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Depletion of marine megafauna and shifting baselines among artisanal fishers in eastern Brazil

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Abstract

Increasing exploitation effort and efficiency have been leading to population declines and extinctions among large marine animals. Understanding the magnitude of such losses is challenging because current baselines about species' abundances and distributions in the sea were mostly established after humans had started affecting marine populations. For artisanal fisheries, from which written historical records are rarely, if ever, available, approaches based on gathering anecdotal information from fishers' knowledge are a promising method to know the past environmental conditions. We interviewed coastal artisanal fishers, with ages varying from 15 to 85 years, to detect temporal changes in the catch abundance of large fish species, particularly the largetooth sawfish *Pristis pristis* and the goliath grouper *Epinephelus itajara* within Abrolhos Bank, Brazil. Most fishers considered that fishing has led to species depletion. However, older fishers reported significantly more species and larger species as depleted than young fishers. Older fishers caught significantly larger largetooth sawfish and goliath grouper in the past than younger fishers. The largetooth sawfish has not been caught or sought for more than 10 years. Probabilistic tests provided no definitive evidence for local extinction, although the past record of sightings indicates a population decline close to the threshold level for extinction probability. We provide evidence that small-scale artisanal fisheries can decimate the abundance of large coastal fishes, one of those almost close to local extinction. Finally, our results suggest that the younger generation is not aware of past ecological conditions, indicating the occurrence of a shifting baseline syndrome among the fishing community.

Introduction

Hunting by humans, in combination with large-scale habitat modification and climate change, had a decisive role in the Pleistocene and Holocene terrestrial megafauna (e.g. mammals and birds) extinctions in several continents, beginning around 15 000 years ago (Turvey, 2009; Prescott *et al*., 2012). A similar pattern of depletion and extinction is seen in the world's ocean megafauna (Jackson *et al*., 2001; Lotze *et al*., 2006) where a variety of taxa, including sharks, rays, large teleost fishes, sea turtles, sea birds and marine mammals, declined to extremely low levels during the last century mainly because of direct exploitation and/or incidental bycatch (Myers & Worm, 2003; Lewison *et al*., 2004). Similar to the long-lived giant terrestrial beasts of the Pleistocene, the marine megafauna of today are declining largely as a result of human's improved efficiency and expansion of fishing (Heppell *et al*., 2005).

Data about the history, magnitude and drivers of past changes are needed to assess the conservation status marine megafauna targeted by fisheries (e.g. elasmobranchs and teleost fishes) (Lotze & Worm, 2009). However, this type of information is seldom available because scientists started documenting patterns of diversity and abundance in the sea long after the ecological responses to human impacts in the marine realm (Jackson, 1997; Roberts, 2007). The discovery of centuries-old commercial fishery logbooks (Bolster, Alexander & Leavenworth, 2011) and historical written accounts made by early explorers (Sáenz-Arroyo *et al*., 2006; Luiz & Edwards, 2011) illustrates alarming estimates of population decline. However, in most tropical regions, the historical trajectory of the fishery is unwritten (Diamond, 2001) and therefore alternative sources of data are needed if we ought to understand past abundance changes in marine megafauna.

The engagement with local ecological knowledge (LEK) by scientists is now a well-established area of ecological research (Johannes, 1998; Huntington, 2000; Drew, 2005). An alternative to overcoming constraints imposed by limited data sets is to tap into the memories of fishers (Venkatachalam *et al*., 2010), an approach linked to various scientific disciplines investigating the past such as historical ecology (McClenachan, Ferretti & Baum, 2012). In many places, reminiscences of elders are the only source of data to inform science and management about changes in artisanal fisheries that are typically multispecific, present diffuse fishing effort and landing at a number of scattered sites (Munro, 1996; Johannes, 1998; Sáenz-Arroyo *et al*., 2005*a*; Ames, 2007).

For instance, Sáenz-Arroyo *et al*. (2005*b*) have remarkably illustrated how older fishers in the Gulf of California had experienced not only higher catches but also caught larger-sized fish than younger fishers. The number of fish caught in their best-day catch declined by 96% from 1940 to 2000. This and other studies alike (Ainsworth, Pitcher & Rotinsulu, 2008; Bunce *et al*., 2008; Turvey *et al*., 2010) provide evidence that the shifting baselines syndrome – a phenomenon originally described to show changes in perspectives of what was natural among fisheries scientists as one generation replace another (Pauly, 1995) – is pervasive among fishers as well. In a system that has experienced environmental changes, younger generations may have less awareness about the diversity and/or abundance of species in the recent past (Papworth *et al*., 2009). This presents a particular problem for understanding 'natural' environmental conditions and past human effects on ecosystems, especially in systems for which few data on historical patterns of biodiversity are available (Jackson, Alexander & Sala, 2011).

