



# Assessing captures of recreational spearfishing in Abrolhos reefs, Brazil, through social media



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## ABSTRACT

Recreational fishing is an important economic and social activity in many countries. However low- and middle-income nations often lack basic data, like catch recording, on this fishery. To gather data to better understand recreational spearfishing catch in Abrolhos Bank, we assessed images posted on Facebook between June 2014 and January 2015. We described species richness, individual fish body size, and trophic group, as well as conservation status and local retail value. A total of 217 images were analyzed, featuring the capture of 962 individuals from 25 species. Captures were composed mainly of the piscivores black grouper *Mycteroperca bonaci* (36%), dog snapper *Lutjanus jocu* (35%), and great barracuda *Sphyraena barracuda* (11%). Herbivores comprised 6% of catches, represented mainly by the endangered the greenback parrotfish *Scarus trispinosus*. Overall, half of the captured fish were below the first gonadal maturation size and 43% are currently on the national Red List of endangered species. The retail value of 97% of specimens captured was high or very high, composed mainly of species with individuals longer than 40 cm. Social media can provide a complementary data source for recreational fisheries research, offering a rich and dynamic snapshot of these fisheries.

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## 1. Introduction

Recreational fishing is a popular activity worldwide, from temperate to tropical seas, ranking among the most popular recreational marine activities globally (Cooke and Cowx, 2004; Elmer et al., 2017). Recreational fisheries may represent a significant proportion of fisheries landings, and have considerable socio-economic importance in many countries (Radford et al., 2018; Arlinghaus et al., 2019). It is estimated that the expenditure generated by 220 million recreational fishers is around US\$ 190 billion (World Bank, 2012). However, despite its importance, recreational fisheries commonly lack data, mainly in low- and middle-income nations (Belhabib et al., 2016; Pauly and Zeller, 2016). Some countries, such as Brazil, have little or no catch recording, and the total harvest and economic value of the fishery are unknown (Freire et al., 2016). Data from recreational fisheries

are difficult to obtain due to their spatiotemporal heterogeneity, practitioners fishing in a complex framework with multiple access points, and uncertain temporal frequency (Giovos et al., 2018). However, despite limited knowledge, recreational fishing has been increasingly recognized for its potential to contribute to the depletion of fishing stocks (Cooke and Cowx, 2004; Godoy et al., 2010; Altieri et al., 2012).

To overcome the lack of data on recreational fisheries, non-conventional approaches have gained attention among scientists as an alternative tool that can cost-effectively gather information. For instance, social media may provide a relevant source of information for studying people's activities in and attitudes towards nature (Toioven et al., 2019). Data mining on social media can play a useful role in science, being used to describe the social/human dimension of recreational fishing, as well as the harvesting patterns (e.g. Martin et al., 2014; Young et al., 2015; Shiffman et al., 2017; Adams et al., 2018; Monkman et al., 2018; Sbragaglia et al., 2019). Records of captures from images (photos and videos) posted on social media have proved to be an alternative or complementary approach to assess (i.e. species composition, techniques used, spatial patterns and estimations of fishing effort) from recreational fishing (Belhabib et al., 2016; Giovos et al., 2018; Sbragaglia et al., 2019).

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Among recreational fishing techniques, spearfishing is popular from temperate to tropical seas (Godoy et al., 2010; Young et al., 2015; Pita and Freire, 2016). The increasing number of recreational spearfishers, and consequently fishing effort, may result in greater pressure on reef fish assemblages, leading to a decline in stocks (Godoy et al., 2010; Young et al., 2014). Such decline may be more exacerbated for species considered vulnerable because of their biological traits (i.e., large body-size, late maturation and formation of seasonal spawning aggregations) (Sadovy de Mitcheson et al., 2012; Bender et al., 2013) and behavioral traits (i.e., schooling behavior and lack of fear of humans) (Samia et al., 2019). Such characteristics make species such as groupers, snappers, and parrotfishes vulnerable to fishing (Pinheiro and Joyeux, 2015; Jiménez-Alvarado et al., 2019; Samia et al., 2019). Data on recreational fisheries catches is essential to management planning, since it may be used to regulate captures of targeted species (e.g., capture limits, minimum and maximum capture sizes – slot sizes), spatial zoning and strategies for increasing compliance (Young et al., 2015).

