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Research Letters

Opportunities to close the gap between science and practice for Marine Protected Areas in Brazil

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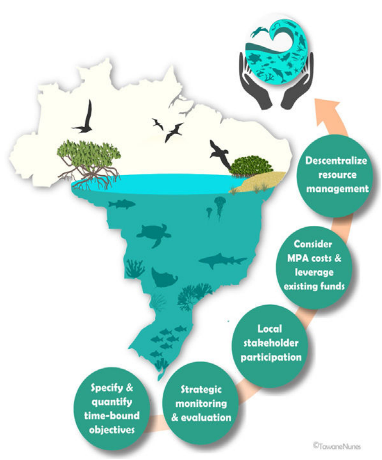
HIGHLIGHTS

- Identify specific and quantitative objectives associated to MPA goals and link these objectives to time-frames and budgets.
- Develop strategic monitoring and evaluation programs focussed on MPA performance.
- Enable local stakeholders to participate in planning processes.
- Explicitly consider MPA costs and leverage existing sources of funding.
- Decentralize resource management and empower local stakeholders to manage resources sustainably.

GRAPHICAL ABSTRACT



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ABSTRACT

Conservation science is a mission-driven discipline, yet there are few assessments on whether conservation practices follow scientific recommendations. Brazil has among the greatest gaps in species protection by marine protected areas (MPAs) globally and is thus a priority for future marine conservation efforts. In this paper, we assess the federal marine protected area (MPA) planning process in Brazil and compare it to a systematic conservation planning approach, focused on achieving conservation benefits while

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minimizing associated costs. We review the available information for all (70) federal MPAs, and the 26 associated management plans available. We found five simple opportunities for improving national MPA planning: (1) identifying specific and quantitative objectives and linking them to timeframes and budgets; (2) developing strategic monitoring and evaluation programs focused on MPA performance; (3) enabling local stakeholders to participate in planning processes, (4) explicitly considering MPA costs and leveraging existing sources of funding, and (5) decentralizing resource management and empowering local stakeholders to manage resources sustainably. Many reviewed MPA planning efforts fall short in providing clear management guidance and our recommendations can foster a stronger platform for the conservation and sustainable use of marine resources in Brazil.

Background

Marine biodiversity and associated ecosystem services are declining due to overfishing, habitat destruction, pollution and climate change (Sala and Knowlton, 2006; Pinheiro et al., 2019). Marine Protected Areas (MPAs) are among the main strategies that can mitigate the rapid loss of marine biodiversity and ecosystem services (Edgar et al., 2014; Roberts et al., 2005). While scientists recognize the benefits of MPAs (e.g. biomass increases, spillover, and larval export), only a very small percentage of the ocean is protected by MPAs (Wood et al., 2008). In fact, MPAs currently represent less than 10% of the range of 97% of marine species (Klein et al., 2015), and most fail to achieve conservation outcomes due to limitations in design, management and compliance (Edgar et al., 2014). Recently, the extent of MPA coverage in Brazil increased sharply, from 1.5% to 24.5% of the country's marine jurisdiction, with the creation of four very large MPAs in 2018 (Fig. 1; Magris and Pressey, 2018). However, Brazil still has one of the world's greatest gaps in species protection by MPAs (Klein et al., 2015; Giglio et al., 2018; Magris and Pressey, 2018). Brazilian MPAs unevenly represent the country's coastal and marine habitats and ecosystems (Magris et al., 2013; Schiavetti et al., 2013; Giglio et al., 2018) and most lack adequate management and enforcement (Gerhardinger et al., 2011; Moura et al., 2013).