Artisanal fisheries account for as much as 50% of Brazilian fish catches. In the northeast Brazil, artisanal fisheries contribute with 88% of the fish production (Begossi, Lopes & Silvano, 2012). While information from fishers interviews used for scientific inference is not exempt of caveats (Daw, 2010), it still can make a valuable contribution to the body of scientific knowledge concerning species abundance trends in data-poor fisheries (Sáenz-Arroyo *et al*., 2005*a*; Ames, 2007). Fisher-derived data are relatively inexpensive to obtain. It may therefore be helpful for conservation assessments of the fishes, especially in an area lacking resources for science and management such as the tropical Brazil.

This study focuses on historical changes in captured fish species sizes and frequency over three generations of fishers in Abrolhos Bank. This is an area of high marine biodiversity conservation concern as it is home to nearly 300 species of fish and 20 species of corals (Dutra *et al*., 2005). The Abrolhos Bank covers a mosaic of marine habitats, such as coral reefs, sea grass beds and mangroves, and is considered the largest and most diverse reef complex in south-west Atlantic (Leão & Kikuchi, 2001). However, the area is increasingly affected by anthropogenic activities such as overfishing, unordered tourism, dredging and pollution (Ferreira & Gonçalves, 1999; Moura *et al*., 2013). Our study will focus in two iconic Atlantic megafauna species: the largetooth sawfish *Pristis pristis* and the goliath grouper *Epinephelus itajara*. They are one of the largest elasmobranch and teleost fish, respectively, which are restricted to coastal shallow water (<50 m depth). We selected these species because large-bodied organisms are likely to remain on collective consciousness (Turvey *et al*., 2010) and concerns rose after reports of widespread reductions in abundance along its original range over the past three decades (Simpfendorfer, 2000; McClenachan, 2009).

Both species are currently listed as critically endangered by the International Union for Conservation of Nature (Craig, 2011; Kyne, Carlson & Smith, 2013). Largetooth sawfish reaches >5 m in total length (TL) and was once widely distributed within the coastal waters of the Atlantic and Pacific (Faria *et al*., 2013). In the western Atlantic, its historical distribution ranged from the US to Brazil (Faria *et al*., 2013). However, this species has become remarkably rare because of overfishing. In the US, largetooth sawfish was last recorded in 1961 (Fernandez-Carvalho *et al*., 2014). Because recent records are lacking from many localities where it was once common, the largetooth sawfish may be locally extinct in most part of its historical range (Dulvy *et al*., 2014), including Brazil, where they are caught for meat consumption (Palmeira *et al*., 2013). Goliath grouper is the largest Atlantic grouper, reaching up to >2 m TL and 455 kg (Bullock *et al*., 1992). Its historical range comprised the coastal waters of the Atlantic, from North Carolina to southern Brazil and western Africa (Craig *et al*., 2009). However, its abundance strongly decreased in almost the entire range (Craig, 2011; Koenig, Coleman & Kingon, 2011). In the southeastern US, protection of goliath grouper started in 1990 through a moratorium on harvest. Both species possess life-history traits that make them extremely vulnerable to fishing, namely, occurrence in coastal habitats, large body size, long lifespan, slow growing and late maturation (Sadovy & Eklund, 1999; Fernandez-Carvalho *et al*., 2014).

Quantifying population declines and verifying the validity of local extinctions is an important measure to uncover management limitations and can be instrumental in promoting political will to develop legal protection to prevent further losses. Therefore, this paper aims to: (1) assess temporal changes in a largetooth sawfish and goliath grouper size frequency on Abrolhos Bank using interviews with artisanal fishers; (2) verify fishers' perceptions regarding declines in the number of fish species commonly caught in coastal areas; and (3) evaluate the probability that smalltooth sawfish has become locally extinct in the Abrolhos Bank.

Materials and methods

Study site and fishery characteristics

The Abrolhos Bank is an enlargement of eastern Brazil's continental shelf (42 000 km^2, <50 m depth) (Martins & Coutinho, 1981) and some of its critical ecosystems are under special governing regimes. For instance, our research directly relates to the Cassurubá Extractive Reserve (CER;

