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Stakeholders' perceptions on environmental quality and threats to subtropical marine reserves

Vinicius J. Giglio, Guilherme H. Pereira-Filho, Marina Marconi, Fernanda A. Rolim, Fabio S. Motta *

Laboratório de Ecologia e Conservação Marinha, Instituto do Mar, Universidade Federal de São Paulo, Rua Dr. Carvalho de Mendonça, 144, 11070-100, Santos, Brazil

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ABSTRACT

Marine Protected Areas (MPAs) have been one of the main strategies for the conservation of marine ecosystems and an attempt to buffer or revert anthropogenic and natural disturbances. However, only the implementation of an MPA does not guarantee effectiveness in the maintenance of these environments. The involvement of the stakeholders in the whole process is crucial for the MPAs to achieve their conservation goals. With this, we provide here an understanding of the dynamics on how different stakeholders engage in marine reserves management, to inform courses of action and improve conservation and governance at multiple scales. Through semi-structured questionnaires, we investigated which anthropogenic threats were mostly perceived by stakeholders in three Brazilian marine reserves. We compare the perceptions of the members of the management councils and the staff of each reserve, in addition to verifying whether there were differences among their perceptions and to identify correlations between perceptions on management effectiveness and environmental quality. Illegal fishing and exotic species were the most important threats identified. No differences were verified between the perceptions of managers and members of the management board of the marine reserve and there was also no relationship between the perception of effectiveness and quality of environmental attributes. The different stakeholders' interests and their socioeconomic and cultural background is discussed as influencing the perceptions of management effectiveness. However, the similarity in threat perceptions reported in this study may be explained by the lower level of complexity and subjectivity in opinions in comparison with management effectiveness evaluations. Our results provide an overview of perceptions on threats and on the environmental quality of subtropical marine reserves in the Southwestern Atlantic, which can be used to guide funding and policy priorities that mitigate the effects of anthropogenic threats on marine reserves and thus contribute to creating a win–win scenario.

1. Introduction

Marine environments are affected by multiple anthropogenic impacts. The increasing use of ocean resources from a growing world population poses a number of challenges to the maintenance of biodiversity and the formulation of management and governance mechanisms (McCauley et al., 2015; Jouffray et al., 2020). Anthropogenic environmental threat is defined as any negative human-related output which may affect environmental health and functioning (Battisti et al., 2016). The establishment of marine protected areas (MPAs) has been an important strategy to deal with anthropogenic environmental threats through the maintenance of ecological processes and ecosystem services (Sala and Giakoumi, 2018; Sala et al., 2021).

MPAs in general have to deal with multiple pressures and threats from different scales and persistence levels. Globally, the impacts related to global climate change have been reported (Bruno et al., 2018); at regional scales MPAs have faced issues such as urbanization and habitat fragmentation (Montefalcone et al., 2009) and at a local scale, problems such as illegal fishing (Bergseth et al., 2018), excessive tourism (Giglio et al., 2020), invasive species (Mazaris and Katsanevakis, 2018) and chemical pollution (Abessa et al., 2018; Nunes et al., 2021). While MPAs are not a panacea to mitigate all kinds of impacts, these must be identified, quantified and monitored to guide effective conservation measures when possible, as well as to delineate management effectiveness evaluation and promote adaptive management.

* Corresponding author.
E-mail addresses: vj.giglio@gmail.com (V.J. Giglio), ghfilho@yahoo.com.br (G.H. Pereira-Filho), marina@atuair.com.br (M. Marconi), fernandarolim2@gmail.com (F.A. Rolim), fmotta@unifesp.br (F.S. Motta).

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Among MPA categories, marine reserves (or no-take MPAs) have been described as the most effective in mitigating threats, restoring and protecting the biodiversity by banning extractive activities like fishing and mining (Roberts et al., 2000; Sala and Giakoumi, 2018). However, the implementation of a marine reserve is not a guarantee of ecological success (Edgar et al., 2014; Gill et al., 2017) or social benefits (Christie, 2004).

The effectiveness of MPAs depends on adequate implementation, planning and monitoring (Bennett and Dearden, 2014). An increasing number of studies has measured the performance of ecological, economic and social aspects of MPAs to move forward our understanding on success and failures to guide policy and management strategies (Gill et al., 2017; Giakoumi et al., 2018; Pendleton et al., 2018; Ban et al., 2019; Mizrahi et al., 2019). Understanding the magnitude and occurrence of human pressures and their ecological effects/implications is critical for assessing and monitoring MPAs effectiveness (Zupan et al., 2018; Dunham et al., 2020).

Besides classic ecological studies, an increasing number of initiatives have evaluated the perception of experts to assess multiple aspects of management effectiveness in formally managed areas (Mangi and Austen, 2008; Kusumawati and Huang, 2015; McClanahan et al., 2021). The use of perception from local experts is an alternative approach that can provide valuable insights into observations, understanding and interpretation of the multiple outcomes and impacts from a given area (Bennett, 2016; Thiault et al., 2021). Research on perceptions can inform courses of action to improve conservation and governance at multiple scales. Most researches using expert perceptions have been conducted using MPA managers as a source of information (e.g. Pelletier, 2011; Santos and Schiavetti, 2014; Oliveira-Júnior et al., 2016) because they are considered to provide more reliable data due to their daily relation with the area (Brandão et al., 2021). However, perceptions of other stakeholders also may be used to explore the nature and magnitude of social and environmental impacts to get a broader view of the MPA context. The knowledge and perceptions of different stakeholders have been increasingly used to map multiple anthropogenic ocean impacts from local (Martins et al., 2014) to global scales (Halpern et al., 2008). Understanding the concerns and priorities related to impacts and threats to MPAs is important to provide insights into how different stakeholders perceive potential barriers to MPAs meeting their goals.