To ensure MPAs achieve conservation outcomes, researchers have developed and intensively refined MPA planning principles and guidelines (e.g. Fernandes et al., 2005; Green et al., 2015; Pressey and Bottrill, 2009). Despite persistent knowledge gaps, especially in the socioeconomic and cultural dimensions of MPA design and management (Ban et al., 2019), the existing guidelines comprehensively account for MPA size adequacy, spacing, location, and recognize the central role of stakeholder engagement in planning. However, the extent to which increasing scientific knowledge has guided MPA development is contested (e.g. Knight et al., 2008; Sinclair et al., 2018). There are only a few accounts of planning processes that range from their conception to implementation (e.g. Álvarez-Romero et al., 2018), and assessments of whether scientific knowledge has been incorporated into planning is generally based on peer reviewed literature or surveys mostly focused on academics (Knight et al., 2008; Sinclair et al., 2018).

Here we review and synthesize past planning experiences in Brazil and elicit the key ingredients for improving MPA planning and management. To do this, we collated the available information for all the 70 MPA undertaken in Brazil under federal jurisdiction and compared their processes to a systematic conservation planning process, considered best practice (Groves and Game, 2016; Pressey and Bottrill, 2009). There are 12 categories of protected areas in the national system (SNUC, Brazilian federal law number 9.985/2000), varying based on primary objectives (e.g. sustainable use or strict conservation) and governance structure or management regimes. Categories are assembled into two groups: "full protection" (i.e. no-take), in which only particular non-extractive activities are allowed (e.g. National Parks, Biological Reserves); and "sustainable use," in which some extractive activities are allowed and regulated, as long as they do not compromise conservation and cultural objectives. The latter includes MPAs proposed to guarantee local needs while conserving biodiversity (e.g. Extractive Reserves).

We gathered information about the management plans from within the national agency for biodiversity conservation website (Supplementary Table 1 for list of MPAs; ICMBio, 2015). If a management plan was not available, we gathered the available information from the automatic online reports published by the Ministry of Environment (MMA) on the same website (ICMBio, 2015). These data included basic information such as the MPA name, the status of the management plan, area, establishment date, management plan characteristics (e.g. goals, objectives) and governance, actions to be implemented and associated costs (see Supplementary Table 2 for full complete list). The data gathered for each of the MPAs was informed by the systematic conservation planning database (Álvarez-Romero et al., 2018).

All managers from the MPAs with management plans ($n = 26$, 40% of federal MPAs) were contacted to ensure we had the most recent documents. The statements defining MPA goals were classified into ecological (biodiversity richness, biodiversity representation, biodiversity persistence, ecological restoration, ecosystem services), governance (management, monitoring, enforcement, local participation, institutional alignment) and social (sustainable development, wellbeing, development of common vision, historical and cultural, education and outreach, science) goals. Management plans did not detail MPA designation, e.g. such as what stakeholders triggered the MPA establishment, so we do not consider MPA designation in this study.

We highlight five opportunities to improve planning for all MPAs in Brazil based on our review and our collective experience in MPA planning and management in Brazil and overseas. We discuss each opportunity within the sections below, where we review our main findings and identify best practices from around the world from which future plans can draw lessons. We propose that these opportunities will facilitate the evolution of the desired environment and social outcomes for Brazilian MPAs.

Opportunity 1: Specify and quantify objectives, and link them to timeframes and budgets

We examined the objectives stated within 26 management plans (all the management plans available) to understand their variety, frequency, and characteristics, and we identified 16 types of objectives within the plans (Fig. 2). Objectives were all qualitative and related to either ecological, social and governance dimensions (Fig. 2). Objectives suffered from issues of clarity and specificity, hindering their translation into action. Ecological objectives focused on biodiversity representation and persistence, ecological restoration, ecosystem services and biodiversity richness. Social objectives focused on furthering sustainable development, wellbeing, establishing the area as a symbolic environmental reference point (common vision), protection of historical and cultural sites,

