Co-management of marine protected areas: Challenges and lessons from the most urbanized coastline of the South Western Atlantic

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Abstract

Marine Protected Areas (MPAs) are powerful instruments to conserve biodiversity and ecosystems, if supported by an effective management structure. In Brazil, no-take and multiple-use MPAs have advisory councils that allow co-management as an important strategy to deal with conservation challenges, mainly in urbanized coastal areas. However, the profile of members and their perceptions regarding advisory council challenges remain poorly known. Here, we assessed the advisory management councils of the largest network of MPAs in the South Western Atlantic, situated next to one of the largest metropolitan areas in the world. Seven MPA advisory councils were initially characterized through consultation with the MPA managers, followed by interviews with each advisory council member. We found that advisory council members were mostly agents of the local government, university scientists, members of local associations, and employees of non-governmental organizations. Compared with no-take MPAs, multiple-use MPAs tended to have greater diversity of member profiles in terms of institutional affiliation, gender, training level and age group. Although the majority of respondents considered the advisory councils an effective management tool, almost 30% of the interviewees did not recognize this mechanism as efficient, and the perceived capacity for advisory councils to respond to challenges was lower in no-take MPAs. This perception was attributed to a lack of complete actor inclusivity and the low decision-making power of advisory councils. There was a general agreement that no-take MPA advisory councils in particular are not achieving their sustainability goals and have progressed less than multiple-use MPAs in terms of co-management. To overcome this, we provide a series of recommendations to improve stakeholder participation and co-management of MPA operation.

Keywords: MPA, management council, Sao Paulo, conservation, ocean governance, stakeholders, interview.

1. Introduction

Marine Protected Areas (MPAs) have been recognized worldwide for their potential in regulating ecosystem use, reducing human pressures on biodiversity and promoting outreach and conservation actions (e.g., Leisher et al. 2012; Sala & Giakoumi 2018; Rolim et al. 2019; Hall et al. 2023). MPAs also assist in the recovery of species populations and marine food webs (Gell & Roberts 2003; Sala & Giakoumi 2018), promoting adaptation against climate change (Roberts et al. 2017; Maestro et al., 2019), maintaining oceanic processes, ecosystem services and functions (Leenhardt et al., 2015), and supporting food security (Cabral et al., 2020). Nevertheless, the conflicts between MPA goals and economic interests put at risk the effectiveness of MPAs for marine conservation. Appropriate governance structures and management regimes capable of responding to surrounding pressures are therefore necessary (Edgar et al., 2014; de Sousa & Serafini 2018; Mills et al. 2020).

MPAs occur in many forms. No-take MPAs – where fishing and other extractive uses are not allowed – are known to promote the conservation and recovery of fishing stocks and associated ecosystems (Sala & Giakoumi 2018), with benefits beyond the target species and/or MPA boundaries (Gell & Roberts 2003; Roberts et al. 2017; Rolim et al. 2019; Motta et al., 2021). Multiple-use MPAs, which permit the sustainable use of resources, allow fishing and other extractive activities if these are compatible with the aims of the MPA (e.g., Mills et al. 2020; Hall et al. 2021). Specific terminology of related to MPA classification varies from jurisdiction to jurisdiction. In Brazil, the legal

framework for the creation, maintenance, and classification of protected areas is based on the Federal Law 9985/2000, which establishes the National System of Conservation Units (SNUC) and its corresponding regulations (Federal Decree 4340/2002). The SNUC establishes five categories of "strictly conservation units" (i.e., no-take) and seven categories of "sustainable use conservation units" (i.e., multiple-use). In Brazil, the Environmental Protected Areas were established within multiple-use group, inspired by European models, and are equivalent to the IUCN Category V. Environmental Protection Areas (EPAs) are designed to protect landscapes, ensuring biodiversity, regulating human occupation, and promoting the sustainable use of resources. Misunderstandings of their function and objectives have led to controversies (Maretti et al., 2012). Besides the need for a proper classification, MPA restrictions (however lenient) must be well-enforced and effectively managed if conservation success is to be realised (Edgar et al., 2014; Mills et al. 2020). This includes: adequate planning of the MPA goals, spatial design and level of enforcement, environmental monitoring to detect changes in the metrics of interest (backed up by robust scientific evidence and sufficient funding), and stakeholder engagement to reduce conflicts – thereby increasing adherence and compliance to MPA rules (Gleason et al. 2010; Edgar et al., 2014; Rolim & Ávila-da-Silva 2016; Giglio et al. 2019; Mills et al. 2020; Olaya-Restrepo et al. 2022).

In Brazil, the implementation of MPA advisory councils is a strategy that has been applied to improve stakeholder involvement, co-management, and cross-stakeholder communication (Gerhardinger et al., 2009; Giglio et al. 2019; Olaya-Restrepo et al. 2022). However, of the 70 MPAs established in Brazil under federal jurisdiction, only 25 (36%), called Marine Extractive Reserves (RESEX), represent deliberative management councils that engage their main stakeholders in decision making (article 18, second paragraph of Federal Law 9985/2000). The other 45 federal MPAs have consultative

97 advisory management councils – the focus of this paper – where decision-making is
98 undertaken by public managers (Mills et al. 2020). Although advisory councils have less
99 decision power than deliberative councils, both encourage members to contribute their
100 views – an important step towards equal stakeholder engagement and ultimately
101 improved MPA co-management effectiveness (Giglio et al. 2019).

102 The present study focuses on the Sao Paulo state coastal region – which has the
103 largest MPA network in Brazil, with 74 Coastal and Marine Protected Areas under
104 federal, state, or municipal jurisdiction (de Sousa & Serafini 2018; Magris et al. 2021;
105 Motta et al. 2021; 2022). These MPAs cover a wide range of ecosystems, including large
106 estuaries, mangroves, sandy beaches, coral reefs, rhodolith beds and rocky reefs (Pereira-
107 Filho et al. 2019; 2021; 2023; Motta et al. 2021; 2022), and are located in one of the most
108 densely populated and urbanized metropolitan areas of the world – with about 24 million
109 people living less than 100 km of the ocean (including one the largest cities in the world
110 – Sao Paulo; Fig. 1), the largest port in Latin America (Santos), one of the most important
111 Brazilian fishing areas (including artisanal, industrial and recreational fishing), large-
112 scale oil and gas industrial activity (Magris et al. 2020), and a complex multilevel system
113 of governance (Gonçalves et al. 2021).

114 Given the diversity of the natural environment and the diverse socioeconomic
115 demography along the Sao Paulo state coastline, it is expected that the MPA advisory
116 councils would represent this diversity, but this information remains unknown (Giglio et
117 al. 2019). Characterization of the composition of MPA advisory council representatives
118 could be used to identify management challenges and explain differences between MPA
119 types. Such an analysis would illuminate knowledge and stakeholder gaps in the Sao
120 Paulo MPA network, at local and regional scales. The present study aims to understand
121 better the composition of advisory management councils of no-take and multiple-use

MPAs along the Sao Paulo coastline, and to understand the council members' perceptions of the challenges for co-management effectiveness in an area subjected to multiple anthropogenic pressures.

