communities of Yó-Grande and Praia Pesqueira) (n = 17) and Praia de Porto Alegre (including the community of Malanza) (n = 30) (Fig. 1C).

Among the interviewed fishers, 81% (145) reported changes in fisheries composition and/or catches in São Tomé and Príncipe over time, while only 18% (33) reported no change. The vast majority of these 145 fishers reported declines in fish sizes and catch trends (90%). The proportion of fishers that reported a decline in catches over time differed according to experience categories: all of the very experienced fishers reported a decline, compared to 75% of experienced and 50% of intermediately experienced, and to only 35% of inexperienced fishers. Only inexperienced or intermediately experienced fishers reported no change in fisheries composition over time, whereas only inexperienced fishers reported an increase in the captures. Regarding changes in fisheries composition, 76% (134) of the fishers mentioned species that were not targeted in the past but that have become economically important over time. Among these species, the most cited were: sharks (Nurse shark, *Ginglymostoma cirratum;* Blue shark, *Prionace glauca;* Sand tiger shark, *Carcharias taurus and* Scalloped hammerhead, *Sphyrna lewini*), West African goatfish, *Pseudupeneus prayensis;* Broadbanded moray, *Channomuraena vittata;* Stout moray, *Muraena robusta;* Creolefish, *Paranthias furcifer;* Flat needlefish, *Ablennes hians;* Atlantic agujon needlefish, *Tylosurus acus rafale;* Cornetfish, *Fistularia tabacaria;* Balao halfbeak, *Hemiramphus balao;* Blackbar soldierfish, *Myripristis jacobus;* Senegalese rockfish, *Scorpaena laevis;* Swallowtail seaperch, *Anthias anthias;* Tripletail, *Lobotes surinamensis;* Bogue, *Boops boops;* Chubs, *Kyphosus* spp.; African sicklefish, *Drepane africana;* Cape Verde gregory, *Stegastes imbricatus;* Blackbar hogfish, *Bodianus speciosus*. Sete Pedras, Ilhéu das Rolas, Ilhéu Santana, Lagoa Azul and Ilhéu das Cabras were sites repeatedly mentioned as good fishing spots in the past that are now considered overexploited by experienced and very experienced fishers for São Tomé. In Príncipe island, the sites most frequently referred to as overexploited in the present were Ilhéu Bombom, Ilhéu dos Mosteiros, Tinhosas and Pedra da Galé.

The relationship between the largest fish individuals ever caught by fishers against time of fishing event (years ago) revealed changes in fish catch over time (Fig. 2). When looking at each species, the results suggest that best catches have occurred in the past for the White grouper *E. aeneus* (slope = −0.71; *Adjusted* $R^2 = 0.43$; $p < .001$; Fig. 2A) and the Dungat grouper *E. goreensis* (slope = −0.68; *Adjusted* $R^2 = 0.41$; $p < .001$; Fig. 2B). For the Great barracuda *S. barracuda* (slope = −0.43; *Adjusted* $R^2 = 0.11$; $p = .02$; Fig. 2D), the African red snapper *L. agennes* (slope = −0.26; *Adjusted* $R^2 = 0.08$; p = .03; Fig. 2E) and the Gorean snapper *L. goreensis* (slope = −0.51; *Adjusted* $R^2 = 0.16$; $p < .001$; Fig. 2C), a significant but weak negative relationship was found. For *P. caeruleostictus* the relationship was not significant (slope = −0.14; *Adjusted* $R^2 = 0.24$; p = .22; Fig. 2F).

The body size of the largest individual ever caught differed among groups of fishers with different levels of experience, but was not affected by species identity (Table 2; see also Fig. 3A). Very experienced fishers have caught larger fish than all other categories (Tukey test: $p < .01$; mean ± S.E. = 43.3 ± 2.6 kg, Fig. 3A). The largest fish caught by experienced and intermediate level fishers had a similar size (26.7 ± 0.8 kg and 26.5 ± 1.1 kg respectively; Fig. 3A), yet both had caught larger fish compared to inexperienced fishers (21.0 ± 0.7 kg; Tukey test: $p < .001$; Fig. 3A). For each species, the results for the largest individual caught mirrored those of the largest fish caught (Fig. 4). There was a clear increase in the largest individual caught from inexperienced to very experienced fishers for almost all species analyzed (Fig. 4A–E). The exception was the Bluespotted seabream, *P. caeruleostictus*, which only the most experienced had caught larger individuals compared to other categories (Fig. 4F).