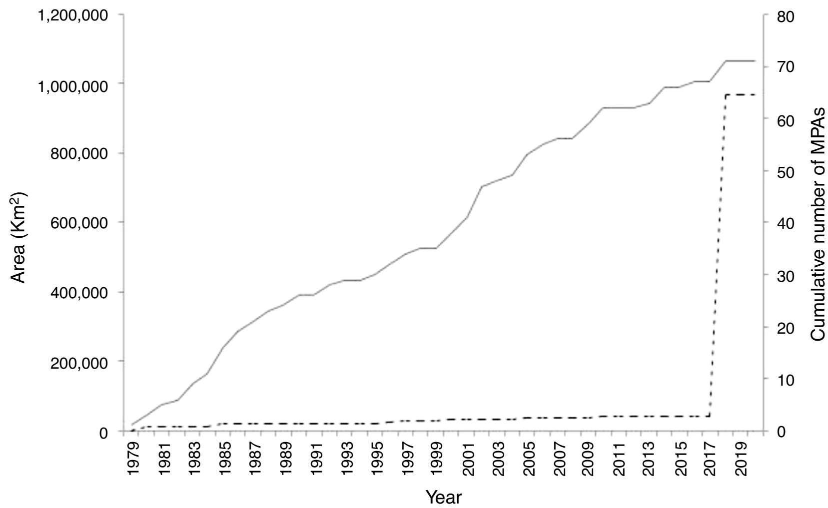

Fig. 1. The history of the legal establishment of MPAs in area (dashed line) and numbers (dark gray line) in Brazil from 1979 to 2020. While the number of MPAs has steadily increased over time, the increase in area of MPAs had been somewhat modest until 2018 with the declaration of four large offshore MPAs.

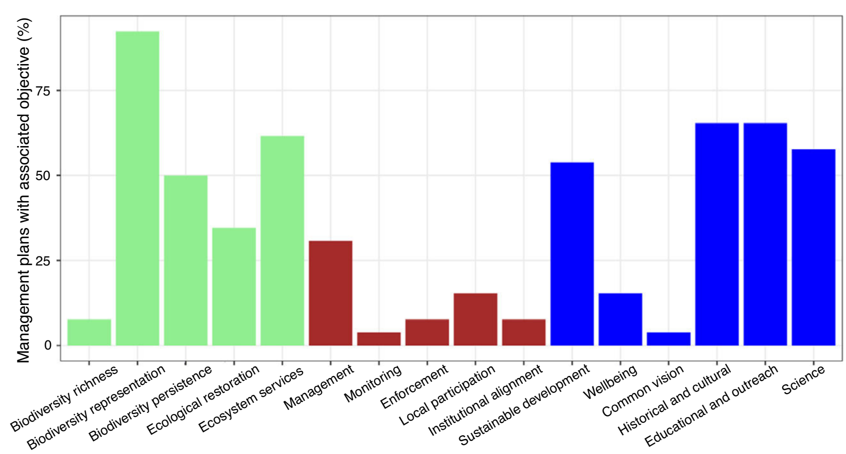

Fig. 2. Classification of ecological (orange), governance (red), and social (blue) objectives for the 26 Brazilian MPAs that had this information available. Graphs indicated the percentage management plans that had an objective within each category.

education and outreach, and scientific research. Governance objectives focused on management, monitoring, enforcement, local participation and institutional alignment by better integrating the MPA with regional governance.

Most plans presented a commendable balance of social and ecological objectives ($n = 25$) but they all lacked a quantitative formulation and a link to specific timeframes. Quantitative objectives are refinements of the high-level goals, and allow the integration of scientific insights within the MPA design; they inform assessments of progress toward desired impacts and outcomes (Game et al., 2013). Overarching objectives such as "to promote the maintenance of genetic variability" are operational with well-defined reference points; for example, "identifying the top x% of sites ranked by their expected contribution to population persistence and gene flow" (Magris et al., 2014).

Social objectives can also be better specified, especially when accounting for measurable increases in physical, social and material wellbeing (e.g. health, self-respect, and food security respectively) or inequality (e.g. changes in social mobility, Hicks et al., 2016). Stakeholders and managers can assess the outcomes of using these objectives and iteratively refine them. Plans should link objectives to realistic timeframes, budgets, and the agencies responsible for their implementation to facilitate transitioning from objectives to actions (ICSU, 2015).