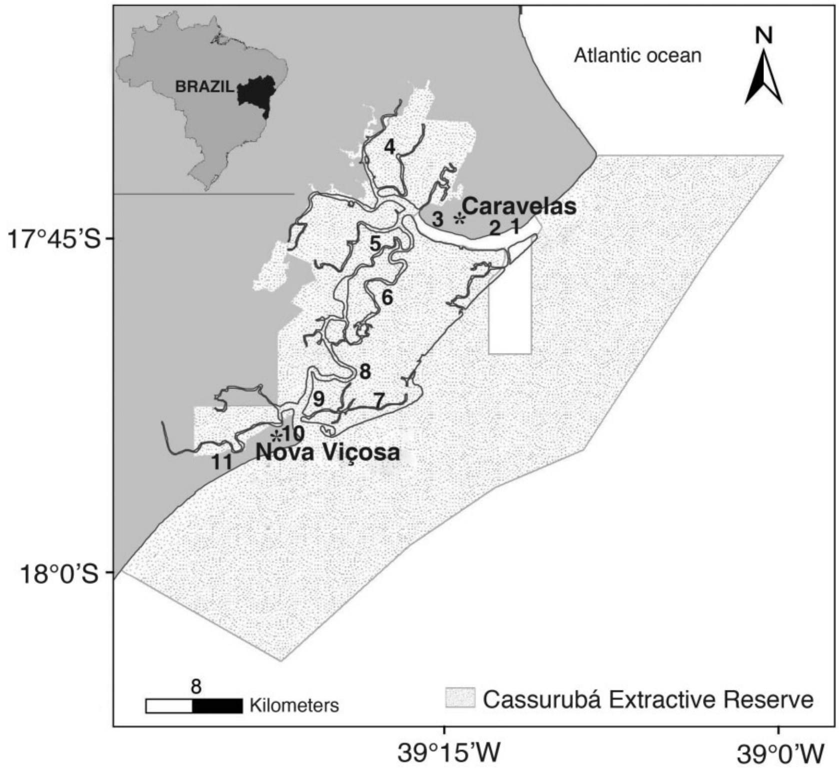

Figure 1 Location of Cassurubá Extractive Reserve, Abrolhos Bank, eastern Brazil. Distribution of fishing villages where we conducted interviews, Caravelas city: 1 – Barra, $n = 17$; 2 – Ponta de Areia, $n = 12$; 3 – Cooperativa, $n = 8$; 4 – Massangano, $n = 5$; 5 – Tapera, $n = 4$; 6 – Caribê, $n = 9$. Nova Viçosa city: 7 – Barra Velha, $n = 13$; 8 – Peróba, $n = 5$; 9 – Tranqueira, $n = 3$; 10 – Mercado do Peixe, $n = 21$ and 11 – Pau Fincado, $n = 5$.

Fig. 1). This is a community-based marine protected area designated in 2008 to encompass a large estuarine/mangrove ecosystem (Caravelas and Nova Viçosa municipalities) and to assign exclusive fishing rights to local fishers. Overall, approximately 20 000 local artisanal fishers work in the wider Abrolhos Bank mainly targeting snappers and grouper species such as: the black grouper *Mycteroperca bonaci*, the coney *Cephalopholis fulva*, the dog snapper *Lutjanus jocu*, the yellowtail snapper *Ocyurus chrysurus* and the lane snapper *Lutjanus synagris* (Freitas *et al*., 2011). Fishers use mainly hand lines, gillnets, longline and spearfishing. The fishing fleet is composed of small-motorized boats (6–20 m trawlers), sailboats and rowing boats (only in the estuaries) fishing throughout the Abrolhos bank and, more recently, have expanded to slope areas (Moura *et al*., 2013).

Data collection

We interviewed artisanal fishers in 11 fishing communities within the CER. Interviews were performed in fishing ports or at fishers' households. To obtain a required representation of all types of fishing practices within the CER, we performed interviews along the riverside to access fishers that operate exclusively in estuarine area, usually paddling or with motor canoes ($n = 57$), and in nearby town to access fishers that operate in coastal areas, usually with motor vessels ($n = 45$). To ensure a representative sample, interviews were applied to a range varying between 5 and 35% of the fishers' population in each of the 11 communities visited (Fig. 1; Bunce *et al*., 2000). The number of fishers interviewed was established after a census performed to monitoring fishing activities in CER in 2010 (Dapper, Giglio & Teixeira, 2010).

The fieldwork was performed by two researchers during 42 non-consecutive days (2009–2010). We followed technical and ethical recommendations proposed by Bunce *et al*. (2000) for conducting respectful interviews acknowledging local customs and culture and minimizing disruption to people's routines. Our questionnaires were individually applied and consisted of three sections. The first section was designed to elicit fishers' perceptions on how human-related impacts had broadly altered the marine and estuarine environment. We asked them to list species they believed to have been depleted in their lifetime. Common fish names vary little among neighboring villages and thus are reliably used in fisheries monitoring programs in the Abrolhos Bank (Previero, Minte-Vera & Moura, 2013). Nevertheless, we assured correct species identification by using colored photos to clarify species identification during the interviews. In the second section, we asked fishers the weight of the largest individual of largetooth sawfish and goliath grouper they had ever caught. We used weight as a metric for body size because fishes are sold per kilogram and the weight of largest individual captured is generally recorded into the fishers' memory. We also asked wherever they recognized a sawfish in a picture, and when positive, the year of last sight. In the third section, respondents were free to report their opinions about the factors that cause a decrease in abundance of these species.