We investigated the perceptions of stakeholders involved in marine reserves management (managers and staff and management council members) regarding anthropogenic environmental threats and environmental quality. In addition, we verified if environmental quality scores are positively correlated with management effectiveness perceptions. We hypothesize that perceptions of threats and environmental quality vary among managers and management council members since previous studies verified incongruences in perceptions of management effectiveness (Giglio et al., 2019; Brandão et al., 2021). We also hypothesize that higher perceptions of management effectiveness are positively correlated with higher levels of environmental quality. People who perceive higher management effectiveness can be more able to also perceive positive outcomes of management in the environmental attributes (McClanahan et al., 2005). Our study provides an understanding of the dynamics on how different stakeholders engaged in marine reserves perceive threats and management effectiveness aspects.

2. Material and methods

2.1. Study area

Located on the southeastern region of Brazil, the state of São Paulo has a 700 km long coastline with 56 coastal islands and a diversity of subtropical environments like rocky shores, sandy beaches, seagrass, mangroves, rhodoliths beds and a coral reef (Gibran and Moura, 2012; Pereira-Filho et al., 2019, 2021). São Paulo is the most populous and developed Brazilian state. Its coastal ecosystems have been historically impacted by overfishing and related consequences (Keunecke et al., 2007; Link et al., 2019), invasive species (Luz and Kitahara, 2017), urban and industrial growth, including the expansion of ports and oil exploration (Amaral et al., 2010). The studied marine reserves are located in a region with a higher proportion of endangered fish species along the Brazilian coast (Ceretta et al., 2020). The marine reserves have provided evidence of effectiveness by harboring higher abundances and body size of commercially important species when compared to unprotected areas (Rolim et al., 2019; Motta et al., 2021).

The Tupinambás Ecological Station (hereafter Tupinambás ES) is a no-take area (IUCN Category Ia) established in 1987 and is composed of two sets of islands and submerged rocky reefs, around which there are circular areas of one-kilometer radius of no-take reserve. In 2016, after this study, a new and larger no-take MPA (Alcatrazes Archipelago Wildlife Refuge – 674.09 km^2 – IUCN Category III) encompassing Alcatrazes Archipelago, including the Tupinambás ES was established. The integrated management plan for the two MPAs was published in 2017. The Laje de Santos Marine State Park (Laje de Santos MSP) is also a no-take reserve (IUCN Category II) and it was established by the state government in 1993. Its council has been operating since 2009, and a management plan was approved only in 2018 (after the data collection from this study). Despite the extensive period without a management plan, diving activities were regulated in 2010 by an Emergency Plan for Public Use (Fundação-Florestal, 2013; Marconi et al., 2020). In addition, since 2012, the Laje de Santos MSP is surrounded by a fishing restriction area, which expanded the no-take area from 50 km^2 to 560 km^2. Visitation occurs mainly through scuba diving where the main attractions are the seasonal occurrence of megafauna like manta rays, sea turtles and large meso-predators like groupers and snappers (Luiz et al., 2009; Marconi et al., 2020). Tupiniquins Ecological Station (Tupiniquins ES) is also totally restricted (IUCN Category Ia) and covers six small islands with circular areas of one-kilometer radius of no-take reserves around the islands. Its management plan was finalized in 2008 and the management council was constituted in 2012.

2.2. Data collection

The data collection was approved by the Research Ethics Committee of the Federal University of São Paulo (CEP-Unifesp: 1154/2015) and Brazil Platform (49349515.1.0000.5505). The three investigated management councils have their seats instituted by normative published after the reserve establishment and are collegial bodies of stakeholders from different social sectors (e.g., NGOs, Navy, public administration, research institutions, local tourism, and lawyers associations) constituting democratic formal forums to discuss the management of each reserve. Between November 2015 and April 2016, all members of each management council were asked to fill a structured questionnaire with 25 questions encompassing topics regarding management effectiveness, threats, and environmental quality for each of the three marine reserves. Beyond the council members, the same questionnaire was also applied for the management staff, totalizing 56 stakeholders interviewed (i.e., >70% of the management councils and the whole staff from the marine reserves) (Table 1). The questionnaire was elaborated using Staub and Hatziolos (2004) protocol with adaptations based on Hockings et al. (2006). Both frameworks described approaches to evaluate

Table 1
Characteristics of studied marine reserves. IUCN category represents the categories of marine protected areas described by the International Union for Conservation of Nature (Day et al., 2012). M = managers and staff, and MB = management council members.