Here we provide insights about recreational spearfishing captures in Abrolhos Bank, Brazil using images of fish captures mined from Facebook. Abrolhos reefs are popular among recreational spearfishers because of the complex habitat mosaic of shallow reefs and the abundance of reef-associated fishes (Moura et al., 2013). On the other hand, the current overexploitation of marine resources is a matter of concern among scientists and managers (Moura et al., 2013). In addition, the lack of long-term monitoring for recreational and even commercial catches is hampering efforts to manage fisheries in the region. In this paper we describe the composition of the fishes captured (species richness, body size and trophic level), as well as their conservation status and local commercial value. We also discuss the use of complementary and/or alternative methods such as social media data mining as a source of information.

## 2. Material and methods

### 2.1. Study area

The Abrolhos Bank comprises an extension of the continental shelf (46,000 km<sup>2</sup>) with waters rarely exceeding 30m depth, representing the largest and richest area of coral reef in the south Atlantic (Moura et al., 2013). Abrolhos Bank concentrates the largest fisheries landings of the northeastern region of Brazil, with ~20,000 small-scale fishers working currently (Freitas et al., 2011). However, previous studies have revealed increasing evidence of overfishing among targeted species, such as groupers, snappers, and parrotfishes (Freitas et al., 2011, 2019; Moura et al., 2013; Giglio et al., 2015; Barbosa-Filho et al., 2019; Zapelini et al., 2019). Efforts to manage fisheries have focused primarily on the creation and implementation of co-managed marine protected areas, aiming to decrease fishing effort through fishery agreements that impose minimum body size regulations on captures, and on improving the fishing supply chain (Santos Neto et al., 2016; Nobre et al., 2018). However, these initiatives have failed to reduce fishing effort due to a lack of compliance and insufficient monitoring.

### 2.2. Data collection and analysis

Data from recreational spearfishing captures were obtained through images posted on Facebook, the most popular social network in Brazil (<http://vincos.it/world-map-of-social-networks/>). We also searched for posts about angling, but the number of images was few ( $n < 25$ ) compared with data from spearfishing. Data mining was conducted between June 2014 and January

2015, and the search was restricted to content posted in this period. After this period, fishers may have avoided posting images of captures because of the publication of the new national Red List of endangered species (Di Dario et al., 2015). The updated Red List included some species commonly captured by recreational spearfishers, where the capture was banned. The data collected is anonymized and followed ethical principles previously outlined for using social media in fisheries research (Monkman et al., 2018b). Data extracted from Facebook does not require specific ethical review because the data are publicly available. We searched for captures using combinations of the following search terms in Portuguese: “pesca sub” and “caça sub” (English terms: spearfishing and underwater hunting) plus terms that refer to the region “Abrolhos”, “Nova Viçosa”, “Caravelas”, “Prado”, and “Alcobaça”. The search was restricted to images posted by practitioners of recreational spearfishing through free-diving (e.g. using recreational boats and recreational equipment) or employees/owners of boats rented to recreational spearfishers. We assumed that images posted on Facebook by recreational spearfishers represent a proxy of captures from targeted fish species.

For each image, we identified the species and number of individuals captured, and estimated the body size (total length) of each fish. For the videos, we used screenshots of footage that showed the catch. To estimate fish body size, we used objects of known size as a reference, using the open-source image analysis software IMAGEJ (Abràmoff et al., 2004). Common reference objects were parts of the spearfishers' body or their gear (e.g. arm, forearm, speargun and ballast belt). When a fisher's body part was used for scale, our calculations were based on a 1.75 m tall adult man. When a scale was not available the image was discarded. We also discarded photos with low resolution and those where it was not possible to identify the species – a total of 56 images.

All species observed were classified according to their trophic group and conservation status at the national and global level using the Southwestern Atlantic Reef Fishes database (Pinheiro et al., 2018). We also compiled data on first gonadal maturation size from FishBase (Froese and Pauly, 2019). To verify the overlap among species targeted by recreational spearfishers and commercial fishers, we assessed the commercial prices per kilogram of all species in 2014 through consultation with 13 fishmongers from three coastal municipalities along Abrolhos Bank: Prado, Alcobaça and Nova Viçosa. We used the average retail price as a reference. Prices were classified in four categories: low (US\$ 0–1.5), medium (US\$ 1.6–3.0), high (US\$ 3.1–4.0), and very high (US\$ > 4.0).