3.2. Causes of change based on local knowledge

Fishers identified seven main causes for changes in local fisheries: 1) increases in the number of fishers (reported by 45; 31% fishers); 2) destructive fishing practice (blast fishing, 32; 22%); 3) presence of industrial fishing (51; 35%); 4) climate change (12; 8%); 5) presence of whales (1; 1%); 6) pollution with chemicals (2; 1%); and 7) black magic (a cultural practice evocating supernatural powers, mentioned by two fishers; 1%). The perceptions of those causes varied among fishers of different experience categories. For example, the proportion of fishers that cited blast fishing as a cause of change in fish catches decreased from very experienced (28%) to experienced (23%), intermediate (22%) and inexperienced fishers (12%) (Fig. 3B). The cause "increase in the number of fishers" had a similar pattern of decline from very experienced (37%) to inexperienced (28%). Contrarily, the perception of

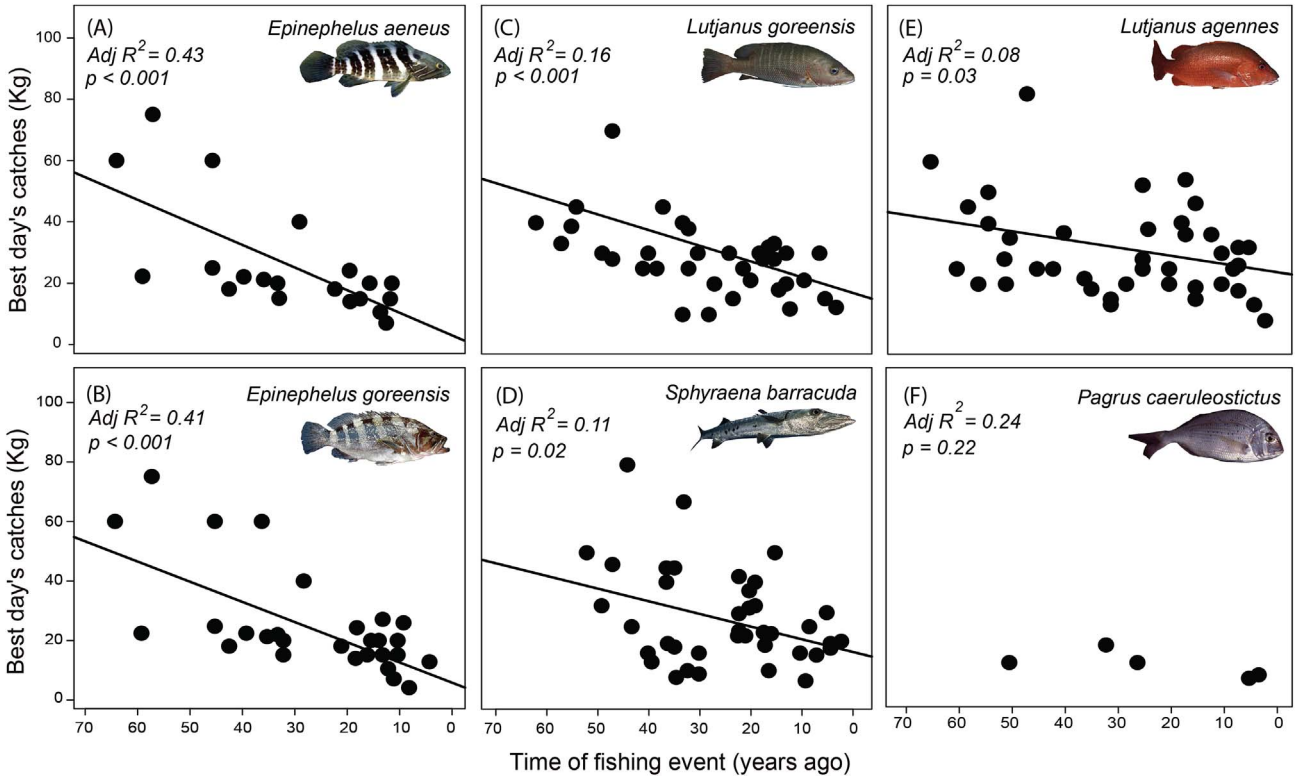

Fig. 2. Relationship between best day's catch (largest individual caught in kilograms) that fishers remembered and the time of fishing event (years ago) by species.

Table 2
Results of GLM evaluating the influence of fishing time and fish species on the body size of the largest individual ever caught. Bold values indicate p < .001.

Source	Estimate	Std. Error	t value	p-value
(Intercept)	0.066	0.035	1.85	.0663
Fishing time: very experienced	−0.015	0.004	−3.50	**.0006**
Fishing time: inexperienced	0.009	0.005	1.82	.0704
Fishing time: Intermediate	0.004	0.004	0.09	.9258
Fish species: *E. aeneus*	−0.019	0.035	−0.54	.5836
Fish species: *E. goreensis*	−0.030	0.036	−0.82	.4090
Fish species: *S. barracuda*	−0.031	0.035	−0.89	.3718
Fish species: *L. agennes*	−0.028	0.035	−0.81	.4195
Fish species: *L. goreensis*	−0.029	0.035	−0.83	.4060
Fish species: *P. caeruleostictus*	−0.007	0.044	−0.15	.8741

industrial fishing as a driver of change in local fisheries increased from very experienced fishers (25%) to inexperienced (44%) (Fig. 3B).

Among 136 fishers interviewed in São Tomé island, 68 (50%) affirmed that they have never heard about blast fishing, 19 (14%) fishers have heard but have never witnessed its use, and 49 (36%) had witnessed and knew fishers that practiced this type of fishing. In Príncipe, among 42 interviewed fishers, 15 (36%) declared they have never heard of blast fishing, 13 (31%) have