Marine reserve	IUCN category	Jurisdiction	Year creation	Area (km^2)	Year management council establishment	No. of interviewees M/MB
Tupinambás Ecological Station	Ia	Federal	1987	24.63	2006	3/15
Laje de Santos Marine State Park	II	State	1993	50	2009	3/17
Tupiniquins Ecological Station	Ia	Federal	1986	17.28	2012	3/15

management effectiveness of MPAs using score cards. Before data collection, we presented the survey aims during the management council meetings and requested members to fill a printed form. Questionnaires were distributed to managers and management staff and for members of the management council which is composed of representatives of public and private institutions. Management council members represent different sectors like social and environmental NGOs, Brazilian Navy, public administration, research institutions, local tourism associations and lawyers' associations. Fifty-six questionnaires were distributed between November 2015 and April 2016 comprising >70% of the management council members from each marine reserve (Table 1). Respondents were asked to score threats to MPAs through an order of importance ranging from 1 (less important) to 10 (extremely important). Ten potential threats considered most relevant to the study area were added in the questionnaire: (1) illegal fishing; (2) overfishing; (3) climate change; (4) pollution; (5) exotic species; (6) tourism; (7) urban expansion; (8) port expansion; (9) oil and gas exploration; and (10) enterprises (large infrastructure projects). Threat categories were chosen based on the protocols and authors' experience on the studied marine reserves. Respondents were also asked to rank the environmental quality of the MPA in four categories: (a) low; (b) regular; (c) good and; (d) excellent. Data of management effectiveness was extracted from Giglio et al. (2019). Herein, we defined the term *"perceptions"* according to Bennett (2016): as the way an individual observes, understands, interprets, and evaluates a referent object, action, experience, individual, policy, or outcome.

2.3. Data analysis

Kruskal–Wallis tests were fitted to test for differences in threats scoring values between managers and management council members of each marine reserve. The ten categories of score values range from 1 (less important) to 10 (extremely important). Differences among groups were tested using the Dunn test. Wilcoxon rank-sum tests were conducted to verify for differences in perceptions of threats between managers and council members. The relationship among perceptions on management effectiveness from managers and council members and environmental quality was tested using Spearman rank correlations. For analysis purposes, the environmental quality categories were coded as 1 to low, 2 to regular, 3 to good and 4 to excellent. Statistical analyses were conducted using R software version 3.5.2 (R Core Team, 2019) at a significance level of $p < 0.05$.

3. Results

3.1. Perceptions on threats and environmental quality per marine reserve

Illegal fishing and overfishing were mentioned as the main threats to marine reserves, receiving scores >9 and >7.5, respectively (Fig. 1). For Laje de Santos MSP and Tupiniquins ES, urban expansion accounted lowest threat score (average ±s.e. = 2.7 ± 2.2 and 3.25 ± 2.1, respectively), while in Tupinambás ES climate change received the lowest score (2.6 ± 1.9). Significant differences in scores between MPAs were observed for illegal fishing ($H = 7.39$, $p = 0.02$) where Laje de Santos MSP received higher scores than Tupinambás ES and Tupiniquins ES. Port expansion also revealed significant differences ($H = 9.79$, $p = 0.007$), Tupiniquins ES received lower scores than other marine reserves.

Concerning environmental quality, higher scores were given to Laje de Santos MSP and Tupinambás ES, about 90% of respondents classified as good or excellent (Fig. 2). In Tupiniquins ES, 39% of respondents perceived environmental quality as regular and only 11% as excellent. Low environmental quality was not attributed to marine reserves.

3.2. Perceptions on anthropogenic threats and environmental quality between stakeholders in marine reserves

No significant differences were found in perceptions of threats to marine reserves between managers and management council members (Fig. 3). Illegal fishing was perceived as the most important threat among managers and management council members in all marine reserves, receiving scores higher than 8.3. In Tupinambás ES, managers cited exotic species as the most important threat (9.3 ± 0.57), followed by illegal fishing (8.3 ± 1.5), while management council members ranked overfishing with higher scores (8.1 ± 1.4) than exotic species (6.76 ± 2.9). In Laje de Santos MSP, managers ranked exotic species with second highest values (8.7 ± 0.58) while management council members perceived overfishing and pollution as the second most important threats with scores higher than 7.4. In Tupiniquins ES, managers perceived similar importance for overfishing, climate change, pollution, exotic species and port expansion (scores higher than 6), while management council members were more concerned with overfishing (8.2 ± 1.97).

In Tupinambás ES and Laje de Santos MSP, managers tended to rank environmental quality with higher scores, mentioning "excellent" with a higher frequency (~67% of responses for both) than the management council members (29.4% and 17.6%, respectively) (Fig. 4a, b). On the other hand, in Tupiniquins ES, management council members tended to rank with higher environmental quality scores than managers (Fig. 4c). The only "excellent" scores were given by a management council member, representing 13.3% of responses.

3.3. Relationship between management effectiveness and environmental quality

No significant relationship was found between the perceptions of management effectiveness and environmental quality by managers and management council members of the three marine reserves (Table 2, Fig. 5). When managers and management council members were grouped, marine reserves tended to show a positive relationship with higher scores of management effectiveness and environmental quality.