A generalized linear model with Poisson distribution was fitted to verify relationships between body size and retail price (four levels). We assessed the model fit by checking the plot of the residuals vs. the fitted values, and used a 95% confidence interval. All analyses were performed in R software version 3.5.1 (R Core Team, 2017).

## 3. Results

A total of 962 individuals belonging to 25 species from 13 families were observed in 217 images, representing an average of  $4.4 \pm 27.1$  ( $\pm$  s.d.) individuals per image. Carangidae ( $n = 7$  species), Lutjanidae and Scombridae ( $n = 3$  species each) were the most represented families. The most frequently caught trophic group was piscivores ( $n = 897$ , 93%), followed by herbivore detritivores ( $n = 57$ ; 6%) and mobile invertebrate feeders, ( $n = 13$ ; 1%; Table 1). The most captured species were the piscivorous black grouper, *Mycteroperca bonaci* with 350 individuals (36% of the total), followed by the dog snapper, *Lutjanus jocu* ( $n = 336$ ; 35%) and great barracuda, *Sphyrna barracuda* ( $n = 107$ ; 11.1%; Table 1). Piscivores presented the largest body

**Table 1**

Fish species captured by recreational spearfishers in Abrolhos Bank. Trophic level: PS = piscivorous; MIF = mobile invertebrate feeders; HD = herbivore detritivore. Conservation status: DD = data deficient; LC = least concern; NT = near threatened; EN = endangered. US dollar value on 22/02/2019.

Family	Species	No. of individuals	Trophic level	Global status	National status	Maturation size (cm)	Mean body size (cm) ± SD	Price
Epinephelidae	<i>Mycteroperca bonaci</i>	350	PS	NT	VU	67.7	60.2 ± 19.6	Very high
Lutjanidae	<i>Lutjanus jocu</i>	336	PS	DD	–	32.4	32.9 ± 12.1	High
Sphyraenidae	<i>Sphyraena barracuda</i>	107	PS	LC	–	66	117.9 ± 33.5	High
Scarinae	<i>Scarus trispinosus</i>	53	HD	EN	EN	30.5	29.4 ± 12.2	High
Carangidae	<i>Caranx hippos</i>	14	PS	LC	–	55	66.8 ± 29	High
Rachycentridae	<i>Rachycentron canadum</i>	14	PS	LC	–	78.4	101.1 ± 27.6	High
Carangidae	<i>Alectis ciliaris</i>	11	PS	LC	–	57.2	94.5 ± 22.1	High
Carangidae	<i>Carangoides bartholomaei</i>	11	PS	LC	–	3.38	41.1 ± 12.8	High
Centropomidae	<i>Centropomus undecimalis</i>	10	PS	LC	–	60	55 ± 15.6	Very high
Haemulidae	<i>Anisotremus surinamensis</i>	7	MIF	DD	–	50	37.8 ± 16	Low
Scombridae	<i>Scomberomorus brasiliensis</i>	7	PS	LC	–	37	47.1 ± 28.7	High
Coryphaenidae	<i>Coryphaena hippurus</i>	6	PS	LC	–	55.8	148.3 ± 33.7	Medium
Scombridae	<i>Scomberomorus cavalla</i>	6	PS	LC	–	63.3	146.6 ± 13.66	High
Carangidae	<i>Caranx crysos</i>	4	PS	LC	–	27.4	48.7 ± 6.3	Medium
Lutjanidae	<i>Lutjanus cyanopterus</i>	4	PS	VU	VU	65	87.5 ± 33	High
Scombridae	<i>Scomberomorus regalis</i>	4	PS	LC	–	50	92.5 ± 38.6	High
Scarinae	<i>Sparisoma amplum</i>	4	HD	LC	–	17.6	43.7 ± 17.5	High
Epinephelidae	<i>Epinephelus morio</i>	3	PS	NT	VU	50	50 ± 20	Very high
Carangidae	<i>Caranx latus</i>	2	PS	LC	–	37	55 ± 15.6	Medium
Carangidae	<i>Trachinotus falcatus</i>	2	MIF	LC	–	64.7	70 ± 0	Medium
Echeneidae	<i>Echeneis naucrates</i>	2	MIF	LC	–	–	22.5 ± 10.6	Low
Lutjanidae	<i>Lutjanus synagris</i>	2	PS	NT	–	23.8	30 ± 7.1	Medium
Carangidae	<i>Trachinotus carolinus</i>	1	MIF	LC	–	23	30	Medium
Dasyatidae	<i>Hyanus americanus</i>	1	MIF	DD	–	85	200	Low
Megalopidae	<i>Megalops atlanticus</i>	1	PS	VU	VU	128	120	Medium

size ( $58.9 \pm 46$  cm), followed by mobile invertebrate feeders ( $58.1 \pm 36.4$  cm) and herbivore detritivores ( $30.4 \pm 37.6$  cm).