heard but have never seen it, and 14 (33%) declared themselves as witnesses of this practice. None of the fishers declared himself as a blast fisher. Fourteen sites were mentioned as being targeted by blast fishing in São Tomé island, three sites (Ilhéu Santana, Sete Pedras and Ilhéu das Rolas) being the most cited (Fig. 5). Figure S1 details community reports for each site. The sites were reported in six of the eight communities where we interviewed fishers. Fishers from the community of Santa Catarina mentioned six blasted sites, followed by the fishers from Porto Alegre who cited five sites. In the other communities, less than three sites were mentioned. Fishers from two nearby communities (Praia de Ribeira Peixe and Praia de Angolares) presented several citations of Sete Pedras (SPE) site. At Príncipe island the sites with the highest citations were Ilhéu dos Mosteiros and Pedra da Galé (Fig. 5B). Fishers from Praia Abade cited seven spots while fishers from Praia das Burras and Praia da Lapa mentioned four spots (Fig. S1B).

4. Discussion

We observed a strong negative relationship between the maximum size of fish caught by fishers and time before present for two of the six species evaluated. For three other species we also observed a significant, albeit weak, negative relationship. Also, fishers with more than 40 years of fishing practice reported having caught larger fish than less-experienced fishers. This pattern was also observed when looking separately at species. For instance, the size of the largest *S. barracuda* and *E. aeneus* caught by fishers was smaller for the inexperienced when compared with the intermediate and experienced classes. This suggests a potential decline in the catch trends of São Tomé and Príncipe's artisanal fisheries. A related similar pattern was observed for the perceptions of fishers regarding fishing activities over time: while all of the very experienced fishers declared that fisheries have declined, only 35% of the inexperienced fishers have recognized that pattern. Fishers who were not able to perceive changes in fisheries catch and composition were either inexperienced or intermediately experienced. Furthermore, all fishers that reported an increase in catches were inexperienced ones. These results collectively suggest that fishers in São Tomé and Príncipe might have been experiencing the Shifting Baselines Syndrome (Pauly, 1995).