Opportunity 2: Develop strategic monitoring and evaluation programs focused on MPA performance

We reviewed all the information on monitoring within the federal MPA plans and found that none of the existing management plans available for the federal MPAs has explicitly linked their monitoring programs to their stated objectives. Thus, we could not find any information on how the proposed (or ongoing) monitoring would answer questions around management effectiveness. Additionally, while the scientific literature stresses the importance of adaptive management, where a structured approach is taken to decision making based on learned lessons (Holling, 1978; Walters and Hilborn, 1978), plans were not regularly revised or updated. We found that only two federal MPA management plans had ever been updated in Brazil, and only one additional manager indicated that a revision was scheduled. Although learning will continuously happen through the exchange of information within management councils, the lack of strategic monitoring and evaluation of management plans currently hinders this learning and improvements of national MPA planning.

Monitoring, evaluation, and adaptation ensure that marine management is continuously assessed, improving future planning and decision-making (Douvere and Ehler, 2011). To meet those needs, MPA managers are required to continually collect evidence to determine whether management actions lead to the desired outcomes. The systematic quantification of the MPAs impacts in Brazil has been recently established by a participatory monitoring program called Programa Monitora (Ribeiro, 2018). At the outset, the appropriate rigor of design protocols for such assessments of the MPA performance are lacking because they do not identify the state of ecological health in a 'control' area. A rigorous evaluation involves comparing the changes in social, economic or ecological characteristics attributable to MPAs against changes in comparable areas without MPAs (Basurto et al., 2016). More sophisticated evaluations require baseline data and often involve a "theory of change" which describes the sequence of outcomes expected to occur from interventions (Mascia et al., 2017). Ideally, MPAs would be implemented as policy experiments, with explicit adaptive and collaborative governance approaches in the framing of management plans, which include monitoring and assessment of management interventions as key components (Fox et al., 2012). Learning and adaptive management will require systems, a secure work environment, staff autonomy and capacity building, and are critical given MPAs are part of a dynamic social-ecological system.

Opportunity 3: Enable local stakeholders to participate in planning processes

Our review of the federal MPA plans found that of the 70 Brazilian MPAs, 25 have deliberative management councils, comprising the federal authority (*Instituto Chico Mendes da Conservação de Biodiversidade*) and societal constituents with a statutory focus on local traditional people (e.g., Extractive Reserves). The remaining 45 have consultative management councils, where decisions are led by government. Involving stakeholders in the planning processes and creating opportunities for dialog is critical in the implementation of MPA plans (e.g. Gleason et al., 2010), and a deliberative decision-making structure is likely to provide a better platform for legitimate decisions. However, this structure does not guarantee full participation or perceived legitimacy of the MPA (Gerhardinger et al., 2009). The frequency and size of meetings, differences in interest groups, access to and context of the process, discontinuity and delays in processes and decision-making, and the degree of influence of different stakeholders in decisions affect the perceived legitimacy of rule-making (Dalton, 2006). Decisions of the management councils can be overruled: the lobby of influential sectors often overturns management council decisions for sustainable use MPAs in controversial environmental licensing processes (Macedo et al., 2013). Typically, sustaining long-term collaboration is challenging in Brazil, where a lack of institutional and resource provision stability; combined with little political culture of social participation in the development of MPAs hinders public environmental stewardship (e.g. Trimble et al., 2014).

Past research has shown that greater levels of participation are paramount for Brazilian MPA planning processes (Gerhardinger et al., 2009). Stakeholder participation in the design and implementation of MPAs can provide multiple benefits. The integration of resource users and their knowledge into MPA planning fosters compromise, responsibility, and empowerment (Berkes, 2004; Gerhardinger et al., 2009). Stakeholder participation facilitates congruence between the distribution of benefits and costs of MPAs and local conditions, as those impacted by decisions can express and resolve their concerns. Additionally, collective-choice arrangements can increase perceived legitimacy of rules and subsequently their compliance (Moura et al., 2009; Ostrom, 1990).