Data analyses

The relationship between fishers' age and the number of species thought to be depleted was analyzed with a generalized linear regression assuming a Poisson distribution (O'Hara & Kotze, 2010). For the rest of the analyses, the age of respondents was grouped in three categories corresponding to different generations: young (15–30 years, $n = 32$), middle-aged (31–54 years, $n = 41$) and old (≥55, $n = 29$). We used a binomial test of proportions (Crawley, 2005) to test for significant changes in the identity of the species mentioned as depleted by at least 10% of informants within the three age groups. We then performed a randomization procedure to test the null hypothesis that the mean body size of those species, within each age class, represents a random sample of the mean reported body size of all species mentioned as depleted. We randomly drew samples of two fishes species (for young fishers) and seven fishes species (for middle-aged and old fishers) without replacement from the list of all 30 species mentioned as depleted at least once and calculated the mean body size of species for each sample. This was repeated 10 000 times to generate a distribution of mean body sizes for the random samples. To evaluate changes in the maximum body size among captures of largetooth sawfish and goliath grouper experienced by different generation of fishers, differences among age groups were tested using non-parametric analysis of variance (Kruskal–Wallis test). All tests were performed with a significant level at $P < 0.05$.

A chronological record of sightings for largetooth sawfish was constructed based on the year this species was last caught as reported by each respondent, allowing us to explore sawfish population trends using a method designed for opportunistic sightings (McPherson & Myers, 2009). This method fits a series of trend analyses using generalized linear models and assumes that the number of sightings per unit of time follows a Poisson distribution. The magnitude of relative population change between any reference date and the most recent point is estimated as the magnitude of change in the number of reported sightings. Values larger than 1 are indicative of decline, values of 1 or less suggest a stable or increasing population (McPherson & Myers, 2009). Finally, because no sawfish has been captured in the CER since 2002, we applied four probabilistic statistical methods to the sighting record to assess the probability that largetooth sawfish has become extinct in Abrolhos Bank (Solow, 1993; Solow & Roberts, 2003; McInerny *et al.*, 2006). These probabilistic methods have been developed to generate confidence intervals for the estimated extinction time given the characteristics of a sighting record, which can then be used to evaluate whether a species that has not been sighted for some time is likely to be extinct. High probability values indicate that the lack of sightings at the end of the record could happen by chance, implying that extinction has not occurred. Low probabilities ($P < 0.05$) suggest that the lack of sightings is due to extinction (Rivadeneira, Hunt & Roy, 2009). Details about the assumptions using the methods and programming code to implement them in the freely available software R can be found in Rivadeneira *et al.* (2009) and McPherson & Myers (2009).

Results

We interviewed 102 artisanal fishers, with ages varying between 15 to 85 years and with fishing experience of 1 to 62 years. The majority of fishers interviewed (84%) considered that fishing has led to depletion of at least one species, mainly elasmobranchs. The number of species mentioned as depleted was positively correlated with fishers' age (Fig. 2; Poisson I = –0.82, $P < 0.001$). On average, young fishers mentioned 1.8 species as depleted, middle-aged fishers mentioned 2.6 and old fishers 3.4. Old and middle-aged fishers mentioned elasmobranchs, such as the largetooth sawfish, the smalleye hammerhead *Sphyrna tudes* and the goliath grouper more frequently than younger fishers (Table 1). Young fishers mentioned the mid-sized species common snook *Centropomus undecimalis* and catfish *Aspistor luniscutis* more frequently, although the first was not significantly different from the middle-aged and old fishers (Table 1). In general, species frequently mentioned (>10% of informants) as depleted by old and middle-aged fishers are larger than would be expected if they were drawn randomly from the list of all species mentioned (e.g. 170 vs. 330 cm, $P < 0.05$, Fig. 3a,b). Species mentioned frequently as depleted by young fishers are within the average size (Fig. 3c).