The aims of the present study are to: (I) compare the profiles of advisory council membership in no-take and multiple-use MPAs along the Sao Paulo state coastline; (II) identify advisory council members' perceptions regarding the main impacts and challenges for co-management effectiveness in no-take and multiple-use MPAs; and (III) assess the degree of discourse agreement or disagreement between advisory council members across the Sao Paulo MPA network. This will provide a model for understanding the main challenges that no-take and multiple-use MPAs may face in implementing effective co-management in heavily urbanized coastal areas. Considering the relevance of Sao Paulo in the national and international context, acquiring this knowledge could significantly inform MPA advisory management council operation throughout Brazil and more widely.

2. Methods

2.1. Study area

The present study was undertaken in the largest network of exclusive MPAs in Brazil (~12,055 km^2) (Fig. 1), located along the Sao Paulo state coastline, southeastern Brazil. This network includes three large multiple-use MPAs: the Center, North, and South Coastal Environmental Protected Areas (Center, North, and South CEPAs; each corresponding to IUCN Category V): created in 2008. These category of "Environmental Protection Area (EPA)" belong to the group of "sustainable use protected areas" according to the Brazilian legal framework. These MPAs were intended to contribute to

146 the management of fisheries (Rolim and Ávila-da Silva, 2016), support nautical tourism
147 and promote regional sustainable development (Motta et al. 2022). Artisanal (family-
148 based) and commercial fishing are allowed in the Center, North, and South CEPAs (Motta
149 et al. 2022). Four no-take zones are nested within these larger MPAs: (1) the Tupiniquins
150 and Tupinambás Ecological Stations (Tupiniquins and Tupinambás ESs) - established by
151 the Federal government in 1986 and 1987 respectively, these no-take MPAs aim to protect
152 the natural environment and promote scientific research (IUCN Category Ia); (2) the
153 Alcatrazes Wildlife Refuge (Alcatrazes WR) - established in 2016, with the primary
154 objective of conserving biodiversity, but recreational scuba diving has been allowed since
155 2018 (Marconi et al. 2020) (IUCN category III); and (3) the Laje de Santos State Marine
156 Park (Laje de Santos SMP) - created by the state government in 1993, intended to
157 conserve regional biodiversity and promote scuba diving tourism (Motta et al. 2021)
158 (IUCN category II) (Fig. 1). These categories of "Ecological Stations", "Wildlife Refuge",
159 and "State Park" belong to the group of "strictly protected areas", according to the
160 Brazilian legal framework.

161 An advisory management council is present in each one of these seven MPAs,
162 tasked with co-management of marine resources and local conservation (Motta et al.
163 2021; 2022). Although the advisory council profiles are still unknown, the Brazilian
164 Federal Decree 4340/2002 (Article 17) addresses the creation of advisory councils,
165 highlighting that representation of public entities in these councils shall include
166 environmental agencies at the three levels of government (municipal, state and federal)
167 and entities from related areas such as national defense, tourism, among others.
168 Representation of civil society should include the scientific community and non-
169 governmental environmental organizations, resident populations, traditional
170 communities, private sector, among others (Federal Decree 4340/2002, Article 17).

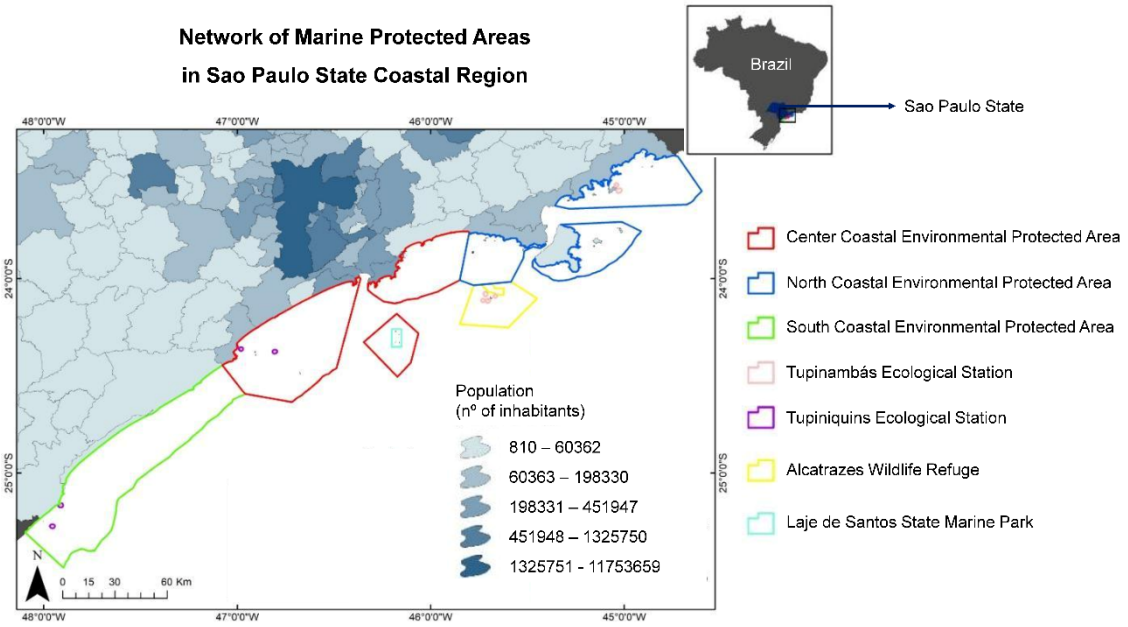

Figure 1. Study area with the seven Marine Protected Areas (MPAs) assessed on the Sao Paulo state coastal region, southeastern Brazil. The map shows the municipal divisions of the region. The aggregation of darkened municipalities indicates the Sao Paulo metropolitan region, with Sao Paulo as the most prominent and darkest city in the center.

2.2. Data collection

The profile of the advisory councils from each of the seven MPAs was initially characterized through a consultation with the MPA managers and then followed up with an interview administered to each advisory council member (see Supplementary Material 1). This enabled us to build a profile of each MPA advisory council membership (e.g. gender balance, training level, age group and the institutional category they represent). All interviews were conducted via video calls or audio calls (according to the interviewee's preference), as they were carried out during the COVID-19 pandemic period (July-December 2020). Although the pandemic period also imposed some limitations on the number of interviewees (because of difficulties in the online recruitment of participants), interviews were secured with at least 30% of the advisory council membership for the majority of the MPAs.

190 The main pressures that act on the marine environment (as identified by the
191 interviewees) were assessed by ranking word abundance from open-text answers in the
192 interview (e.g., “Fishing”, “Waste”, “Sewage”), and semi-quantified by asking
193 interviewees to rate the scale of the impact from 0 - 100. We also assessed the perception
194 of advisory council members on the capacity of the advisory councils to respond to the
195 challenges of multiple-use and no-take MPAs (using a scale from 0 – 100). All
196 questionnaires and data acquisition procedures were approved by the relevant authorities:
197 Ethics Committee process (Plataforma Brasil) (CAAE 30624420.8.0000.5505), and
198 Fundação Florestal de São Paulo Technical-Scientific Committee (process 003665/2020-
199 97).