The declining trend in artisanal fisheries as reported by fishers in São Tomé and Príncipe has also been reported in many other localities around the world, including continental Africa (Baum and Myers, 2004; Dulvy and Polunin, 2004; Sáenz-Arroyo et al., 2005a, 2005b; Bunce et al., 2008; Pinnegar and Engelhard, 2008; Bender et al., 2014). The single artisanal fisheries statistics available for São Tomé and Príncipe encompasses landings of coastal species from 1961 to 1978 (EST (Estatística de São Tomé), 1980). In this report, there is an apparent decline pattern for traditional fisheries over the period. Nevertheless,

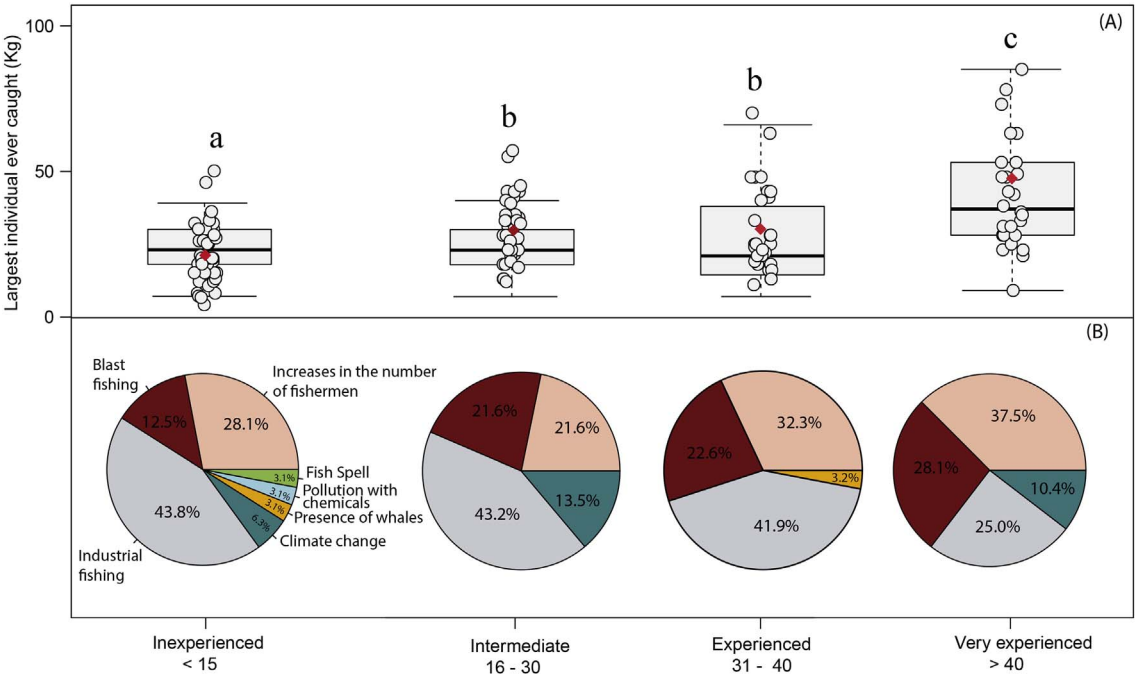

Fig. 3. (A) Variation between largest individual ever caught (in kilograms) across generations of fishers (years of practice). (○ = a fisher's catch; ◆ = mean). (B) Pie charts represent the proportions of causes of change indicated by fishers. Each color represents a different category of cause. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

17 years can be considered, in most cases, an insufficient time to reliably detect trends in fisheries or fishing stocks, especially in tropical fisheries targeting multiple species (Pauly and Murphy, 1982).