4. Discussion

Our results revealed congruences in perceptions of anthropogenic environmental threats between different stakeholders,

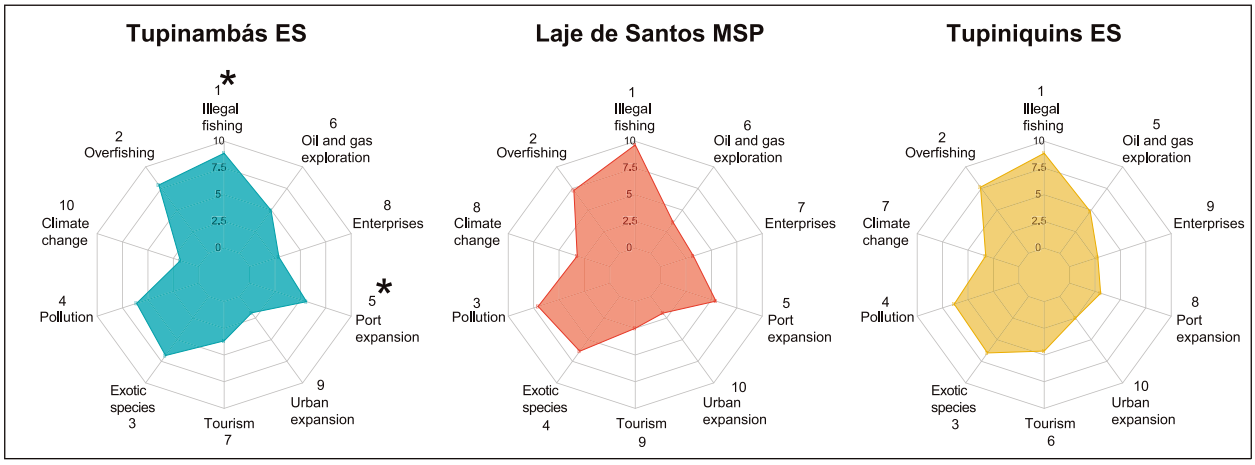

Fig. 1. Perceptions of managers/staff and management council members on threats to marine reserves in southeastern Brazil. Number above each threat represents the decrescent order of importance that was cited by interviewees of each marine reserve. Asterisks in Tupinambás ES represent significant differences in the scores of a threat among marine reserves.

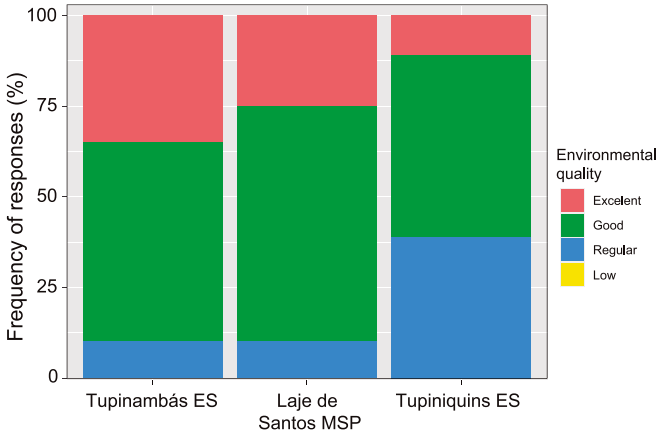

Fig. 2. Perceptions of environmental quality among managers and management council members of marine reserves in southeastern Brazil.

Table 2
Summary of Spearman rank correlation tests for perceptions of management effectiveness and environmental quality in marine reserves of southeastern Brazil. Statistical tests were not conducted for managers due to small sample numbers in each MPA (n = 3).

Tupinambás ES	Spearmans' ρ	P-value
Managers/staff	–	–
Management council	0.04	0.9
All respondents	0.08	0.8
Laje de Santos MSP		
Managers/staff	–	–
Management council	0.41	0.1
All respondents	0.43	0.06
Tupiniquins ES		
Managers/staff	–	–
Management council	0.24	0.4
All respondents	0.19	0.4

managers and management council members of the three marine reserves evaluated. No significant differences in perceptions were verified for the nine threats investigated. In this light, we reject our hypothesis that perceptions of managers and management council members may be different, as reported in previous research with the same stakeholders assessing management effectiveness of marine reserves (Giglio et al., 2019) and other Brazilian MPAs (Brandão et al., 2021). The different stakeholders' interests and their socioeconomic and cultural background has been related to influence the perceptions of management effectiveness. However, the similarity in threat perceptions reported in this study may be explained by the lower level of complexity and subjectivity in comparison with management effectiveness evaluations. In Brazil, the determinants to the scale of threats to MPAs is related to its category, being higher in MPAs close to areas with high human density and prevalence of nearby human population suffering from high levels of poverty and social inequality (Oliveira-Júnior et al., 2021).

Considering all stakeholders perceptions, from the ten investigated threats, only illegal fishing and port expansion received different scores between marine reserves. These results were context-dependent since illegal fishing is a relevant threat to the visitation of a marine park (Laje de Santos MSP) and both Tupinambás ES and Laje de Santos MSP are located near to two important ports: the São Sebastião and Santos Port, respectively, and illegal fisheries have indeed been reported in those areas (Castro, 2016; Pimentel, 2019). However, despite differences, illegal fishing was perceived as the main threat in the three marine reserves and port expansion was ranked similarly (5th in Tupinambás ES and Laje de Santos MSP, and 7th in Tupiniquins ES). Extractive activities from illegal fishing and overfishing were perceived as the main threats to marine reserves in southeastern Brazil. Such topics have been perceived by managers from low- and low-middle income countries as strong threats to MPAs, such as for nations of west Africa (Failler et al., 2020) and Brazil (Oliveira-Júnior et al., 2021).