200

201 *2.3. Data analysis*

202 Most of the questions were analyzed using descriptive statistics, allowing
203 visualization of advisory council membership profiles in terms of gender balance, training
204 level, age group and institutional category. Next, we evaluated the degree of discourse
205 agreement or disagreement regarding the management of the marine environment. This
206 was achieved using a content analysis of the responses to the following survey open
207 questions: (1) “Why do you believe that Advisory Management Councils are not effective
208 mechanisms for multiple-use MPAs (or no-take MPAs)?” (2) “What are the success
209 factors of a multiple-use MPA (or a no-take MPA)?” (3) “What are the main challenges
210 for the council when implementing the Management Plan in multiple-use MPAs (or in
211 no-take MPAs)?” (4) “What are the main perceived negative impacts [pressures] on the
212 marine environment?” (5) “What kind of information should be shared among to the
213 councils and between councils and managers and how could this occur?”

These questions were used to construct a document-term matrix (Harris 1954), frequently used in Natural Language Processing (NLP) and Information Retrieval (IR). Under this model, words in a document are considered independent of both each other and their position in the document; only their presence is considered. Given a dictionary (D), which contains a set of viable words, a document can then be encoded to a vector. Each vector dimension corresponds to a word in the dictionary and the vector value can be 0 or 1 to indicate the absence or presence of the word in the document, or, usually, an integer to indicate how many times the word appeared in the document. Often in IR, we are given a collection of documents, called the *corpus* (C). Using the Bag-Of-Words model, one would encode the documents in C in a matrix of size $|C| \times |D|$, where each cell i, j contains the number of times word j appears in document i.

Next, we used advanced Natural Language Text Kernels and specifically the p−Spectrum Kernel method (Leslie et al. 2001) to extract the clustering information. Spectral clustering is an approach based on the Laplacian of a graph formed between sample points by considering their weighted distance (Von Luxburg 2007) and designing a distance matrix using the p-spectrum kernel. Thus, each sampling point in the matrix corresponds to overlapping answers of two participants. The distance degree of the overlap answers varies from 0 (complete similarity between the answers) to 1 (complete difference between the answers). The distance gradient (0-1) is represented as a color gradient (dark blue - yellow) in the matrix. Therefore, yellow clusters represent groups of different opinions and little overlap (low degree of discourse agreement) while dark blue clusters represent similar overlapping opinions (high degree of discourse agreement). Larger matrices and/or yellow clusters indicate a greater divergence of opinions.

Finally, we perform K-means clustering to assess the groups of opinions in each question. The goal of the K-means algorithm is to create clusters of samples such that the

intra-cluster variance is minimized (Shukla & Naganna 2014). The criterion we aim to optimize during clustering is the within-cluster sum of squares between the cluster points and the mean of all the cluster points – known as inertia. To specify the number of clusters to look for, we conducted a grid search for the number and stopped once single-sample clusters began to form. Thus, each cluster represents a group of stakeholders who had similar opinions.

3. Results

3.1. Advisory council profiles

A total of 75 members from the seven MPA advisory councils answered our interview - 48 were members of only one advisory council, while 27 were members of two or more advisory councils. The MPAs with the highest total number of members (interviewed + not interviewed) were the North and Center CEPAs, followed by the Alcatrazes WR and the Tupinambás ES. For these three biggest advisory councils, about 30% of their members answered the interview, including both permanent and alternate members (Table 1). The advisory councils with the lowest total number of members were the South CEPA and the Laje de Santos SMP. Here, about 60% of the permanent members and about 20% of the alternate members responded to the interview (Table 1). Information about the total number of members in the advisory council of Tupiniquins ES was not obtained since this MPA had not yet formally convened its council due to low engagement of both the manager and local stakeholders. Additionally, only two members of Tupiniquins ES advisory council responded - both were also advisors on at least one other MPA in the network. In the advisory councils of the three CEPAs and the Laje de Santos SMP, about half of the members interviewed had occupied their positions for over 5 years,

263 with some members sitting for 10-12 years. In contrast, in the advisory councils of the
264 Alcatrazes WR and Tupinambás ES, about 70% of the members interviewed had occupied
265 their position for less than 5 years.

266 The North and Center CEPAs had the highest number of institutions represented
267 in their advisory council membership; our interviews encompassed about 40% of these
268 (Table 1). The South CEPA and Laje de Santos SMP advisory councils had the lowest
269 number of institutions represented; about half of these were captured in our interviews.
270 The Alcatrazes WR and Tupinambás ES captured the greatest diversity of institutions
271 (Table 1).

272 Overall, the most frequently represented institutions by the advisory council
273 members interviewed were the municipal public authority (city hall members),
274 universities, local associations (e.g., fisher associations), non-governmental organizations
275 (NGOs), and state or federal environmental agencies (Table 1). The CEPA advisory
276 councils also had members representing state-owned companies; no-take MPAs did not.
277 Answers from company representatives were obtained from the Center and North CEPA,
278 but not the South CEPA (Table 1). With the exception of Tupiniquins ES (where the
279 information was not available), all MPAs had advisory council members from state public
280 authorities (i.e., state government members). Interviews from these state representatives
281 were not secured from the Alcatrazes WR, Tupinambás ES and North CEPA advisory
282 council groups. Similarly, with exception of Laje de Santos SMP, all MPA advisory
283 councils had members from federal public authorities (i.e., federal government members),
284 but no responses were received from this group for any of the MPAs (Table 1).

285

286 **Table 1.** Features of the Marine Protected Areas (MPAs) assessed in the Sao Paulo state coastal region,
287 southeastern Brazil, in terms of MPA type (NT: No-take; MU: Multiple-use): number of members
288 (permanent and alternate) in each advisory council and percentage of members interviewed; number of

289 institutions that the members represent in each advisory council and the percentage of institutions
290 represented by the members interviewed; and the institution types represented in those both interviewed
291 and not interviewed (NGOs = non-governmental organization).

MPA name (MPA type)	nº of members (% interviewed)	nº of institutions (% interviewed)	Institution types interviewed	Institution types not interviewed
Laje de Santos State Marine Park (NT)	18 permanent (55.5%) 13 alternate (23.1%)	18 (50%)	Universities, NGOs, state public power, state environmental agencies, and MPA employees.	Federal environmental agencies, municipal public power, tourism and nautical sectors.
Alcatrazes Wildlife Refuge (NT)	27 permanent (37.9%) 29 alternate (27.6%)	23 (65%)	Universities, NGOs, municipal public power, state environmental agencies, federal environmental agencies, regional port agencies, tourism and nautical sectors, and fisher associations.	State public power, federal public power.
Tupinambás Ecological Station (NT)	27 permanent (33.3%) 28 alternate (39.3%)	23 (65%)	Universities, NGOs, municipal public power, state environmental agencies, federal environmental agencies, regional port agencies, tourism and nautical sectors, and fisher associations.	State public power, federal public power.
Tupiniquins Ecological Station (NT)	2*	2**	NGOs, MPA employees.	-

North Coastal Environmental Protected Areas (MU)	42 permanent (26.2%) 42 alternate (26.2%)	39 (46.1%)	Universities, NGOs, municipal public power, state public power, federal environmental agencies, regional port agencies, tourism and nautical sectors, fishers and fish farmers associations, and state-owned companies.	State public power, federal public power, state environmental agencies
Center Coastal Environmental Protected Areas (MU)	37 permanent (35.1%) 37 alternate (18.9%)	42 (40.5%)	NGOs, state public power, municipal public power, state environmental agencies, federal environmental agencies, MPA employees, fisher associations, and state-owned companies.	Universities, federal public power.
South Coastal Environmental Protected Areas (MU)	16 permanent (62.5%) 16 alternate (18.7%)	23 (52.1%)	Universities, NGOs, municipal public power, state public power, state environmental agencies, federal environmental agencies, and fisher associations.	Federal public power, state-owned companies.