Among the challenges of engaging participation are the large numbers of stakeholders, especially when developing large MPAs. Other countries have already faced these same issues, which have been solved through different avenues, including hundreds of meetings and public presentations, ongoing informal public engagement, online tools that allow stakeholders to provide information and feedback on the plan (e.g. http://www.seasketch.org/) and the distribution of brochures and booklets (e.g. Thompson et al., 2004). Brazilian MPAs with long-standing councils can also provide valuable insights by sharing lessons they have already learned (Almeida et al., 2009; Nobre et al., 2017). For example, the management council associated with the Prainha do Canto Verde Extractive Reserve emphasizes the importance to the implementation of measures to protect against land grabbing when defining management rules as many communities only hold informal land rights (Prado, in review).

Opportunity 4: Explicitly consider MPA costs, especially opportunity and management costs, and leverage existing sources of funding

Cost information was available for 10 of the 70 federal MPAs examined, and the detail provided varied widely. Instead of representing current expenditures, costs included only the resources predicted for implementation. We classified these costs into opportunity, acquisition, transaction, damage, and management based on Naidoo et al. (2006). We further divided management costs into fixed and variable (see Table 1). All other costs related to "public communication" and "alternative livelihood programs". We standardized data based on the budget period (five years) and converted the currency into US dollars at 2020 exchange rates (1 R$:0.22 U$) after applying the average inflation rate from the time of the plan publication to 2020 (Supplementary Table 3). Across Brazilian Federal MPAs, the most consistently significant costs involved infrastructure, human resources and enforcement (Fig. 3). Acquisition cost was only estimated for three MPAs and was the highest cost for one of them. A lack of consideration of acquisition costs can reflect systematic avoidance of the acquisition of land associated with a MPA (e.g. to protect coastal vegetation) and, if so, costs of all MPAs are sub-estimated. The average total costs we calculated is consistent with previous estimates that the creation and consolidation of a Brazilian federal protected area costs from R$ 2.24 M (U$1.44 M) with no visitation to R$ 6.67 M with visitation (U$3.11 M; Muanis et al., 2009). Muanis et al.'s (2009) cost estimates are based on an analysis of the expenses of 51 federal protected areas in the Operative Annual Plan of the Amazon Protected Areas Program (Programa Áreas Protegidas da Amazônia – ARPA) between 2005 and 2008.

Management plans did not include all MPA costs; opportunity costs, damage costs and the cost of planning were missing from all MPA plans. Opportunity costs associated with fishery and other marine uses are among the most critical for MPA planning (Ban and Klein, 2009). In Brazil, opportunity costs within the management plan will have different degrees of relevance based on the type of MPA. Sustainable use MPAs, with multiple zones, should consider opportunity costs both before MPA designation and during management plan development as they should provide for biodiversity conservation and the sustainability of fisheries (Brazilian federal law number 5.758/06: National Strategic Plan for Protected Areas). We could not estimate opportunity costs of MPA plans, because they were not found within the Brazilian MPA documents we reviewed, signaling they also did not contribute to planning. In this sense, the spatial allocation of management would be a result of the preferences by those involved in the process. Consideration of damage costs was absent in Brazil and is also rare elsewhere (Ban and Klein, 2009). The costs of developing management plans were not available in the plans reviewed, but Muanis et al. (2009) estimate to be approximately R$ 537,000 (U$250,000) for a federal conservation unit. Estimated budgets for the review of the management plans were also not available.

Table 1
Classification of costs related to MPA management. Costs in italics are not found within the Brazilian management plans examined herein.