Similar to fisheries declining trends, the Shifting Baselines Syndrome has been detected by other studies around the world (e.g. Sáenz-Arroyo et al., 2005a,b; Ainsworth et al., 2008; Bunce et al., 2008; Bender et al., 2014; Giglio et al., 2015), with clear signs of changes in the perception of fishers through generations. For example, Sáenz-Arroyo et al. (2005a,b) identified that older fishers in Mexico's Gulf of California recognized five times more species and four times more fishing sites that suffered severe declines in catches. In the south-western Atlantic, Bender et al. (2014) showed that older fishers not only

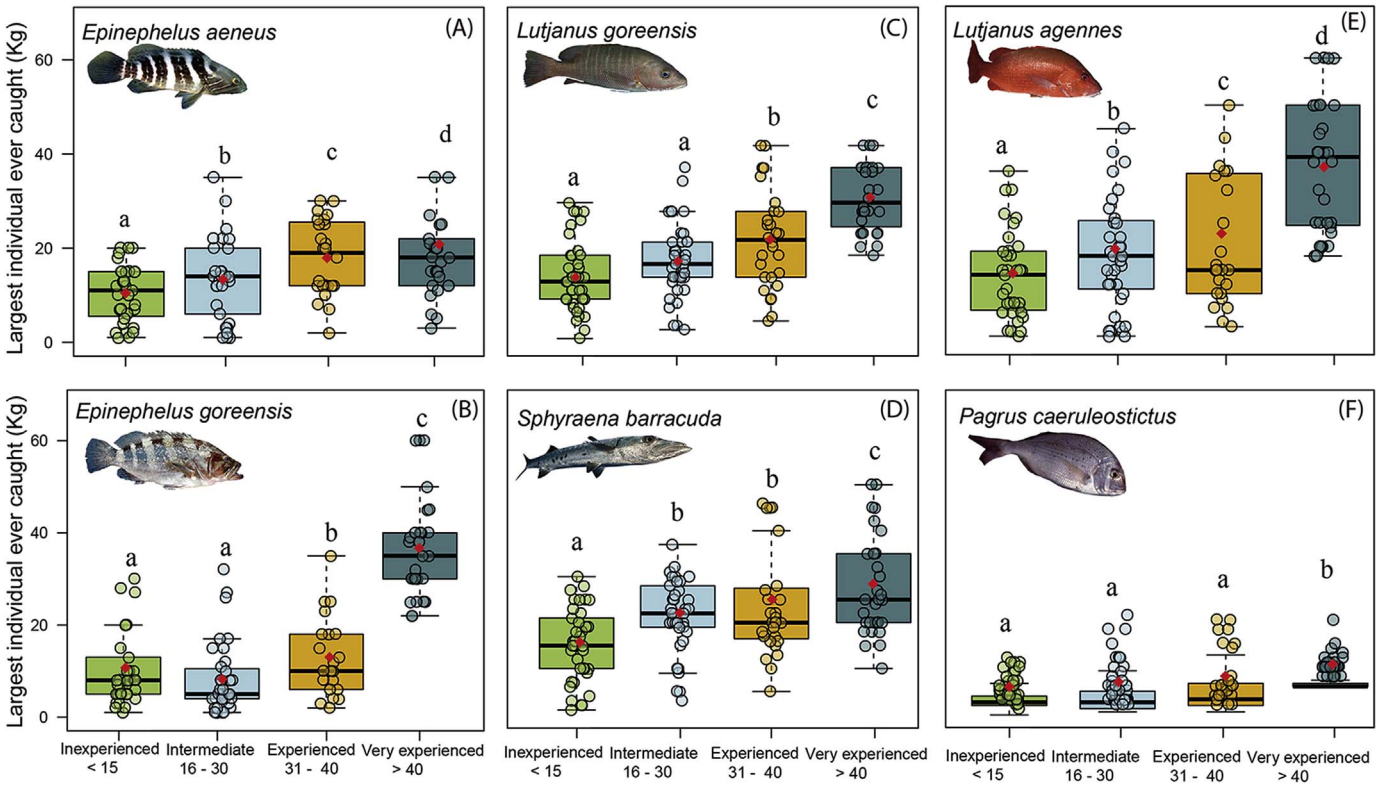

Fig. 4. Variation between largest individual ever caught (in kilograms) across generations of fishers (years of practice) by species. (○ = a fisher's catch; ◆ = mean).