* Information about the number of members in the advisory council of Tupiniquins Ecological Station was not available, the number (2) is regarding only the number of advisory council members interviewed in this MPA.

** Information about the number of institutions represented in the council of Tupiniquins Ecological Station was not available, the number (2) is regarding only the number of institutions represented by the council members interviewed in this MPA.

When considered collectively, advisory council members for both MPA types were more likely to be female, have post-graduate education and be between 35 and 44 years old (Fig. 2). However, notable differences between no-take and multiple-use MPAs were observed. For no-take MPAs, the probability of the member being male was about four times greater than the probability of being female (Fig. 2A). In contrast, multiple-use MPAs had greater gender equitability than no-take MPAs, with a higher probability of female membership than male (Fig. 2A). The advisory council of no-take MPAs was characterized by a high level of training (most with post-graduate education) and older age (>45 years old; Fig. 2B and C). Multiple-use MPAs had more diversity of training levels and a greater probability of younger members (≤44 years old) than no-take MPAs (Fig. 2B and C). Members with incomplete elementary school education were exclusively found in the advisory councils of multiple-use MPAs. We also observed that more than half of the female participants were less than 44 years old whereas most of the male participants were older than 45.

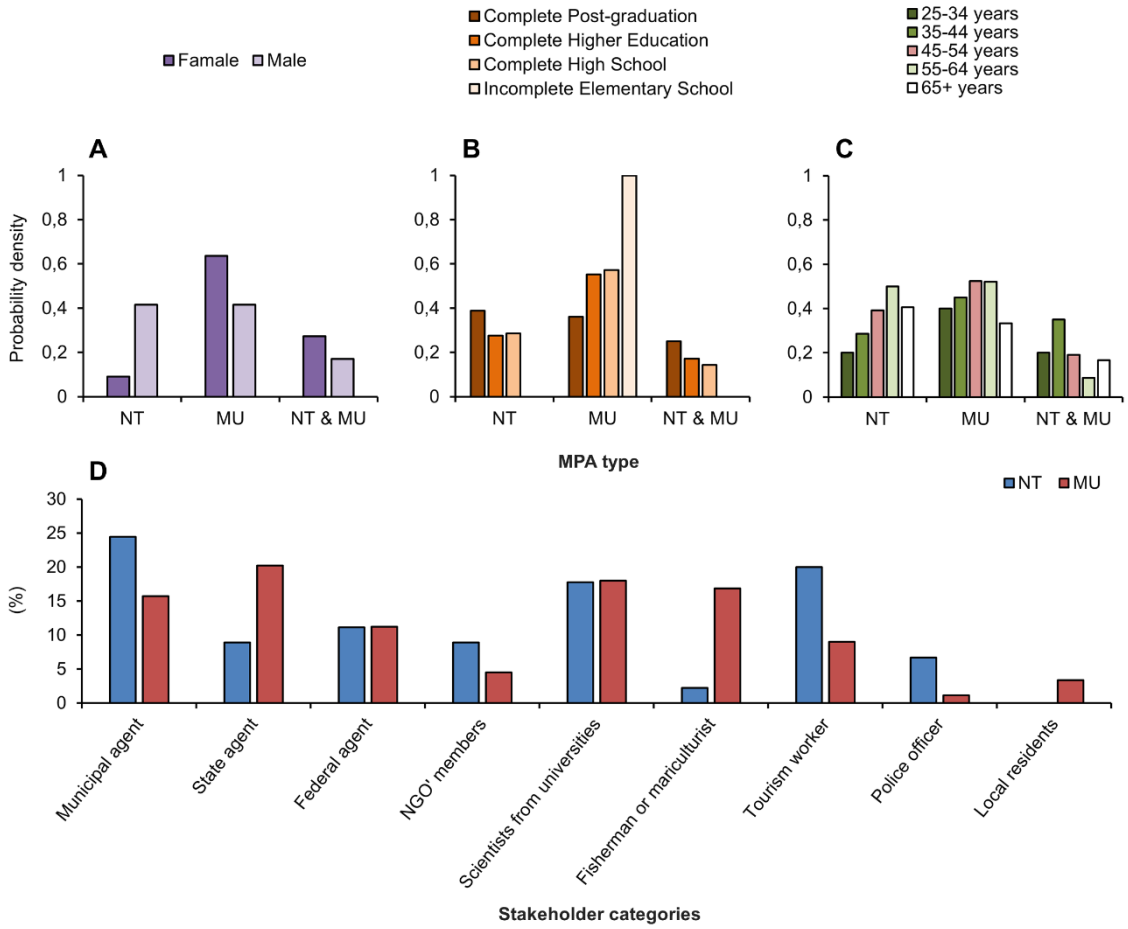

Figure 2. Stakeholder profiles in the advisory councils of the MPAs assessed in the Sao Paulo state coastal region, southeastern Brazil. The advisory councils of two MPA types were assessed: no-take MPAs (NT) and multiple-use MPAs (MU). (A) Gender proportion of the advisory council members interviewed; (B) Level of training of the advisory council members interviewed; (C) Age groups of the advisory council members interviewed; (D) Institutional categories of the permanent advisory council members.

Regarding stakeholder categories (i.e., social functions outside of the councils), we found that the advisory councils of no-take MPAs were formed mainly by municipal agents from the local city halls, university scientists and tourism workers such as diving and nautical operators (Fig. 2D). For multiple-use MPAs, the municipal agents and scientists were proportionally numerous, but tourism workers had lower proportions in comparison to the no-take MPAs. Additionally, state agents (i.e., members of state secretaries, environmental agencies, institutions, and/or foundations), fishers, and mariculturists occurred in great proportions in the advisory councils of the multiple-use

329 MPAs. NGOs members and police officers, although in low proportions, were more
330 highly represented in no-take MPAs compared to multiple-use MPAs (Fig. 2D).

331

332 *3.2. Impacts and challenges for management effectiveness*

333 The main pressures [impacts] perceived by advisory council members on the marine
334 environment were related to fishing, regardless of the MPA type (Fig. 3). The second
335 most commonly reported pressure was pollution, related to waste (i.e., rubbish/trash) and
336 sewage (or lack of sanitation). Other less-mentioned impacts were related to pollution in
337 general, oil and gas exploitation (and its transportation) and tourism activities. All these
338 impacts were considered as high severity, rated >75 (where 100 is the most severe; Fig.
339 3). The impact of sewage was perceived as the most severe (i.e., highest median) by the
340 members of no-take MPA advisory councils, with about 80% of the interviewees rating
341 this ≥75 (Fig. 3A). For multiple-use MPAs, the impacts of waste and sewage were
342 perceived as the most severe (Fig. 3B). Oil and gas impacts were considered less severe
343 by no-take MPA advisory council members (30% scored oil and gas ≤50), compared to
344 ~60% of multiple-use MPA interviewees rating oil and gas at >75 (Fig. 3).