Overall, 49% of individuals caught were below the first gonadal maturation size. Among the six most captured species, we observed higher frequencies of immature individuals caught for *M. bonaci* (64%), the greenback parrotfish, *Scarus trispinosus* (57%), *L. jocu* (55%), the crevalle jack, *Caranx hippos* (29%) and the cobia, *Rachycentron canadum* (14%) (Fig. 1). These species represented 91% of catches, and 51.6% of them were below the first gonadal maturation size.

Regarding the conservation status of captured species, at a global level, 16 species (64%) are classified as least concern. Three species (12%) are data deficient, three are near threatened (12%), two are vulnerable (8%) and one endangered (4%). Near threatened species represent the highest abundance ( $n = 355$  individuals, 36.9%), followed by data deficient species ( $n = 344$ , 35.7%), least concern ( $n = 205$ , 21.3%), endangered ( $n = 53$ , 5.5%) and vulnerable ( $n = 5$ , 0.5%; see Table 1). With respect to the national Red List of endangered species, four species are listed as vulnerable (*M. bonaci*, the red grouper, *Epinephelus morio*; the Cubera snapper, *Lutjanus cyanopterus*; and the Atlantic tarpon, *Megalops atlanticus*) and one as endangered (*S. trispinosus*). These species represented 43% of the total catch (Fig. 2).

Sixty percent of species and 97.5% of individuals captured had high and very high retail value, while medium and low retail value accounted for 30% of species and 2.5% of individuals. Captures of species with high and very high prices were represented mainly by *M. bonaci* (36%) and *L. jocu* (35%). Medium and very high retail value were predictors of larger body size (Table 2; Fig. 3).

#### 4. Discussion

By assessing images posted on social media, we provide insights for the first time into fish captures from recreational fishing in Abrolhos Bank. Our data do not indicate total catch, but indicate trends of targeted species and the body size of fishes captured. Large piscivores appear to be the main targeted species, and 62% of this group had body size greater than 40 cm. The

**Table 2**

Coefficients of the generalized linear model. The reference level for commercialization price in this regression was set as 'high'. Significant values ( $P$ -value < 0.05) in bold.

Predictor	Estimate	Std. Error	t-value	P-value
Intercept	4.00	0.005	37.411	<0.001
Low	−0.07	0.044	−0.341	0.106
Medium	−0.08	0.041	−0.430	<0.05
Very high	0.11	0.008	2.821	<0.001

most common piscivores were *M. bonaci* and *L. jocu*, species heavily targeted by commercial fisheries (Freitas et al., 2011, 2018). Mobile invertebrate feeders represented a small proportion of captures, commonly appearing in images where fishers show the daily captures. In fact, large piscivores are the main target of recreational spearfishers in Abrolhos Bank, mainly among more experienced practitioners (Giglio et al., 2018). As a consequence of harvesting, an increasing number of studies have revealed evidence of alarming levels of overexploitation of targeted species on Abrolhos Bank, including groupers, snappers, and more recently parrotfishes (Freitas et al., 2011; Moura et al., 2013). The body size of individuals captured by commercial fisheries has been decreasing over time (Giglio et al., 2015; Giglio and Bornatowski, 2016; Zapelini et al., 2017) and the fishing spots/grounds have expanded to areas further from the coast (Previero and Gasalla, 2018).