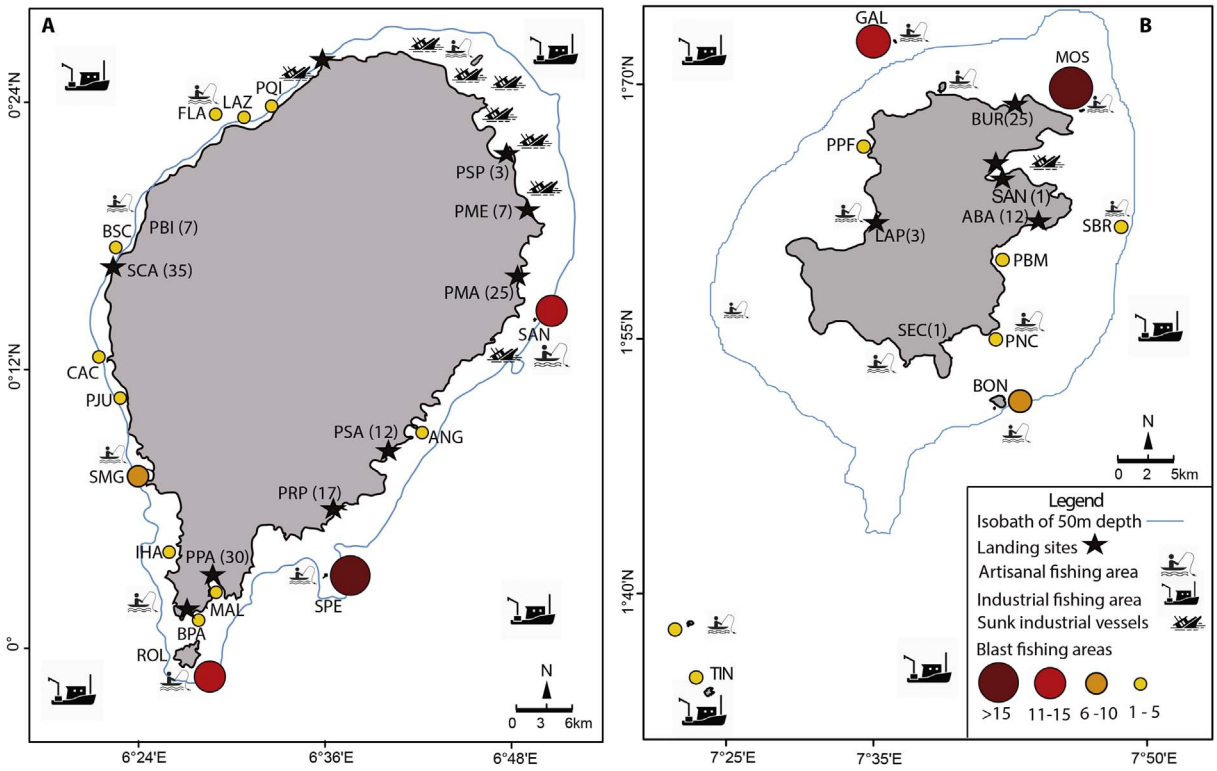

Fig. 5. Spatial distribution of the blast fishing cited by fishers in São Tomé island (A) and Príncipe island (B). Color gradient indicates the degree of impact based on the number of citations by fishers. Sites in São Tomé: SBC – Baia de Santa Catarina; FLZ – Fundão de Lagoa Azul; LAZ – Lagoa Azul; PQI – Praia Quinze; SAN – Ilhéu Santana; ANG – Praia de Angobó; SPE – Sete Pedras; MAL – Baia de Malanza; BPA – Baia de Porto Alegre; ROL – Ilhéu das Rolas; IHA – Praia Inhame; SMG – Ilhéu de São Miguel; PJU – Ponta da Juliana; CAC – Calé Calé. Sites in Príncipe: PPF – Ponta da Pedra Furada; GAL – Pedra da Galé; MOS– Ilhéus dos Mosteiros; SBR – Sete Braças; PBM – Ponta Banana; PNC – Ponta Café; BON – Ilhéu Boné de Jóquei; TIN – Ilhas Tinhosas. Numbers in parentheses represent total interviewed fishers by community. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