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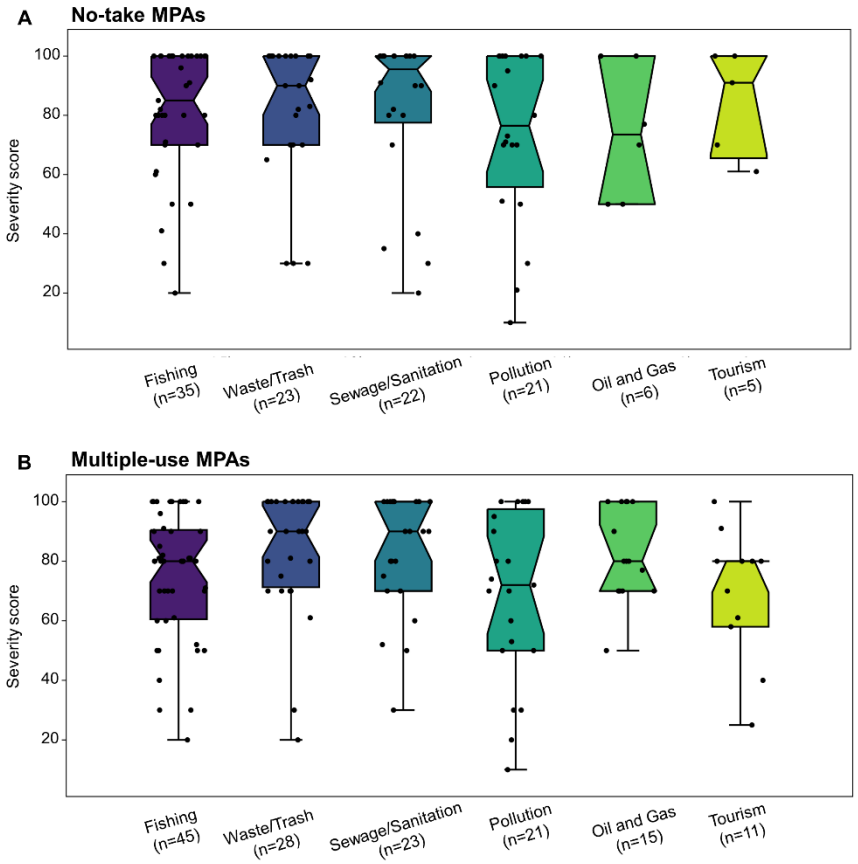

346

347 **Figure 3.** Box plots of stakeholder perceptions of the severity of the main pressures to the marine
348 environment in MPAs assessed in the Sao Paulo state coastal region, southeastern Brazil. The advisory
349 councils of different MPA types were assessed: the no-take MPAs (A) and the multiple-use MPAs (B). The
350 graphics indicate the number of mentions for each impact ("n" on the x-axis) and the impact severity score
351 (y-axis) perceived by the stakeholders in a rating interval between 0 (no impact) and 100 (highest impact).

352

353 Most participants considered the MPAs and their associated advisory councils as
354 effective tools for the management of marine areas (Fig. 4AB). However, no-take MPAs
355 and their associated advisory councils had lower levels of support compared to multiple-
356 use MPAs (Fig. 4AB). The perceived capacity for advisory councils to respond to MPA
357 challenges received a mixed response, with only ~30% of respondents giving this a rating
358 of >75 (Fig. 4C). This was amplified in no-take MPAs, with ~50% of the subjects gave a
359 rating <50 (Fig. 4C).

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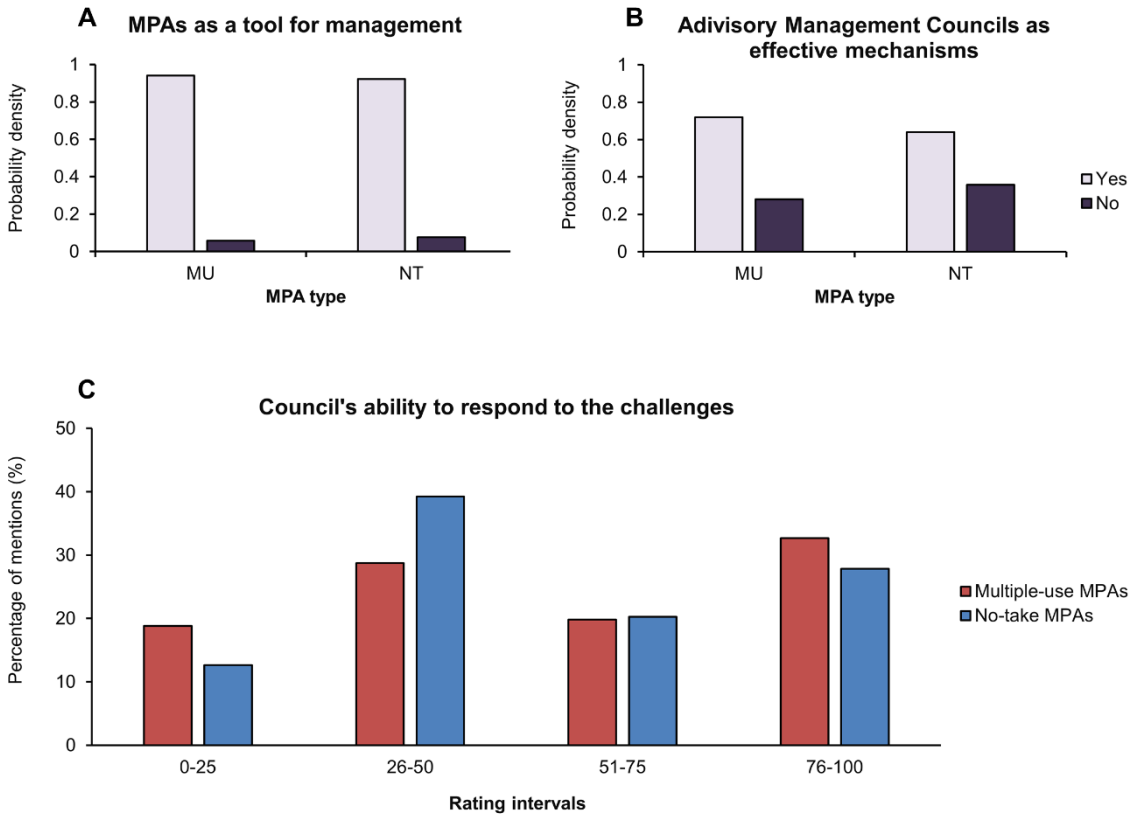

Figure 4. Stakeholder perceptions of the challenges for management effectiveness in the Marine Protected Areas (MPAs) assessed in the Sao Paulo state coastal region, southeastern Brazil. The advisory councils of different MPA types were assessed: the no-take MPAs (NT) and the multiple-use MPAs (MU). (A) Probability density calculated with the answers to the question "Do you believe in the multiple-use MPAs (or in the no-take MPAs) as a tool for the management of marine areas?"; (B) Probability density calculated with the answers to the question "Do you believe that advisory management councils are effective mechanisms for multiple-use MPAs (or for restricted-to-fisheries MPAs)?". (C) Advisory council members' perceptions regarding the capacity for advisory councils to respond to the challenges, indicating the percentage of mentions of each rating interval (between 0 and 100) for both MPA types.