All elders interviewed had caught a sawfish during their lifetime, whereas roughly half of the middle-aged and only six young fishers have ever caught this species before (Fig. 4a). Relationships between the largest largetooth sawfish caught and fishers' age class reveals significant declines in sawfish size throughout generations. The mean weight of the largest sawfish caught by elder fishers was 258 kg, by middle-aged 151 kg and young fishers 66 kg (Fig. 4b; Kruskal–Wallis test, H = 20.38, $P < 0.001$). A

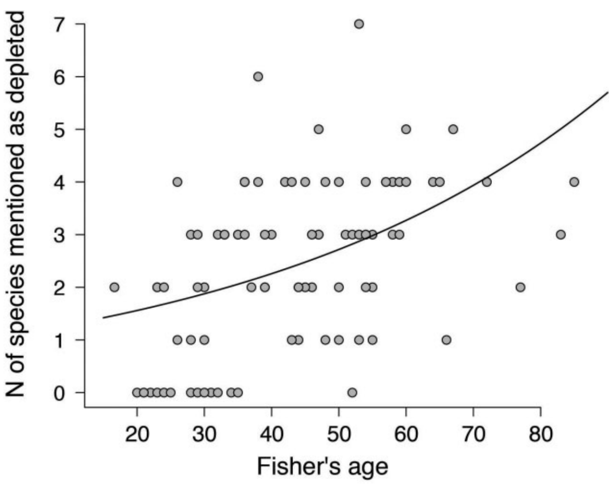

Figure 2 Number of species mentioned as depleted by fishers plotted against fishers' age (with a Poisson regression line shown t = 4.62, $P < 0.001$).

Table 1 Species mentioned as depleted by 10% or more of informants in at least one of the three age groups

	Species	Maximum length (cm)	Young ($n = 22$)	Middle-aged ($n = 40$)	Old ($n = 26$)	Age group contrasts
Elasmobranchs	Largetooth sawfish *Pristis pristis*	760	4	58	46	Y < MA = O
	Tiger shark *Galeocerdo cuvieri*	750	9	15	11	Y < MA = O
	Bonnethead shark *Sphyrna tiburo*	150	0	7	15	Y = MA = O
	Smalleye hammerhead *Sphyrna tudes*	148	4	42	42	Y < MA = O
Bony fishes	Goliath grouper *Epinephelus itajara*	300	9	27	46	Y < MA = O
	Common snook *Centropomus undecimallis*	140	18	10	4	Y = MA = O
	Catfish *Aspistor luniscutis*	120	13	20	19	Y = MA = O
	Acoupa weakfish *Cynoscion acoupa*	110	0	20	8	Y > MA = O
	grey triggerfish *Balistes capriscus*	60	4	5	27	Y = MA < O

Values are given as a percent of the total of fishers interviewed in each age group. A binomial test of proportions was used to estimate the significance among age groups contrasts. 'Less than' and 'greater than' symbols (< , >) indicate that difference is significant ($P < 0.05$). 'Equal' (=) symbols indicate no significant difference. MA, middle-aged; O, old; Y, young.

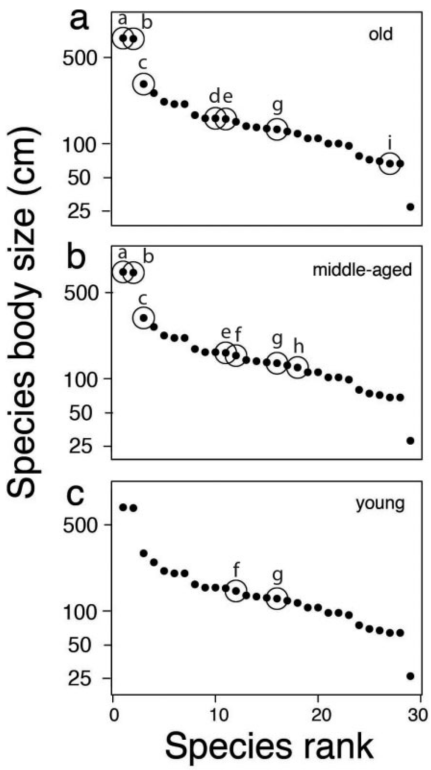

Figure 3 All species mentioned as depleted by young (a), middle-aged (b) and old (c) fishers are rank ordered from the largest to the smallest maximum reported body size. Points representing species mentioned by at least 10% of informants in each age class are circled. Among old and middle-aged fishers, the most mentioned species are larger than would be expected by chance ($P < 0.05$), whereas among young fishers, most mentioned species are within the average size. Species: (a) largetooth sawfish, (b) tiger shark, (c) goliath grouper, (d) bonnethead shark, (e) smalleye hammerhead, (f) common snook, (g) catfish, (h) acoupa weakfish and (i) grey triggerfish.

similar trend was observed for the goliath grouper. The mean weight of the largest individual captured by elder fishers was 186 kg, by middle-aged 149 kg and young fishers 84 kg (Fig. 4c; $H = 24.99$, $P < 0.001$).