have caught larger individuals of specific fishes compared to younger ones, but also reported that the catches of large fish occurred around four decades ago. In this same study, fishers reported a steep declining trend in the catches of five out of nine reef fish species assessed. In Africa, Bunce et al. (2008) noted marked differences in fishers' perceptions of size and number of fish reported by three successive generations of fishers from an island. In this study, the median number of species reported by the oldest group of fishers was twice as high compared to the youngest. For São Tomé and Príncipe, the majority of experienced fishers reported a strong decline in local fisheries. On the other hand, only one-third of inexperienced fishers reported declines over time (with some reports of increasing captures). Furthermore, some inexperienced fishers reported having never caught some of the studied species, in contrast with experienced fishers that recognized all species.

Other species not included in our analyses, but mentioned by the interviewees indicate the occurrence of changes in fisheries composition. Based on the accounts, sharks were not commonly caught in São Tomé and Príncipe before 1970 because they were laborious to capture (requiring between six to 10 h of effort to remove them from the water) and had no commercial value. Despite the relative isolation of the country, since 1975 there has been an increased access to fishing technologies (nylon lines, nets and boat motors) that eventually replaced the traditional fishing gears (Hodges and Mewitt, 1988). Moreover, since the independence of the country, international organizations for fisheries have provided local fishers with equipment and technical support in the form of workshops (Hodges and Mewitt, 1988; Carneiro, 2011). These new technologies and access to new knowledge may have greatly contributed to the increase of fishing pressure on the islands, and to the overexploitation of some species, resulting in the changes perceived by fishers.

4.1. Factors causing changes in reef fish compositions and/or catches

Because of their accumulated empirical knowledge, fishers represent a rich source of information about habitats and behaviors of fish species (Raychaudhuri, 1980; Ruddle, 1993; Silvano et al., 2006; Silvano and Begossi, 2010). In our study, artisanal fishers pointed out seven factors as the main causes of change in fisheries catches and species composition, of which the most cited were: industrial fishing, increases in the number of fishers, blast fishing, and climate change. STP does not have a national industrial fishing fleet, and the fleets operating in the country's Economic Exclusive Zone are mainly from Japan, Taiwan, China and the European Union (Belhabib, 2015). According to 32 fishers, although the amount of fish caught by industrial fleets is high compared to artisanal fisheries, large captures are not the main damage generated for artisanal fishers by industrial fisheries. In their perception, the major damage caused by industrial fishing fleets is the abandonment of ships that brings, over time, impacts to the marine environments like oil-spills.

From 1955 to 2010, the number of artisanal fishers in São Tomé and Príncipe increased approximately 116% from 1127 to 2428 fishers (Costa, 1959; DGAP-RDSTP, 2010). Moreover, this time period also encompassed a huge technological revolution that resulted in more efficient and profitable fisheries all around the world, and STP was no exception. For example, fishers from two communities in our study (Malanza and Angolares) mentioned that nylon lines were scarce in the country before the independence (1975). According to them, before that time they employed hand-made lines from local plants in a laborious process that limited the amount of time they could spend at sea. Thus, technological improvements such as the provision of better quality nets, lines and hooks, and motorized boats, coupled with an increasing demand from a growing population and an increase in the

number of fishers likely resulted in increased catches. In fact, a catch reconstruction estimated that artisanal fisheries captures increased by more than 300% from 1950 to 2002, from around 1,500t to more than 4,700t (Belhabib, 2015; FAO, 2017).