3.3. Discourse content analysis

The discourse content analysis showed, in general, more numerous and bigger clusters of agreement (dark blue clusters) about no-take MPAs (Fig. 5B, D, and F) compared to multiple-use MPAs (Fig. 5A, C, and E). Why advisory councils were not effective had the biggest clusters of agreement, particularly for no-take MPAs (larger, more numerous blue clusters; Fig. 5B). On the other hand, the main challenges advisory councils faced in implementing Management Plans for multiple-use MPAs had the biggest clusters of disagreement (larger, more numerous yellow clusters; Fig. 5E). This

pattern was not found for no-take MPAs (Fig. 5F). Success factors of MPAs and the main perceived pressures also had some commonality, forming some clusters of agreement but also some clusters of disagreement (Fig. 5C, D, and G). A high diversity of opinion was presented in terms of the sharing of information among and within advisory councils, evidenced by a distance matrix with numerous small clusters of both agreement (blue) and disagreement (yellow) (Fig. 5H).

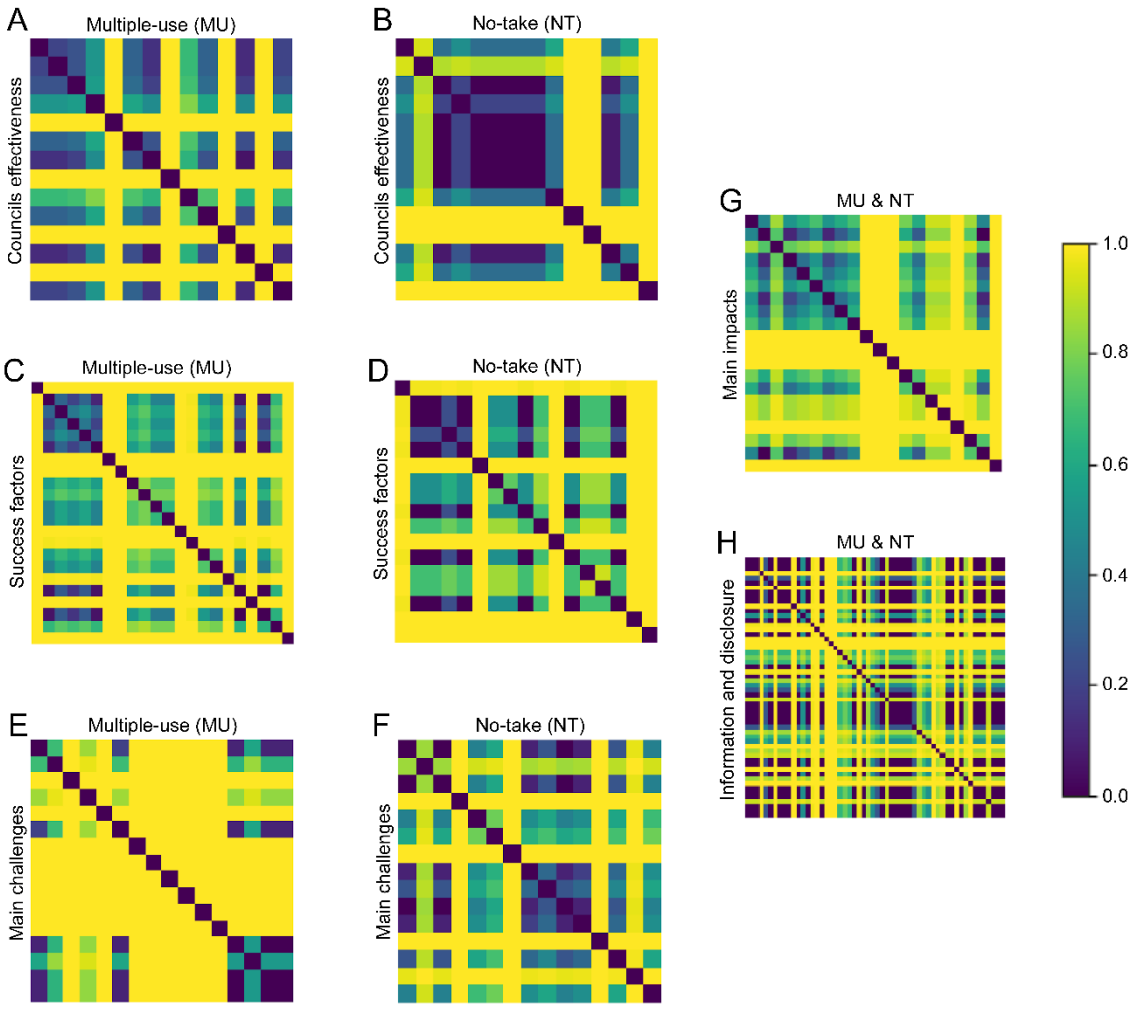

Figure 5. Distance matrices based on the p−Spectrum Kernel method used to evaluate the degree of discourse agreement regarding the challenges for the co-management of the MPAs in the Sao Paulo state coastal region, southeastern Brazil. The matrices were designed using a content analysis of the responses to the following survey questions: A and B - "Why do you believe that advisory management councils are not effective mechanisms for multiple-use MPAs / no-take MPAs?"; C and D - "What are the success factors of a multiple-use MPA / no-take MPA?"; E and F - "What are the main challenges for the council when implementing the Management Plan in multiple-use MPAs / no-take MPAs)?"; G - "What are the

main perceived negative impacts on the marine environment?"; H - "What kind of information should be shared among to the councils and between councils and managers and how could this occur?". The distance degree of the overlapped answers varies from 0 (complete similarity between answers, dark blue) to 1 (complete difference between answers, yellow).

The K-means clustering algorithm produced three clusters of opinions for most of the questions (Fig. 6). We noted that the question asking why advisory councils were not effective was the one with the most similar opinions between the clusters, especially regarding no-take MPAs – corroborating the patterns observed in the distance matrix (Fig. 5A,B, Fig. 6). Clusters of similarity were mainly represented by advisory council members that attributed the non-effectiveness of the advisory councils to a lack of inclusivity for participants and the inability of the advisory councils to enforce the outcome of their deliberations (i.e., low power of the advisory councils' deliberations). A lack of inclusivity was often mentioned by the interviewees as a factor affecting the success of multiple-use MPAs. Conversely, the factors that underpinned success of no-take MPAs were most related to scientific research and surveillance for illegal activities. The main challenges for advisory councils implementing Management Plans for multiple-use MPAs provided the largest differences of opinions between clusters (Fig. 6), again corroborating the distance matrix (Fig. 5E). A similar divergence pattern occurred regarding the means of disclosing information between and within advisory councils. Both these topics formed four K-means clusters (rather than three for the others; Fig. 6), reinforcing the high degree of diversity in interview answers. Lastly, "financial constraints" were commonly mentioned regarding the main challenges for implementing Management Plans in no-take MPAs, and "bad fishing practices" was the common thread between the three clusters of perceived pressures or impacts (Fig. 6).