Noncompliance with conservation norms and dependence of populations upon natural resources and low levels of educational attainment are the main determinants for illegal fishing occurrence (Arias et al., 2015; Iacarella et al., 2021). However, most illegal fishing occurring in the studied marine reserves is practiced by recreational fishers with medium and high income and higher levels of education (Castro, 2016; Freire et al., 2016; Pimentel, 2019). The increasing involvement of this segment in the public forums related to MPA management (e.g., management council members) can be critical to increasing compliance since these stakeholders would be more aware of the MPA regulations and could also bring specific demands to be discussed. Although the willingness to participate must come from the segment itself, the participation of the recreational fishers can be made possible through invitations by managers or articulations and encouragement by other MPA councils' members. On the other hand,

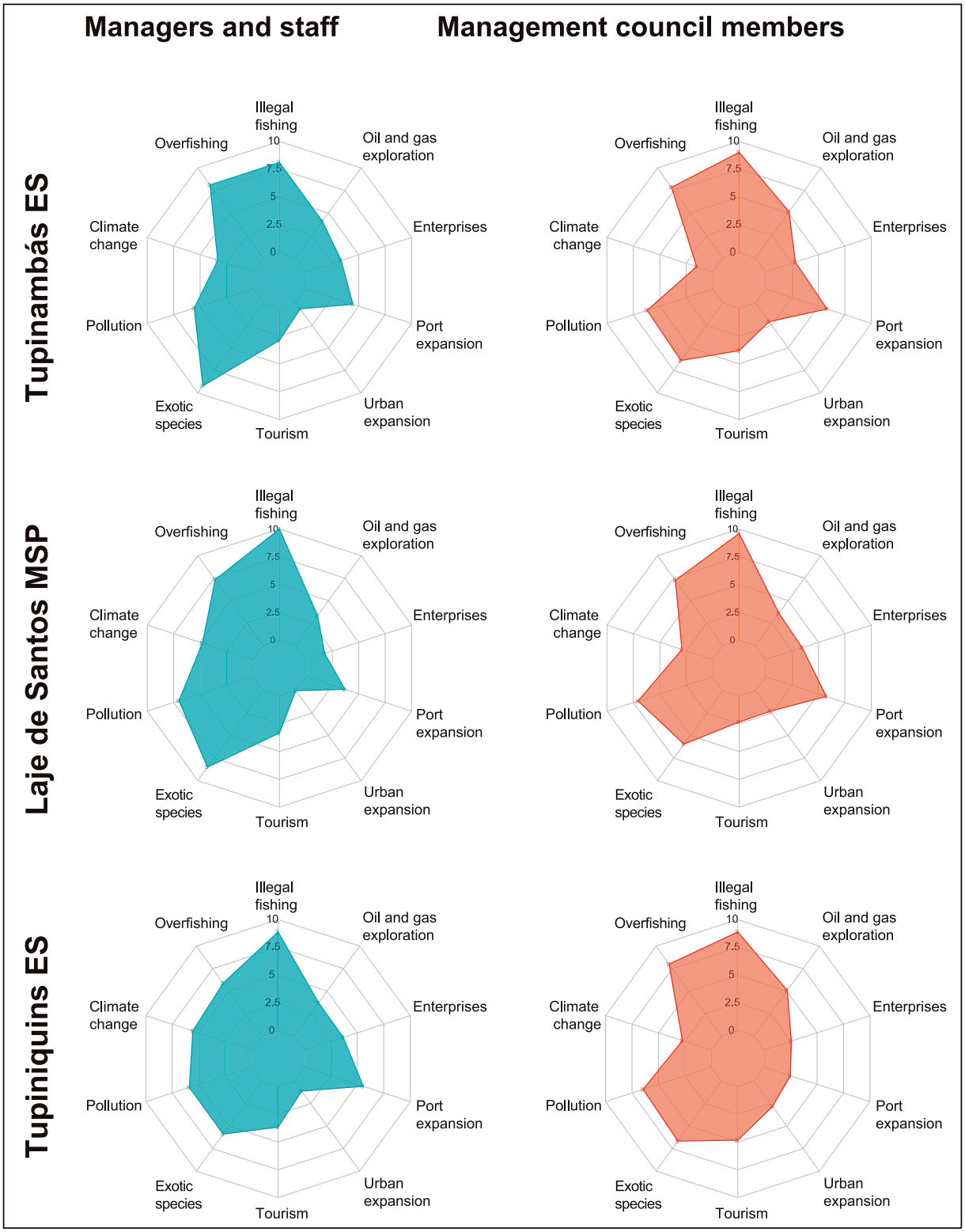

Fig. 3. Perceptions of managers/staff and the management council on threats to marine reserves in southeastern Brazil.

the historical discontinuity and absolute negligence with fishery management in Brazil (Gonçalves-Neto et al., 2021), including conflicts involving small-scale fishers (e.g. federal legislation on gillnet fisheries) can further enhance non-compliance of studied marine reserves. Moreover, the current Brazilian government has been continuously declaring its intentions to change the status of some marine reserves as a part of a systematic dismantling of Brazilian environmental laws ongoing (Abessa et al., 2019; Levis et al., 2020). Thus, instead of enhancing marine reserves compliance, this sector has been encouraged to practice illegal fishery and argue against the reserves legitimacy. However, illegal fishing when recorded is punished with fines calculated based on specific legislation that takes into account a series of parameters (e.g. weight of fish specimens caught, environmental