Ninety-two percent of the informants expressed their opinions on the putative causes of largetooth sawfish depletion in CER. The advent of gillnets and noise from motor boats were, respectively, the first and the second most cited factors (Table 2). Except for migration, all causes for depletion increase in importance from young to old generations. Sixty-seven percent of the informants expressed their opinions on the causes of goliath grouper decline. The most cited cause was overfishing (without the mention of any specific fishing gear), followed by the use of the estuarine '*camboa*' gillnet and shrimp trawling (Table 2).

There is a consensus among fishers from the three age classes that the largetooth sawfish has not been caught since 2002 (Fig. 5a). In general, the probabilistic analyses provided no definitive evidence for local extinction of largetooth sawfish (Table 3). Two of the four tests indicate that the species is still extant in the Abrolhos Bank, although close to the threshold level for extinction. The population trend analysis suggested a three- to 1600-fold decline (median estimate = 16) in abundance given any reference year between 1963 and 2001 (Fig. 5b), representing an estimated reduction in abundance of >90%.

Discussion

Shifting baselines and the marine megafauna decline

By assessing the LEK of artisanal fishers, this study demonstrates changes in assemblages of coastal marine megafauna in eastern Brazil over 40 years. Among the species cited by fishers as depleted, there is a clear trend toward large species. Large-scale removal of marine megafauna biomass has occurred recently and has increased local extinctions (Dulvy, Pinnegar & Reynolds, 2009; Lotze & Worm, 2009; Luiz & Edwards, 2011). In addition, our analysis provides evidence that fishers of the younger generation have

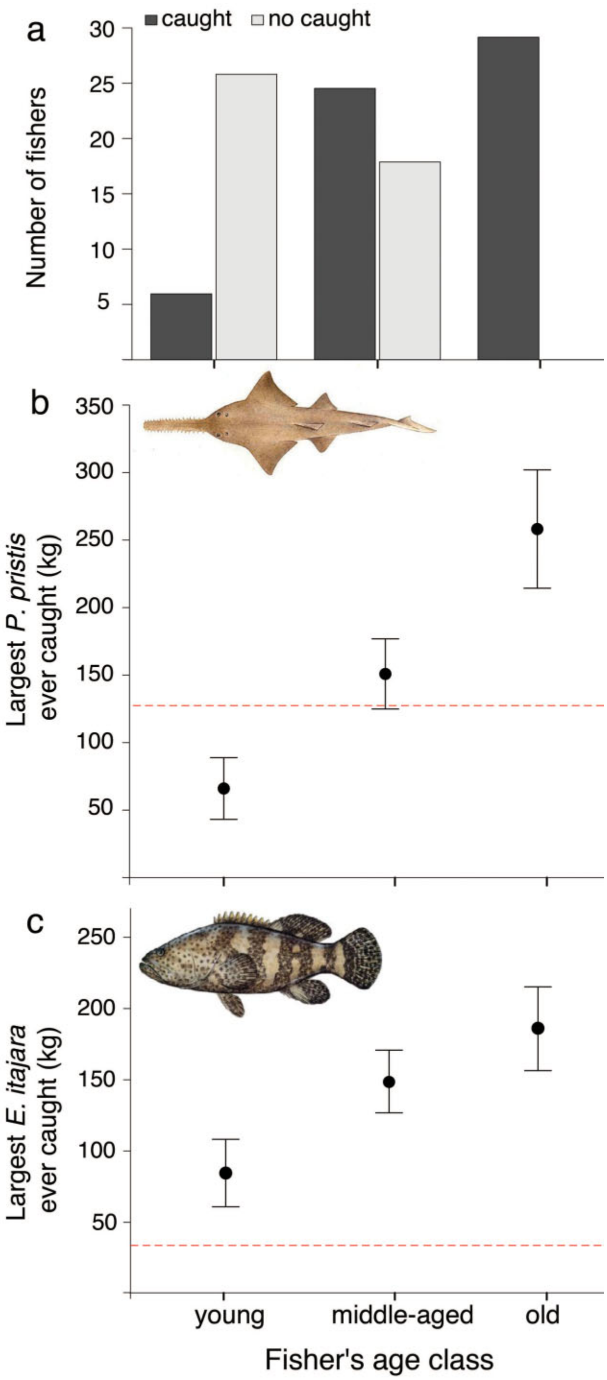

Figure 4 (a) Number of fishers that already caught largetooth sawfish, distributed over fishers' generations; (b) Mean weight (+95% CI) of the largest largetooth sawfish caught (Kruskal–Wallis test, H = 20.38, $P < 0.001$, all groups significantly different) and (c) mean weight (+95% CI) of the largest goliath grouper captured over three generations of fishers (H = 24.99, $P < 0.001$, no significant difference for middle-aged and old). Dashed red lines in (b) and (c) represent the estimated weight of first maturity to largetooth sawfish (Simpfendorfer, 2000) and goliath grouper (Bullock *et al.*, 1992).