The popularization of recreational spearfishing in Brazil and its effects on fish communities is poorly documented (Freire et al., 2016). Such lack of information causes recreational spearfishing to be neglected in the design of fisheries management frameworks. As spearfishing grows in popularity, an understanding of its captures and its socioeconomic context is needed to inform effective management strategies. This fishery's high heterogeneity in space and time makes traditional monitoring approaches difficult to apply. This challenge could be overcome through collaboration with the often-ignored recreational fishing bodies (e.g., formal or informal associations, clubs, or groups like Web forums). For instance, the use of smartphone apps allows recreational fishers to easily record and share details of their

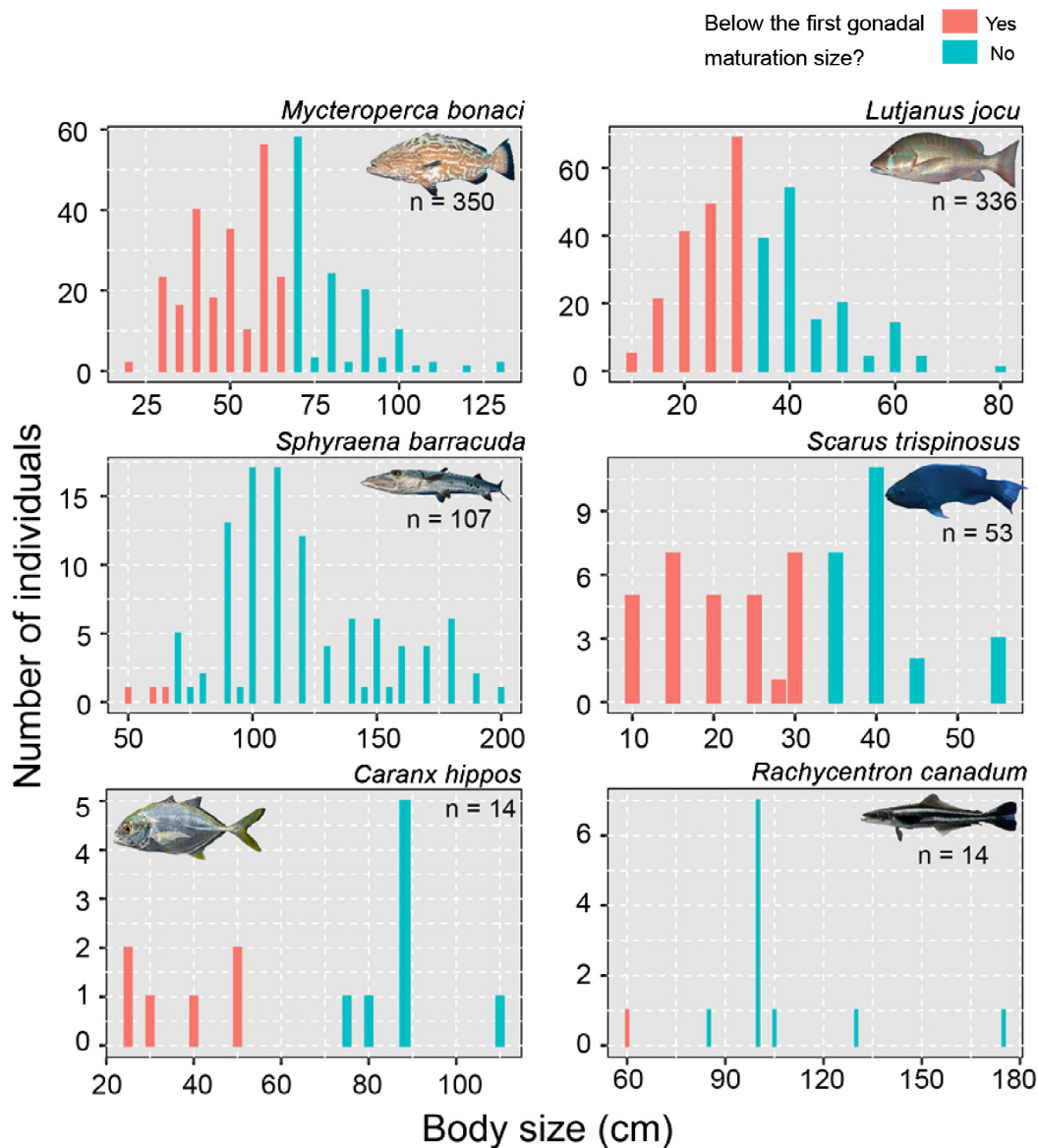


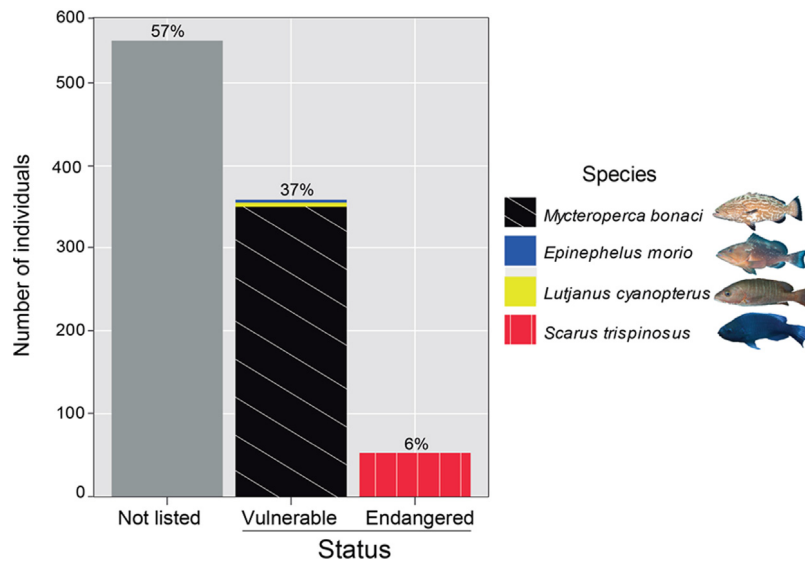
Fig. 1. Body size of the six most commonly captured species posted on social media by recreational spearfishers of Abrolhos Bank.