Acquisition	"Acquisition costs are costs of acquiring a property right to a parcel of land." (Naidoo et al., 2006). They can be total or partial (e.g. short term use rights).	
Transaction	"Transaction costs are those associated with negotiating an economic exchange" (e.g. terms of reciprocity, partnership, contract) (Naidoo et al., 2006).	
Damage	*"Damage costs are those associated with damages to economic activities arising from conservation programs." (Naidoo et al., 2006).*	
Opportunity	"*Opportunity costs are costs of foregone opportunities; that is, they are a measure of what could have been gained* via *the next-best use of a resource had it not been put to the current use.*" *(Naidoo et al., 2006).*	
Public communication	Communication with the general public, e.g. environmental education, public awareness campaigns.	
Alternative livelihoods	Development of economic activities that involve the communities within or surrounding the MPA.	
Management fixed	Infrastructure	The infrastructure required for management (e.g. building, equipment), signalization, internal communication system, database development, licensing for existing operations, sanitation.
	Human	Salaries and capacity building for MPA managers.
Management variable	Internal communication	Communication needs for MPA management and partnership development.
	Enforcement	Resources required for monitoring and enforcement of rules and regulations.
	Monitoring	Actions directed at monitoring biodiversity and environmental health.
	Research	Actions related to gaining biodiversity and environmental knowledge (e.g. research projects, biodiversity inventories).
	Other implementation	Unspecified costs related to the implementation of projects that support management (general community support, unexpected activities).
	Restoration	Actions focused on the recovery of environmental health and removal of invasive species.

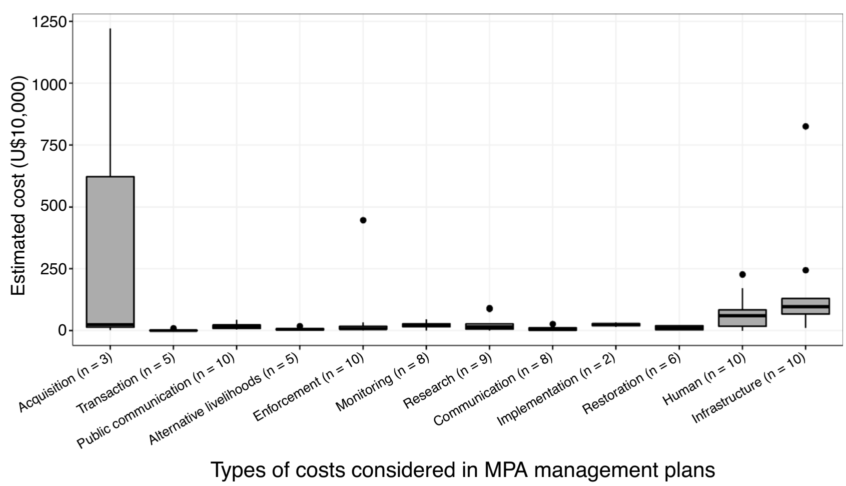

Fig. 3. Costs of MPA implementation in Brazil – not standardized by MPA area. Details are provided in Table 1. The error bars display the variance in the different types of MPA costs for the different MPAs over a 5-yr period ($n = 10$). Only costs that could be classified are included. We consider infrastructure and human costs to be fixed management costs and internal communications, enforcement, monitoring, research, restoration and other implementation costs to be variable management costs.

Understanding the costs of MPAs is critical to planning and management. Besides providing transparency and accountability for the expenditure of public and private funds, a diligent consideration of costs allows planners and stakeholders to understand and minimize impacts (Ando et al., 1998). However, the exact costs of MPAs are rarely available (Balmford et al., 2004), thus the detail provided within some of the management plans are a rich source of information.