adjusted their perceptions of natural resources to a more degraded environment, an indication of the shifting baselines syndrome (Sáenz-Arroyo *et al.*, 2005*a*) among fishers in the Abrolhos Bank. Old and middle-aged fishers not only recognized more species as depleted in comparison with young fishers, a tendency already described for the area (Bender, Floeter & Hanazaki, 2013), but, as we also show here, older fishers also mentioned more large species than the younger generation, an indicative of a body-size component in the process of species depletion. Furthermore, when asked about the largest largetooth sawfish and goliath grouper caught, younger fishers have sought and/or caught significantly smaller individuals than middle-aged and old fishers. Older fishermen have fished for a longer time than their younger counterparts. Hence, they are more likely to have caught species with larger maximum sizes by chance. However, older fishermen also report that these species have declined in Abrolhos Bank and recognize fishing as the main cause. The similarity in number and size of fish species considered as depleted among middle-aged and old fishers, plus the lack of a statistically significant difference in the size of the largest individual caught of goliath grouper between these two age groups, suggests that the shifting baselines syndrome phenomenon may be recent, affecting mostly the younger generation. Large individuals of the two focal species were common in the area, but they appear to exist now only in the memories of old and, less frequently, of middle-aged fishers.

In Brazil, there is a general consensus among the scientific community that the largetooth sawfish (Dulvy *et al.*, 2014; Fernandez-Carvalho *et al.*, 2014) and the goliath grouper (Gerhardinger *et al.*, 2006; Félix-Hackradt & Hackradt, 2008) have been decreasing in abundance over the past three decades. Sawfish populations were extirpated from much of their former range in Atlantic (Lessa *et al.*, 1999) and, at the time of writing this paper, reports of catches of largetooth sawfish are lacking for more than a decade in the Abrolhos Bank, raising concerns about the possibility that it has become locally extinct. The results of four statistical analyses for extinction based on past captures yielded mixed results. Two tests supported local extinction and two tests suggested that more time without capture or sightings is needed in order to consider the species extinct in the region, yet with predicted dates for extinction worrisome close. If the largetooth sawfish remains unrecorded in the region until 2021 or 2059 (Table 3), then there will be strong support for its local extinction based on statistical probabilities.

The impact of fishing and conservation needs

The susceptibility to overfishing and consequently abrupt declines in goliath grouper catches along the Brazilian coastline led managers to establish a fishing moratorium since 2002. However, opportunistic exploitation (Branch, Lobo & Purcell, 2013) is regularly observed at fishing ports within the Abrolhos Bank (V. J. Giglio, pers. comm.).

Table 2 Determinants of largetooth sawfish and goliath grouper catches decrease mentioned by fishers in the Cassurubá Extractive Reserve

Species	Cause	Young (*n* = 6)	Middle-aged (*n* = 24)	Old (*n* = 29)
Largetooth sawfish	Gill net excess	33	41	79
	Migration	33	4	0
	Noise (motor boats)	17	21	38
	Silted up river	0	8	0
	Increased water temperature	0	8	10
	Pollution	0	8	10
Goliath grouper	Overfishing	50	50	83
	Spearfishing	17	12	7
	Camboa gillnet fishing	33	21	41
	Shrimp trawling	0	21	28
	Pollution	0	0	10

Values are given as a percent of the total of fisher interviewed in each age group.

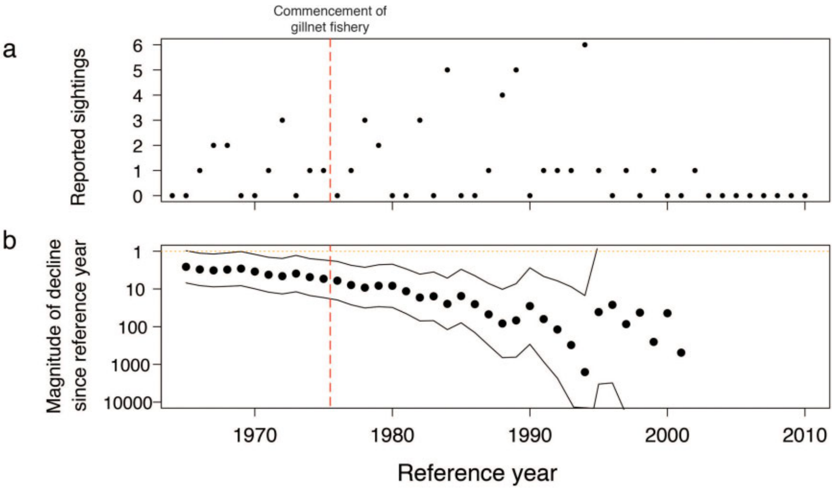

Figure 5 (a) Number of largetooth sawfish occurrences based on the year of the last capture reported by fishers from 1963 to 2010 and (b) estimate of relative decline in abundance (dots) with confidence bounds (lines) for any reference year between 1963 and 2002. The commencement of gillnet fishery, as reported by fishers, is when nylon nets become popular in the Abrolhos Bank.