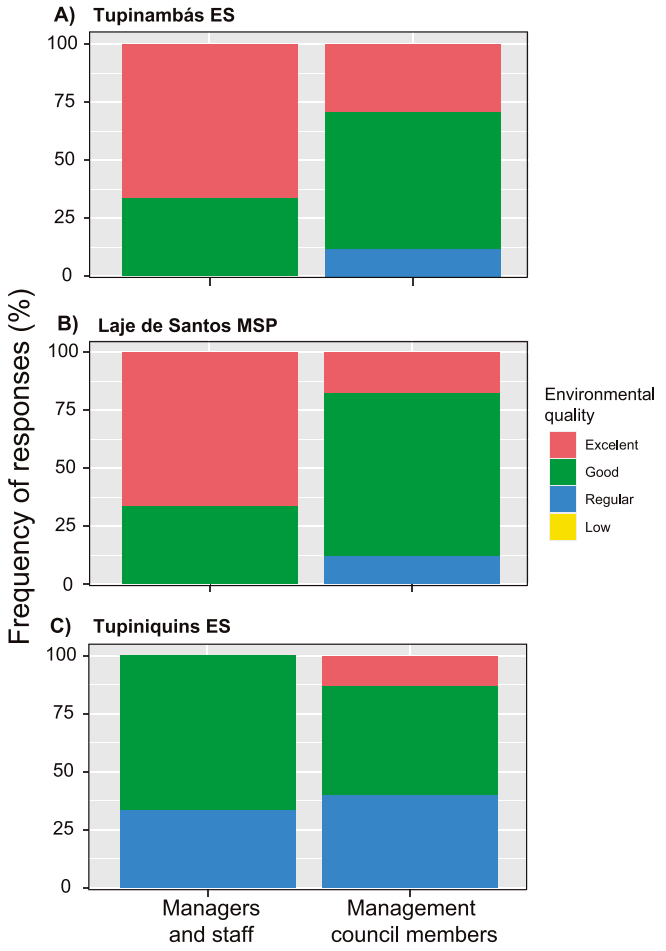

Fig. 4. Perceptions of environmental quality between managers/staff and management council of the marine reserves of southeastern Brazil: (a) Tupinambás Ecological Station; (B) Laje de Santos Marine State Park; and (C) Tupiniquins Ecological Station.

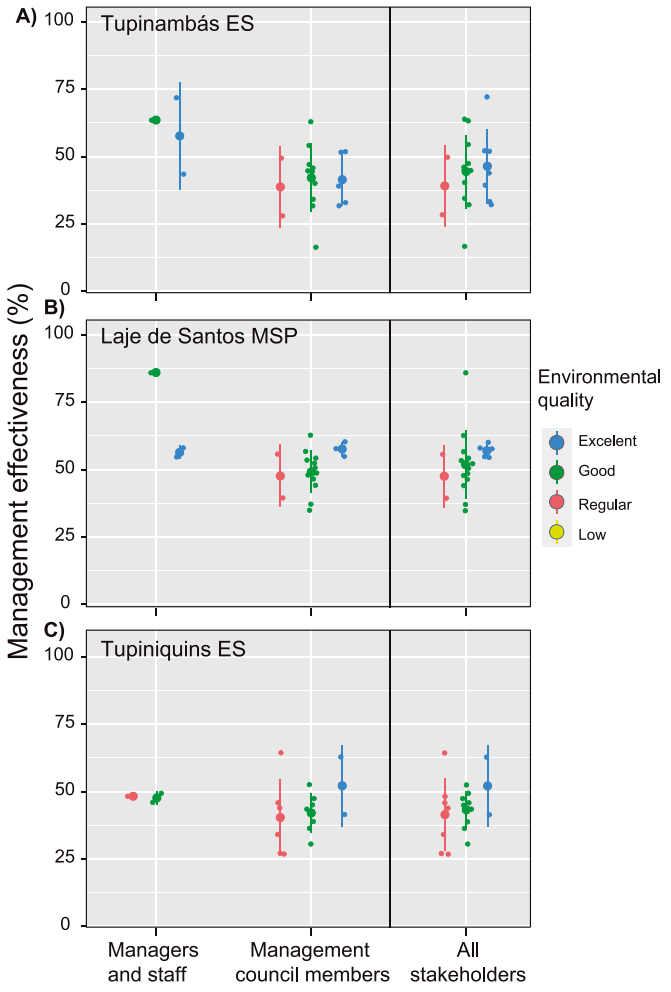

Fig. 5. Relationship between perceptions of management effectiveness and environmental quality in marine reserves (A) Tupinambás Ecological Station; (B) Laje de Santos Marine State Park; and (C) Tupiniquins Ecological Station. Larger circles represent the average and the smallest the raw data. The deviations are standard deviations.

consequences, protected site among others). In addition, fishing gear is seized, including the boats in some circumstances. Despite the challenges, due to the need for human and financial resources, enforcement efforts have increased in recent years, especially in Tupinambás ES (Menegassi, 2020; Quimbayo et al., 2022).