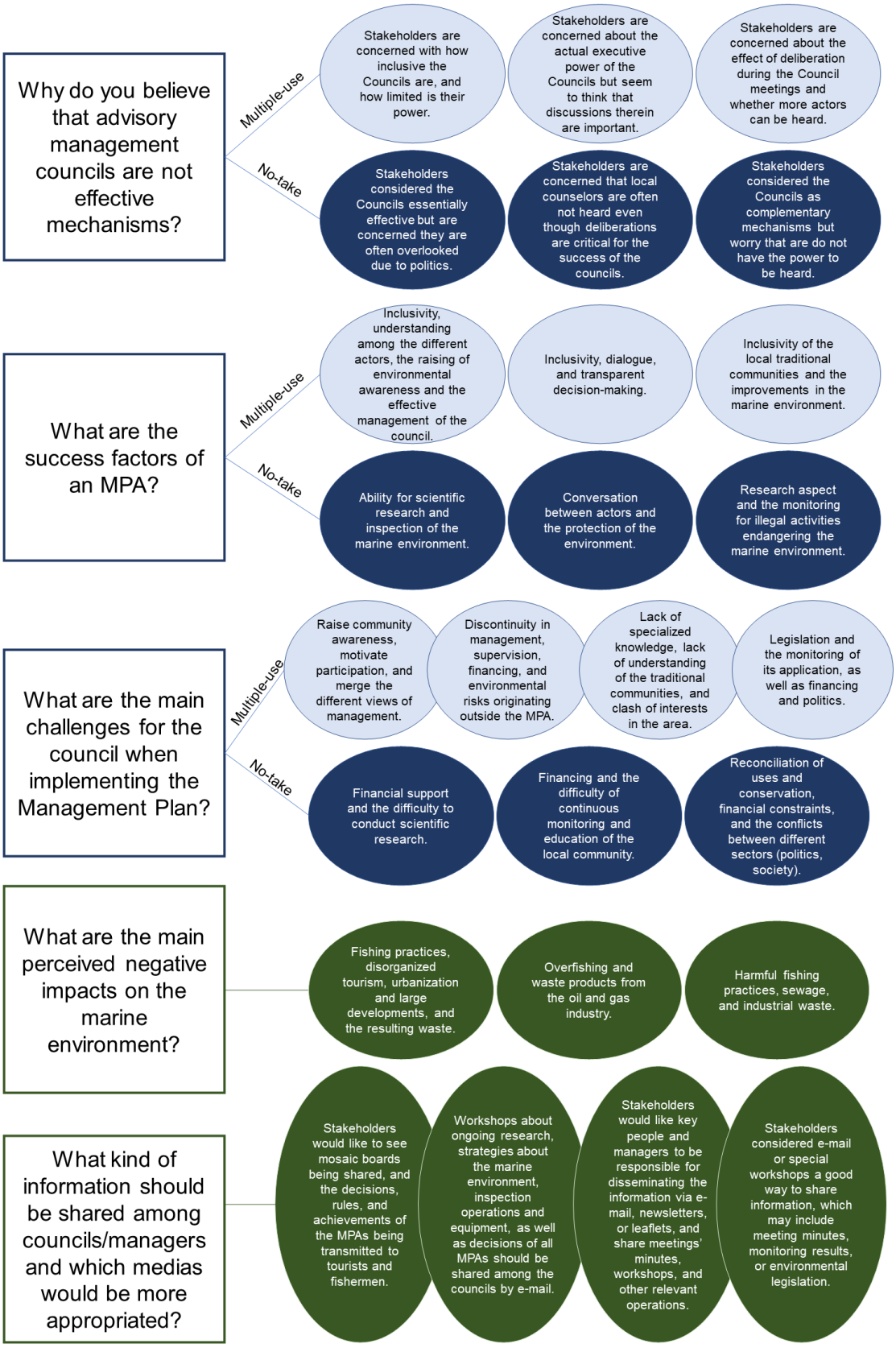

Figure 6. K-means clustering on the document-term matrix formed using the interviewee answers, illustrating the groups of opinions (circles) from the answers provided to each question. The squares are the questions, linked to the clusters formed considering multiple-use MPAs (light blue circles), no-take MPAs (dark blue circles), and all MPAs (green circles).

4. Discussion

Here, we present the first profiling of Sao Paulo MPA advisory council membership, and examine their perceptions of advisory council capacities to achieve their goals, MPA challenges and effectiveness of advisory councils as a marine management tool. Advisory council members were mostly agents of the local government, scientists of universities and local associations. However, we showed that the MPA type (no-take vs multiple-use) influenced the advisory council member profiles. Multiple-use MPAs tended to have the greatest diversity of advisors in terms of institutional affiliation, gender, training level and age group. Despite these differences, advisory council member perceptions regarding the major pressures and impacts acting on MPAs were similar for all MPAs, and fishing impacts were the most frequently perceived pressure. Advisory councils were not recognized as an effective management mechanism by a notable proportion of the advisory council members (~30%) and an advisory council's capacity to respond to challenges was perceived as lower for no-take MPAs compared to multiple-use MPAs. The perception is that since advisory councils lack complete inclusivity, their decision-making power is weakened because of lower consensus. For no-take MPAs in particular, there was general agreement that advisory councils are not achieving their sustainability goals because they lack the authority to make effective interventions and mitigate against pressures.

4.1 Varied actor inclusivity on advisory councils

The Center and North CEPAs (multiple-use) MPAs had the greatest number of members and diversity of institutions. This can be explained by their size and location - both MPAs are large and situated along the coast of the Sao Paulo Macrometropolitan Region (Figure 1, Gonçalves et al. 2020; 2021) - but both are also characterized by a high level of resistance from stakeholders in the establishment of these MPAs. The São Paulo

macrometropolitan coast is characterized by a complex multilevel system of governance formed by 60 organizations (Gonçalves et al. 2021), and the economic sector in this region is dominated port activity and associated industries. Interviews from state-owned companies were obtained only in these two Central and Northern multiple-use MPAs. Ocean governance in Brazil is highly fragmented and the economic sector is usually prioritized to the detriment of sustainability goals (Oliveira et al 2022) – a problem faced by the North and Central CEPAs. However, the institutional diversity of their advisory councils, including the presence of the economic sector, promotes the integration, dialogue, and social learning between different stakeholders, potentially reducing conflicts and management fragmentation (Xavier et al. 2018; Mills et al. 2020; Gonçalves et al. 2021). However, to achieve this a high level of organization, transparency, respect, and trust between stakeholders of diverse interests would be needed (Gleason et al. 2010). In contrast, the South CEPA presented a smaller number of members and institutions in its advisory council. Although similar in sea area to the North and Center CEPAs, the South CEPA is located outside of the macrometropolitan region within a mosaic of protected areas and faces lower levels of resistance from local communities and stakeholders (Lino and Moraes, 2005).

The presence of academics, NGOs and government agents in the MPA advisory councils is a common feature across Brazilian MPAs (Olaya-Restrepo et al. 2022). The higher representation from tourism workers in the advisory councils of no-take MPAs highlights the importance of no-take MPAs for activities such as scuba diving (e.g., Marconi et al. 2020). Conversely, fishers and mariculturists naturally increase their participation in the advisory councils of multiple-use MPAs, as fishing and aquaculture is only allowed inside the three CEPAs (Motta et al. 2021; 2022).

To avoid fragmentation of management, and considering the interdependence of marine resources present in the area, integrated management along the Sao Paulo coastline is needed across all levels and scales. Management has the potential to improve governance by promoting an interplay of the cross-level interactions among scale-dependent institutions – enhancing synergies and minimizing tensions among the institutions (Gonçalves et al., 2021). This can occur by fostering cognitive interaction between institutions with complementary and / or similar objectives (i.e., promoting inter-institutional learning and assistance) (Fidelman et al. 2013). One way of promoting interplay is the formation of alliances across scales and levels to exchange knowledge, lessons learned and information (Horigue et al., 2012).