fishing trips, engaging them in citizen science (Venturelli et al., 2017). However, to be effective this kind of approach needs to be transparent in design and implementation, informing recreational fishers about how their data will be used and how apps can benefit them through the two-way communication channel (Venturelli et al., 2017). The use of social media data mining is not overly time- and resource-consuming and may be used as a complementary approach to obtaining information for fisheries monitoring. Alternative approaches to gathering data may be particularly important to data-poor countries such as Brazil (Freire et al., 2016), in providing information to fisheries management.

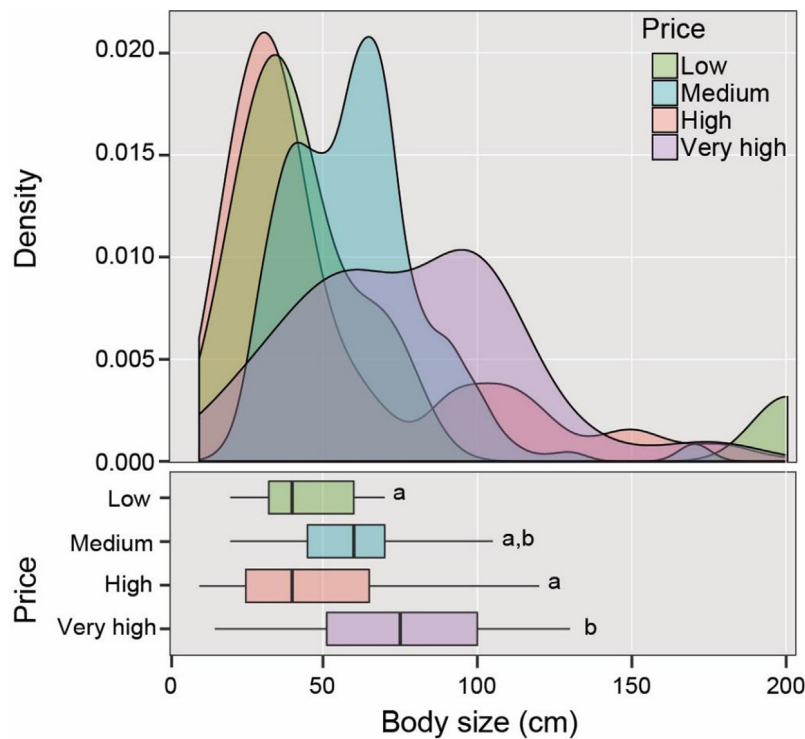
Findings from this study add to evidence of the unsustainability of fisheries in Abrolhos Bank, where targeted individuals are from overexploited species. It is important to note that our results provide no factual indication that images may be representative of their actual catches or sizes, but some insights can emerge. Almost half of the individuals were above the first gonadal maturation size, mainly the heavily targeted and overexploited species *M. bonaci* (64%), *S. trispinosus* (57%) and *L. jocu* (55%) (Freitas et al., 2011, 2019; Moura et al., 2013; Zapelini et al., 2019). The average size of the commercially important species captured in