Table 3 Local extinction probability values generated by the different statistical methods for the largetooth sawfish

Method	*P*-value for local extinction	Upper bound for 95% confidence interval of expected extinction year
Solow (1993)	<0.001	2007
McInerny *et al.* (2006)	<0.001	2005
Solow & Roberts (2003)	0.272	2059
Roberts & Solow (2003)	0.051	2021

Respondents admitted that when an incidental catch of goliath grouper occurs, they usually consume or sell the fish. To trade the illegal catch, they frequently use means for confound surveillance, that is removing the entire fish skin, head, filleting the fish and selling as other grouper species. Illegal catches have been reported throughout the Brazilian coast (Giglio *et al.*, 2014).

Fishers often mentioned fishing effort increase and popularization of nylon gillnets as the main causes of species depletion in the Abrolhos Bank. However, while 79% and 83% of the old fishers mentioned that overfishing caused declines of largetooth sawfish and goliath grouper, respectively, only 33% of the young fishers mentioned the same for both species.

Major changes in target-species' biomass, particularly among apex predators, can occur at relatively small levels of fishing pressure, as reported in Fiji (Pinnegar & Engelhard, 2008), Seychelles (Jennings *et al.*, 1995), Philippines (Russ & Alcala, 1996) and the Line Islands (DeMartini *et al.*, 2008). Illegal fishing is reported in the Abrolhos Bank, including poaching in the adjacent no-take reserve (Francini-Filho & Moura, 2008) and use of the *camboa* gillnet in estuaries (Giglio & Freitas, 2013). Fishing mortality related to gillnet is a historical problem for sawfish because their long and toothed rostrum renders them susceptible to entanglement in gillnets targeting bony fishes (Seitz & Poulakis, 2006). This may explain the sudden burst in largetooth sawfish catches that took place after the popularization of nylon gillnets in the mid-1970s that eventually lead to their demise after the mid-1990s (Fig. 5a).

Both largetooth sawfish and goliath grouper overlap largely in habitat use, being often found in estuaries and mangroves (Carvalho-Filho, 1999). A life trait-similar sawfish, the smalltooth sawfish *P. pectinata* and goliath grouper present a high level of association in recreational fisheries along the west coast of Florida, US, where they are more likely to be caught together in the same trip than with any other species (Carlson, Osborne & Schmidt, 2007). This apparent association may help to optimize efforts for the conservation of these species because conservation measures directed to habitat protection and/or fisheries restriction will benefit both species at the same time. In fact, conservation measures to protect both the sawfishes and goliath grouper may act in synergy. After a drastic decrease in the abundance along the US waters, conservation programs have focused in the protection of this species along the southeastern US coast and today their populations are apparently stable in some areas (Carlson *et al*., 2007; Koenig *et al*., 2011; Frias-Torres, 2012). These conservation initiatives have focused on research and promote conservation initiatives of essential nursery habitats and spawning sites (Carlson *et al*., 2007; Frias-Torres, 2012). The extensive length of the Brazilian coast (~8000 km) makes its full management an unrealistic task. The choice of priority areas for conservation based on their habitat preferences may be an effective approach.

Conclusions

This study demonstrates that for data-poor areas, accessing LEK is a useful approach to investigate depletion among coastal marine resources and to identify conservation priorities. In the absence of formal scientific data, the use of fishers' LEK is an important component in establishing long-term baseline trends in the abundance of marine megafauna. This approach provides unique data for management, especially in efforts to investigate the status of rare or possibly extinct species.

In summary, our results suggest that overfishing is the principal factor contributing to decline in abundance of marine megafauna in the Abrolhos Bank. It also indicates that a shifting baselines syndrome is developing among artisanal fishers. Local extinction of largetooth sawfish may either have occurred or it is very close in the Abrolhos Bank and its decline was driven mainly by gillnet fishing. Finally, illegal fishing is a worrying threat to the population recovery of goliath grouper. We recommend greater enforcement by the Brazilian Government Environmental Agency to avoid goliath grouper poaching. Moreover, a broad survey for largetooth sawfish occurrences in Brazil is needed to design a conservation program for this species (see Ward-Paige *et al*., 2012). A promising approach could be the implementation of a citizen-science program for continued data gathering from the public, particularly from fishers (Wiley & Simpfendorfer, 2010).

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