4.2 Variation between no-take and multiple-use MPAs

Multiple-use MPAs had a generally higher diversity of advisory council member profiles in terms of gender, training level and age group, while members of no-take MPA advisory councils tended to be older males with post-graduate education. An equal representation of different stakeholder groups is vital in MPA management to avoid power, gender or knowledge imbalances (Gleason et al. 2010). Gender imbalance is a known issue in Brazil, and for MPA and ocean / fisheries management more widely (Andrade et al. 2021), generating difficulties in reaching ecological, social and innovation goals in marine systems in general (Baker-Médard 2016; Andrade et al. 2021, Burdett et al. 2022), and MPAs specifically (Kleiber et al. 2018; Pike e al. 2022). In our interviews, we noted that advisory council effectiveness and the capacity to respond to challenges was perceived as lower in no-take MPAs than in multiple-use MPAs. Female exclusion and other inequalities may be driving this perception since low actor diversity could imply a low plurality of abilities and experiences needed to deal with multiple challenges.

Interestingly, our discourse content analysis showed that more members of multiple-use MPA advisory councils noted a lack of actor inclusivity – indicating that although multiple-use MPAs had higher actor diversity on their advisory councils, there remained a perceived capacity for improvement.

4.3 Recommendations for improving MPA co-management

i) Multilevel government participation: Municipal, state, and federal public powers were present in almost all advisory councils, reflecting the multi-level governance of the Sao Paulo coastline (Gonçalves et al. 2021). The major participation of local city halls (i.e., municipal power), mainly in relation to no-take MPAs, is noteworthy. In Alcatrazes WR and Tupinambás ES, for instance, although these MPAs are under federal jurisdiction there are more municipal agents than federal agents in their advisory councils. For the multiple-use MPAs, which are under state jurisdiction, the participation of state agents was higher.

Despite the national importance of the Sao Paulo state coastal region, our results suggest that local government and local users are more engaged with MPA management dialogue than higher governance levels – somewhat evidenced by the low engagement of federal government members with our study (excepting the federal environment agency ICMBio). Considering the Brazilian legal framework, Federal Decree 4340/2002 (Article 17) highlights the importance of participation across the three levels of government in the advisory councils and suggests, when possible, an equal representation of public entities and civil society in the advisory councils. Our results suggest that the Sao Paulo state MPA network is generally aligned to these recommendations at a local level, but further analysis should be conducted to fully understand the (mis)match between advisory council profiles and the legal requirements for higher governance.

ii) Financial support: Most members across all MPA advisory councils also had personal jobs – this necessity is likely a significant barrier for inclusion of actors with less time flexibility. We therefore propose that government support is needed to incentivize stakeholder participation in the advisory councils. Such support could include, but is not limited to: direct monetary payments to compensate for lost working time, travel support, or a formalized leave of absence (without salary discount) during advisory council meetings. This could be an important step to increase advisory council inclusivity and actor diversity, and in turn improve management effectiveness. In this regard, Federal Decree 4340/2022 establishes that advisory council memberships are not remunerated. However, some advisory council members may currently receive financial support from their institutions to attend the meetings. The institutions to which this applies and the extent of support provided remains undocumented; such information is a key knowledge base that would be required if financial support were to be considered more widely. Future studies could also explore if the topics discussed within advisory councils are driven by managers (i.e. top-down) or advisory council members (bottom-up), since personal empowerment of stakeholders will likely increase engagement and enable co-production and influence (Markantonatou et al 2016).

iii) Reduce pollution inputs and increase surveillance: Advisory council members also highlighted that the MPAs are facing extreme environmental impacts as result of urbanization, which could contribute to some negative perceptions regarding advisory council effectiveness. Conserving biodiversity in MPAs around highly urbanized areas is known to be a great challenge, especially in Brazil where there is historical negligence towards environmental policy and fisheries management (Motta et al. 2021; 2022). Our study and others (e.g. Giglio et al. 2022) show that fishing and pollution are considered major threats to both the no-take and multiple-use MPAs of this study, but the picture is

much more complex – with 132 environmental conflicts recently identified (Prado et al 2022). Pollution problems are typically outside the scope of MPA management, and solutions require federal and state action beyond MPA borders. On the other hand, fishing violations inside no-take MPAs could be comparatively easily overcome by improving surveillance, but this can only be achieved with an increase in funding – two major challenges perceived by our interviewees and a known limitation for MPAs in Brazil and more widely (Gerhardinger et al., 2011; Mills et al. 2020; Olaya-Restrepo et al. 2022). Incentivizing the participation of fishers in the advisory councils might also help, particularly engagement with recreational fishers most likely to illegally use the no-take MPAs (e.g., Giglio et al. 2022, Niz et al. 2023). For multiple-use MPAs, surveillance and monitoring could be combined with spatial and time-limited restrictions such as seasonal fishing closures (Motta et al. 2022, Niz et al. 2023).

iv) Increase bottom-up influence: Advisory council effectiveness in MPA management was also questioned by some members who recognized advisory councils as having low decision-making power. This was particularly true for the no-take MPAs. Low effectiveness might be driven by the predominantly consultative role the advisory councils provide, with final decisions ultimately taken by managers in the service of the government (Gerhardinger et al. 2009; Giglio et al. 2019) – a top-down management approach applied to all no-take MPAs in Brazil (Jones 2002; Gerhardinger et al. 2009). The negative perception may be in part overcome by improving communication about the role of the advisory councils and how to most effectively use advisory council deliberations. This could be achieved by providing positive examples of how advisory councils have created sufficient bottom-up pressure to influence and change federal regulations, such as the sustainable use of gillnets (IBAMA 2007; SAP/MAPA 2021).

5. Conclusions

MPA advisory councils face a series of challenges in realizing their conservation and social goals in a highly urbanized region such as the Sao Paulo coastline, but these advisory councils have great potential to improve co-management and the sustainable use of marine resources. State-led, top-down efforts to ban or restrict human activities in multiple-use areas is known to have limited effectiveness (Bennett & Dearden 2014). Instead empowerment and engagement with local communities in MPA management has become the dominant paradigm of conservation and sustainable development agendas across the globe (e.g. Berkes 2004; Bockstael et al, 2016; Bennett & Dearden 2014). This study provides the first profiling of Sao Paulo MPA advisory councils, showing that actor diversity, inclusivity, and perceptions regarding advisory council effectiveness vary according to the MPA type, but that participatory management is essential either way (see Niz et al. 2023). These data allow us to provide the following recommendations to improve the effectiveness and sustainability of the Sao Paulo state MPA network: (1) Increase the participation of public power in the advisory councils (especially the normative sector of federal public authority) to improve dialogue, reduce conflicts surrounding top-down regulation, and increase feedback from MPAs to public legislators and regulators; (2) Improve government support to incentivize stakeholder participation in advisory councils and increase actor diversity in decision-making; a priority should be to increase women's inclusivity in the advisory councils of no-take MPAs; (3) Increase advisory council pressure on federal and state bodies to reduce sources of pollution outside MPA boundaries and increase financial support for surveillance and monitoring to promote sustainable fishing in multiple-use MPAs; (4) Improve MPA advisory council power to implement regulations, giving more weight to bottom-up decisions. Such tasks could help to improve advisory council performance and MPA effectiveness in this

challenging and conflicted scenario, and provide best-practice evidence with global applications for improving the effectiveness of large-scale MPA networks.

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