Financial difficulty in supporting MPAs is a global issue, and in Brazil, it is particularly acute (Gerhardinger et al., 2011). Therefore, management plans should seek economic sustainability of the MPA whenever possible. For example, supplementing public budgets with alternative financing strategies (i.e. tourism fees or private foundations) could reduce the dependence of federal budget and fund maintenance, monitoring and surveillance programs, enhancing management effectiveness (Araújo and Bernard, 2016). Alternative sources of funding and partnerships are critical for MPAs implementation (Maretti et al., 2019). Integrating existing plans with parallel processes may also provide some ability to reduce costs. Since 2014, the Brazilian Marine Protected Areas Project (called 'GEF Mar') has significantly increased capacity for MPA management, however, the lack of clarity of the priority actions within each management plans and the fact that most plans are outdated has impaired the translation of these resources to real conservation outcomes on ground.

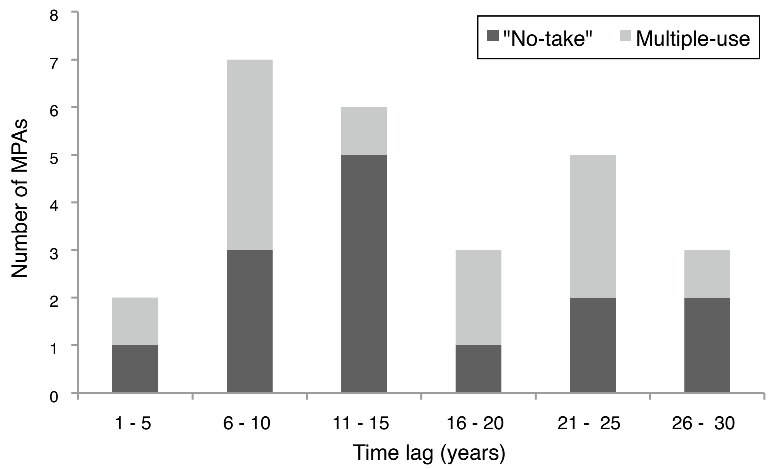

Fig. 4. Time lag between MPA designation and management plan publication ($n = 26$).

Opportunity 5: Decentralize resource management and empower local stakeholders to manage resources sustainably

Out of the 70 existing federal MPAs, 44 have no management plan. For those that do, we calculated the timelag between MPA designation and the development of the management plan, the first phase of MPA implementation (Muanis et al., 2009), and found it spanning up to 30 years (Fig. 4). A protracted application of conservation actions, where incremental actions follow the designation of protected areas, is common globally; likely reflecting limited budgets and the need to consult with the impacted stakeholders (Pressey et al., 2013). The long time lag between implementation (under active management) and the detection of biological benefits (Babcock et al., 2010) and protracted implementation means benefits are likely to take even longer to develop. Initial detection of impacts of target species can take approximately five years, while total recovery from fishing takes in average 35 years (Babcock et al., 2010; MacNeil et al., 2015). Thus, for stakeholders to benefit from MPAs, delays in implementation after declaration should be minimal. Additionally, as MPAs generally involve reorganizing the resource use and access rights, delays in the development of a management plan can result in periods of no resource governance (given previous local rules have been curtailed); negatively impacting resource condition and discrediting future management. According to the Brazilian legislation (Law 9985/2000, Art. 27, § 3), a management plan should be elaborated within five years from the MPA designation.

In recognition of the limited capacity and resources to enforce marine management, some countries have decentralized management to local communities (e.g. Chile and Fiji). Community authorities and fishers organizations can develop and enforce management, closely aligning management with local objectives (e.g. Gelcich et al., 2010). A few initiatives in Brazil are moving toward this direction and can be built on within the context of MPAs. For example, marine extractive reserves represent progress in the implementation of community-led management within traditional fishing areas (Diegues, 2008). Additionally, there has been some progress in defining Fishing Agreements ("Acordos de Pesca") – areas with specific fishing rules defined by the local community (Seixas and Kalikoski, 2009). The movement for the regularization of traditional and artisanal fishing territories is endorsed by thousands of fishers and grassroots organizations, but has not yet ranked high among the governmental agendas. Finally, management councils may delineate decisions in an Action Plan that can rule until a complete MPAs management plan is ready, thus providing an opportunity for decreasing further delay associated to improving resource management. The decentralization of resource management in Brazil can increase progress toward the sustainable use of marine resources, and may be critical given the largely unstable institutional and political state of affairs (Pinheiro et al., 2015).