Overfishing is a common scenario among fisheries resources in Brazil (Freitas et al., 2011; Bender et al., 2014; Haimovici and Cardoso, 2017), and worryingly, there have been no systematic fisheries monitoring at national scale since 2007 (Barreto et al., 2017). Rather than a local problem, a diachronic study revealed that Brazilian MPA managers described extractive activities as persistent threats to MPAs, allied to exotic species, climate change, waste disposal and vessel traffic (Fig. 6; Brandão et al., 2017). The threat from extractive illegal activities inside marine reserves and overfishing in the adjacent areas are the foremost barriers to its ecological performance (Edgar et al., 2014; Zupan et al., 2018). On the other hand, well-managed marine reserves can be effective in mitigating overfishing. This has been demonstrated for Tupinambás ES and Laje de Santos MSP, where a greater abundance and body size of fisheries targeted species have been observed in comparison with non-protected areas (Rolim et al., 2019; Motta et al., 2021). Marine reserves may offer protection for a variety of species and habitats in their limits, and in some cases provide spillover benefits adjacent to their boundaries (Halpern et al., 2009; Di Lorenzo et al., 2016).

While illegal fishing and exotic species were perceived as the main threat by most stakeholders (i.e., managers and council members), the importance of regional/global threats such as pollution, urbanization and climate change were less evaluated as threats by them. This is, in part, because of the sense of incapacity to locally deal with global threats and thus take managers and local actors to an ambushing game of policy and thief rather than find their common challenges. Anyway, regarding the chemical pollution of marine sediments, the stakeholders' perceptions were congruent with the results of assessments conducted in Tupinambas ES and Laje de Santos MSP that detected low concentrations of chemicals (Hoff et al., 2015; Abessa et al., 2017; Moreira et al., 2017; Moreira et al., 2021). On the other hand, 60% of the sewage production in Brazil is released untreated in the environment and several pharmaceuticals, including cocaine and its human metabolites, have been detected in waters surrounding the studied marine reserves (Pereira et al., 2016; Abessa et al., 2018). Santos port dredging and discharging alters sediment quality with consequences for both the local biota as well as for fisheries activities and food security (Cesar et al., 2014). Even not designed to directly deal with these threats, marine reserves are important tools buffering the effects of regional/global threats and improving resources around them. However, the clear perception of regional/global threats locally impacting the marine

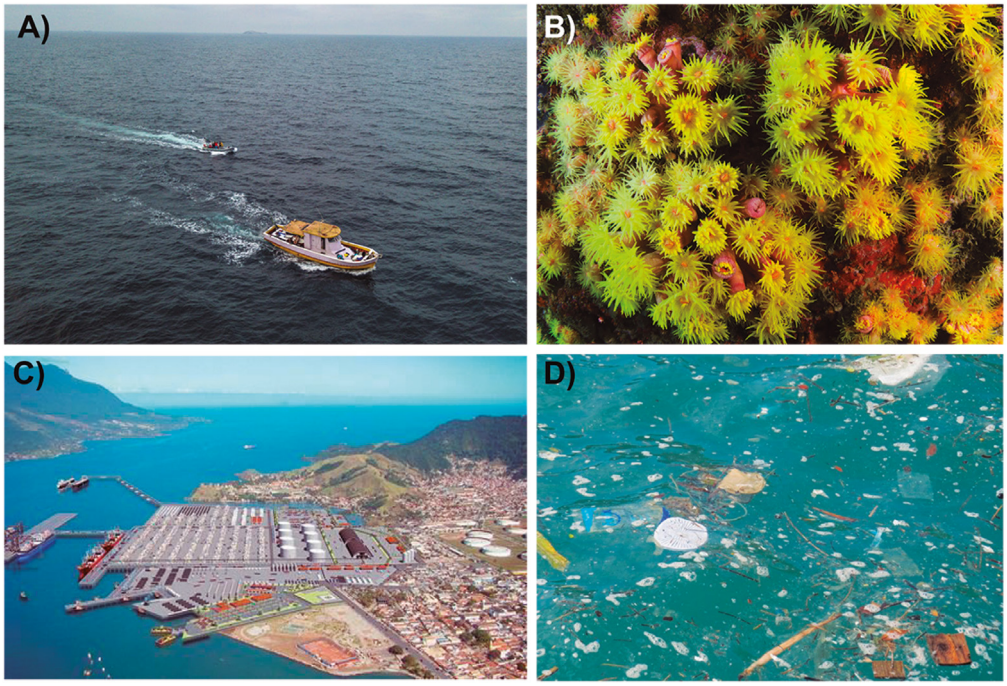

Fig. 6. Threats to no-take marine protected areas of southeastern Brazil. (A) illegal fishing boat being chased by a surveillance boat in Laje de Santos Marine State Park; (B) Sun coral *Tubastrea* spp. in rocky reefs of Tupinambás Ecological Station; (C) Project of port expansion in São Sebastião municipality, close to Tupinambás Ecological Station; and (D) waste residuals from ship containers that fell into the sea near to Tupinambás Ecological Station and Laje de Santos Marine State Park. Credits (A) Clécio Mayrink; (B) Leo Francini; (C) Divulgação Jornal do Litoral; (D) Fiscalização/ICMBio.

reserves should firstly be acknowledged by stakeholders and thus broadcasted to other social actors.