More than a third of the interviewed fishers in São Tomé and Príncipe islands had witnessed blast fishing. Blast fishing not only indiscriminately kills fish, but it also inflicts heavy damage to the reef structure (Fox and Caldwell, 2006). As such, it can have detrimental effects to fishing activities, if the targeted stocks depend on the reef matrix for their life cycles (McManus et al., 1997; Fox and Erdmann, 2000). In 2001, the Santomean government established a legislation banning all fishing activities that have strong negative direct or indirect impacts on aquatic and coastal environments (e.g. fishing with explosives, grenades, toxic products and fishing with homemade bombs; RDSTP, 2001).

The main sites where fishers reported having heard of blast fishing in both São Tomé and Principe are also some of the most sensitive and biologically important of the islands. For instance, in São Tomé island, the sites that present the highest coral cover are Ilhéu Santana, Sete Pedras and Ilhéu das Rolas (Floeter et al., 2008). These are also the most cited places for blast fishing occurrences. This raises a strong concern about the future of coral communities in São Tomé, and suggests that these places should be important targets for conservation efforts. Similarly, Pedra da Galé and Ilhéu dos Mosteiros in Príncipe island, and Lagoa Azul in São Tomé island are areas of concentration of gorgonian and black coral forests (Wirtz & D'acoz, 2008; Morais and Maia, 2016). These places were repeatedly cited by fishers as affected by blast fishing. Fortunately, some of these sites harbor gorgonian and black coral forests in mesophotic depths still far from the reach of blast fishers (Morais and Maia, 2016).

Climate change was also recognized as an important driver of change in fisheries catches and species composition by interviewed fishers. Interviewed fishers mentioned climate change in the context of a recent shortening of the dry season. According to them, the *Gravana*, as the dry season is designated, has begun later and finished earlier in recent times. Fishers also mentioned weaker winds and warmer ocean waters associated to this purported change and that they result in interferences, especially in fish reproductive season. A possible topic for further investigations is to evaluate if these climate change perceptions actually scale with meteorological and oceanographic data and, if so, whether reproductive cycles of target species could be affected. Local Ecological Knowledge of fishers has been applied before in the context of identifying the reproductive season of fish species (e.g. Gerhardinger et al., 2006; Silvano et al., 2006; Silvano and Begossi, 2010; Ferreira et al., 2014). This type of LEK could be allied with meteorological and fisheries research to yield future insights on the possible effects of climate change in fish reproduction and catch rates.

The Gulf of Guinea, including São Tomé and Príncipe, has been considered as one of the 18 global hotspots for the conservation of marine biodiversity (Roberts et al., 2002). However, so far, São Tomé and Príncipe host no marine protected areas. The fishers themselves recognize that the problem of overexploitation of marine resources could be addressed, at least partially, through the creation of marine reserves. According to one of them: “regardless of [fishing activities] being our livelihood it is also a cultural issue”. Our study showed that most fishers perceive a declining trend in fishing catches and changes in fisheries species composition in the last decades in São Tomé and Principe. We also found evidence of the occurrence of the shifting baseline syndrome among fishers' generations. The pattern of change identified by local fishers in STP corroborates the widespread degradation pattern noted for marine environments across the world (Jackson et al., 2001; Worm et al., 2006). We emphasize the importance of using local ecological knowledge, not only to detect baseline changes in marine habitats, but also to identify causes of change to better manage marine resources. We thus recommend: 1) enforcement of the existing laws prohibiting destructive fishing practices (e.g. fishing with explosives, grenades, toxic products and bombs); 2) tracing the origin of the products used for the illegal practices and controlling its use; 3) the creation and enforcement of no-take marine protected areas around both islands; 4) a more strict control of industrial fishing (this could include on-board fisheries observers, setting catch quotas, setting enforcement systems for illegal industrial ships; and 5) the update and maintenance of statistical reports of artisanal fisheries. These actions would help to prevent further declines in STP fisheries and support the maintenance of resources for future generations of artisanal fishers in the islands.

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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.ocecoaman.2018.01.006.

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