A path forward

Drawing science and practice together is needed around the world, and depends on the careful identification of real flaws in practice and simple tools that can aid decision makers. There is a global recognition that Brazil is lagging in its marine conservation commitments and at the expense of rapidly eroding its biodiversity (De Freitas et al., 2015; Pinheiro et al., 2015). While the government, coastal communities and environmental NGOs are slowly progressing marine conservation agendas through programs like Projeto Monitora and GEF Mar. There is much room for improvement in MPA planning and management, and the opportunities detailed above comprise relevant and feasible starting points. For example, an updated plan which has prioritized actions based on the set objectives (Opportunity 1) will be able to take full advantage of financial opportunities such as GEF Mar (Opportunity 4). The lack of such plans risks the misallocation of funding. Understanding the history of MPAs within a particular country is critical to advance practice, as initiatives that are compatible with current practice while adressing pressing needs are more likely to be adopted (Mascia and Mills, 2018).

More effective exchanges between scientists and practitioners rely on efforts on all parts. Scientists have provided multiple tools (e.g. detailing planning process, prioritization software, software to help the development of theories of change) that can inform MPA planning with increased chances of delivering desired outcomes. However, most of these tools are not applied or available in the studied MPAs, as they are costly, unknown or unusable (e.g. due to language barriers) to most consultants and government staff engaged in these planning processes. We encourage scientists to provide free access and training to increase their usability. Academics are found within many MPA management councils in Brazil and can build on scientific evidence and knowledge when designing MPAs and developing management plans.

We further encourage policy makers to incorporate best practices in legislation and MPA guidelines and collaborate toward establishing a national ecologically functional network of MPAs. Management plans should be functional and succinct, guiding implementation, monitoring, use, surveillance, and adaptation. Advancements with MPA management must complement efforts around broader marine spatial planning and the achievement of agreed international targets (e.g. Sustainable Development Goals and Post-2020 conservation targets). A national marine spatial planning agenda has recently emerged in Brazil (Gerhardinger et al., 2019), and can potentially bring opportunities to expand marine conservation beyond MPAs policies through creative design of complementary policies (e.g. 'other effective area-based conservation measures', Laffoley et al., 2017). For instance, fishing agreements have been common in the lower Amazon, where community rules legalized and enforced by the government are set to manage floodplain lake fisheries (Almeida et al., 2009); and catch and commerce of some marine over-exploited species by traditional communities is now officially allowed in managed areas under specific rules, while banned elsewhere in Brazil (DOU, PORTARIA INTERMINISTERIAL No 59-B, DE 9 DE NOVEMBRO DE 2018)]. Our work contributed to a synthesis of existing conservation efforts to aid a clear, transparent and thoughtful incorporation of all MPAs in the broader agenda of coastal management and sustainable development.

Finally, as society shares the mid- and long-term impacts of MPA zoning unevenly, we challenge fishers, scientists, NGOs and coastal industries to work together and to take formal positions on how each sector will consider and minimize the impacts of development and management on people and nature. Such collaborations are essential to protect Brazil's valuable marine resources.

Before designing additional MPAs, planning around the world would benefit from a careful assessment of the status of past planning exercises and outcomes of existing efforts. Tools and frameworks to guide these syntheses are now available (Álvarez-Romero et al., 2018) and the importance of learning to minimize failure is recognized (Catalano et al., 2019). It is essential that we reflect on and learn from past experiences if we are to mitigate global marine biodiversity decline.

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MM conceived research; MM, RM, MMPBF, RB and DFH designed research; MM, RM, MCSL and IKGK collected data; MM, RM, MMPBF, RB, DFH, MCSL, IKGK, LCG, RLM, CD, JBT, HP, GV, RRF analyzed data and wrote manuscript.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.pecon.2020.05.002.

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