Exotic species received higher importance by managers and pollution by management council members. There is a clear link with high concern among managers related to the sun coral invasion (Savio et al., 2021). Sun coral species, mainly *Tubastraea coccinea* and *T. tagusensis*, are a matter of concern in many Brazilian MPAs due to their high reproductive, dispersion and population increase potential (Silva et al., 2011; Creed et al., 2017). Sun coral has detrimental effects on native coral and benthic organisms recruitment (Miranda et al., 2018) and also negatively impacts the satisfaction of divers in Laje de Santos MSP and other marine reserves where diving tourism is allowed in the region (Marconi et al., 2020). In the last year, managers have expended a considerable logistical and fieldwork effort to remove sun corals. Other invasive species such as the blenny fish *Omobranchus punctatus*, as well as the mussels *Leiosolenus aristatus* and *Isognomon bicolor*, the coral *Stragulum bicolor*, and the ascidian *Styela plicata* have been recorded in the coast of São Paulo (Marques et al., 2013; Contente et al., 2015; ICMBio, 2017; Oricchio et al., 2019). However, even though studies of the impact and control measures of these species have not yet been developed, the spreading and colonization do not appear to be as aggressive as the sun corals. Thus, invasive species tend to be perceived as a more important threat to managers than to management council members, who generally do not participate in control operations.

The higher scoring from management council members to pollution may be influenced by some factors. Firstly, marine reserves are closer to urban areas and most management council members have little direct experience with the marine reserve, therefore, by witnessing pollution daily, they tend to give more relevance to the topic. Secondly, the media may influence perceptions since pollution, especially by plastics, have been increasingly addressed in the region (Fig. 6). Plastic pollution has gained increasing attention from the media, also increasing society's concern about this issue (Males and Van Aelst, 2021). Finally, managers are more prone to perceive threats which they are directly able to deal with rather than other threats.

Interestingly, climate change was ranked as the higher threat among managers. Climate change has usually been perceived as an important threat in tropical reefs, mainly by evidencing bleaching events (Thiault et al., 2021). However, in the studied area, coral communities have displayed resilience to bleaching. Despite the high rate of bleaching, mortality of corals in Tupinambás ES was lower than 2% in the most intense bleaching episode ever recorded (Banha et al., 2020). Such higher scoring among managers may be explained by the increasing concern among scientists and media on the effects of the increasing events of temperature anomalies in the region. Thus, we suggest the co-production between scientists and managers of specific climate metrics for these areas so that new scientific approaches emerge, as well as new ways to manage and mitigate this threat (Kripa et al., 2021). Moreover, to deal with this and other threats, science outreach efforts could also be one important strategy to approximate scientists, MPA stakeholders and managers aiming to improve science-based management practices.

We expected that environmental quality was an outcome of management effectiveness, however, we did not verify a significant positive correlation of management effectiveness and environmental quality, which may also be associated with the bias of some perceptions. Marine protected areas with higher management effectiveness scores may not necessarily present less pressures and threats (Brandão et al., 2017). Other characteristics such as the age of management council (Brandão et al., 2017), isolation of the marine reserve (Oliveira-Júnior et al., 2016) and geographic features may influence the perception on degree and persistence of a threat and their management effectiveness (Goodman, 2003).

Participatory assessment of threats and human pressures on MPAs is important to guide adaptive management and interpret ecological performance monitoring. Also, the direct involvement

of stakeholders in planning and management processes is an additional way to address the equity of MPAs as well as to improve compliance with MPA rules (Dunham et al., 2020). Research on stakeholders' perceptions is a quick and easy-to-apply approach, being welcome to provide complementary information on multiple MPA management issues. However, we acknowledge that there are limitations on the use of perceptions because the subjectivity and it may not accurately represent outcome variables, such as the quality of a habitat (Daw, 2010), or may be biased by the expert interests and political or institutional context. Our work provides a baseline for future assessments of stakeholders' perceptions on threats to marine reserves. This study also highlights the challenges faced by complex effects of anthropogenic activities from local to global scales affecting the performance of marine reserves in a hotspot of anthropogenic threats.

5. Conclusion

Our results provide an overview of perceptions on threats and environmental quality of marine reserves in the Southwestern Atlantic. Illegal fishing, overfishing and exotic species were the most important threats identified by managers and management councils. No differences were verified between the perceptions of managers and members of the management council. This may be explained by the lower level of complexity and subjectivity in comparison with management effectiveness evaluations. The lack of relationship between the perception of effectiveness and quality of environmental attributes may be associated with the bias of some perceptions, although MPAs with higher management effectiveness scores may not necessarily present less pressures and threats. Stakeholders' perceptions may be used to guide priorities for new research, funding, and policy mitigating the effects of such threats on marine reserves. Also, they also provide insights and are an important source of evidence that should be integrated with other ones as part of robust monitoring and evaluation protocols to improve the planning and management of MPAs.

CRediT authorship contribution statement

Vinicius J. Giglio: Conceptualization, Formal analysis, Writing – original draft, Writing – review & editing. **Guilherme H. Pereira-Filho:** Conceptualization, Writing – review & editing. **Marina Marconi:** Writing – review & editing. **Fernanda A. Rolim:** Writing – review & editing. **Fabio S. Motta:** Conceptualization, Methodology, Formal analysis, Investigation, Writing – original draft, Writing – review & editing, Funding acquisition.

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.

Data availability

The data that has been used is confidential.

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