our study is near or below the minimum slot size for fisheries (Table 3). Notwithstanding, content posted on social networks tend to show the best catches, the trophy fishes — the largest and most coveted individuals of a fishery (McClenachan, 2009; Giovos et al., 2018). Such images are likely to be posted more often than worse fishing trips and smaller and less preferred species, causing a positivity bias in content (Sbragaglia et al., 2019). This means that results on the size of fish captured in Abrolhos Bank may be overestimated, and actual captures may comprise more than the ~50% of immature fish individuals described in this study.

*Scarus trispinosus*, the fourth most captured species, is the largest herbivore in the southwestern Atlantic and a key reef species (Bonaldo et al., 2014; Freitas et al., 2019). The species is suffering a remarkable abundance decline in Abrolhos Bank and along the entire Brazilian coast (Bender et al., 2014; Roos et al., 2015; Freitas et al., 2019), and is listed as endangered in Brazil (MMA, 2014). Currently, recreational fisheries of *S. trispinosus* are prohibited; the species can only be captured by commercial fisheries within the body size slot of 39–63 cm at specific sites (see Freitas et al., 2019 for details). This body size is greater than the average size of captures recorded in our study (Table 3),



**Fig. 2.** National conservation status of fishes captured by recreational spearfishers in Abrolhos Bank. Only one individual of *Megalops atlanticus* (vulnerable) was captured.



**Fig. 3.** Distribution (density) of commercialization prices of fish captured by recreational spearfishing according to body size. Different letters on the right side of the bars indicate significant differences (P-value < 0.05).

where ~50% of individuals captured were below the first gonadal maturation size. However, a simple search for catches of recreational spearfishing in social media reveals individuals being captured illegally in Abrolhos Bank.

We show that data mining on social media can provide insights as an alternative approach into gathering data on the captures of recreational fishing in understudied sites. Images from Facebook revealed a preference for sharing captures of large piscivores; however, half of individuals captured were immature. Research using data mining on social media can be both cost-effective and easy to implement. However, our results should be interpreted with caution because content posted on social media

may be not representative of current fishing activity, targeting, captures or body sizes. For instance, some species are more valuable and harder to capture and thus are likely to appear more than others. Social media data can be complementary to socioeconomic surveys and landings monitoring to gain a full and dynamic image for fisheries research and management.

#### Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

**Table 3**

Comparison among the average body sizes observed in the present study (data mining 2014–2015) and the current minimum slot size for commercial fisheries in Abrolhos region. Actually, there are no minimum slot sizes for recreational fisheries of *M. bonaci*, *L. jocu*, and *E. morio*, while recreational captures of *S. trispinosus* is prohibited.

Species	Average size $\pm$ s.d.	Current minimum slot size	Average higher than current minimum slot size?
<i>Mycteroperca bonaci</i>	60.2 $\pm$ 19.6	60 <sup>a</sup>	Yes
<i>Lutjanus jocu</i>	32.9 $\pm$ 12.1	34 <sup>b</sup>	No
<i>Scarus trispinosus</i>	29.4 $\pm$ 12.2	39 <sup>c,d</sup>	No
<i>Epinephelus morio</i>	50 $\pm$ 20	45 <sup>a</sup>	Yes

<sup>a</sup>Brasil (2018a);

<sup>b</sup>ICMBio/CDREC (2013);

<sup>c</sup>Brasil (2018b).

<sup>d</sup>Note that currently the recreational fishing of *Scarus trispinosus* is banned. The value was added only to compare the size of maturity with size of analyzed individuals.

### CRedit authorship contribution statement

**Vinicius J. Giglio:** Conceptualization, Data curation, Formal analysis, Methodology, Validation, Writing - original draft, Writing - review & editing. **Ana C. Suhett:** Conceptualization, Data curation, Formal Analysis, Methodology, Writing - review & editing. **Cleverson S. Zapelini:** Methodology, Writing - review & editing. **Aline S. Ramiro:** Data curation, Validation, Writing - review & editing. **Juan P. Quimbayo:** Data curation, Formal analysis, Methodology, Writing - review & editing.

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