Ocean and Coastal Management 261 (2025) 107509

Contents lists available at ScienceDirect

Ocean and Coastal Management

journal homepage: www.elsevier.com/locate/ocecoaman

Beyond area-based targets: Emerging trends in coastal and marine protection in Brazil

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ARTICLE INFO

Keywords:
Marine protected area
Southwestern atlantic
Conservation targets
Marine ecoregions

ABSTRACT

Marine environments face escalating anthropogenic pressures, affecting over 50% of global oceans and posing significant threats to species and ecosystems. Marine Protected Areas (MPAs) have emerged as a key strategy to mitigate these impacts, legally safeguarding areas from harmful human activities. However, the focus on quantitative area-based conservation targets may overlook essential qualitative aspects for MPA effectiveness. We investigated trends in the Brazilian MPA network between 2002 and 2022, focusing on the implementation of formal management tools (management plan and management council), levels of protection, and ecosystem representation. Data from open databases were compiled to assess trends using established indicators. Our findings reveal that most Brazilian MPAs created during this period are partially protected (53%), primarily located in coastal areas (95%), and relatively small (0–100 km^2) (31%). Additionally, more than 50% of MPAs in Brazil lack both a management plan and a management council. While expanding MPA spatial coverage may suggest increased marine regulation, it does not necessarily translate into effective biodiversity conservation. Thus, there is an urgent need to move beyond area-based targets to enhance conservation outcomes. Upgrading partially protected MPAs to more restrictive levels, such as no-take zones, and developing and implementing management plans effectively, will contribute to achieving conservation goals.

1. Introduction

Human impacts on marine and coastal environments have been increasing, with most of the ocean facing some form of anthropic influence. Marine species and ecosystems have been subject to enhanced threats due to complex stressor combinations (e.g., Halpern et al., 2019), including overfishing, habitat degradation, and pollution, which may lead to local extinctions, trophic cascade effects, and significant alterations in ecosystems (McCauley et al., 2015). Therefore, managing human activities to maintain ecological processes, protecting biodiversity and habitats, and maintaining ecosystem services are essential (Díaz et al., 2018).

A widely adopted strategy for preserving marine and coastal ecosystems involves the establishment of Marine Protected Areas (MPAs), where human activities are regulated to conserve biodiversity. MPAs, when well-managed, enforced and legally protected with restrictions on human activities (IUCN, 2018), offer spatial safeguards to different ecosystems and play a crucial role in hampering biodiversity decline and facilitating the restoration of natural resources, such as fish stocks (Edgar et al., 2014; Davidson and Dulvy, 2017). MPAs designed primarily for biodiversity conservation, such as no-take areas, offer greater benefits to biodiversity compared to partially protected areas (Edgar et al., 2014; Costello and Ballantine, 2015; O'Leary et al., 2016). When well implemented, MPAs may also generate economic and societal advantages (Kenchington et al., 2003; Roberts et al., 2017; Ward and Hegerl, 2003), although most evidence of MPA benefits is related to ecological aspects. International agreements, such as the Convention on Biological Diversity (CBD), have aimed to enhance ocean conservation by establishing networks of MPAs. The CBD's Strategic Plan (2011–2020) for Biodiversity, adopted in 2010, included the "Aichi Biodiversity Targets", comprising 20 targets to be met by 2020. Among these, Aichi Target 11 emphasized achieving 10% conservation of coastal and marine areas, integrated into wider landscapes and seascapes (CBD, 2010).

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https://doi.org/10.1016/j.ocecoaman.2024.107509
Received 30 July 2024; Received in revised form 30 October 2024; Accepted 29 November 2024
Available online 8 December 2024

Despite global attention on MPA coverage, qualitative aspects such as ecological representativeness and connectivity have been largely neglected, likely because area-based targets are more straightforward to quantify and understand (Wood, 2011). However, focusing solely on these goals can distort perceptions of protected areas' effectiveness (Coad et al., 2019; Zupan et al., 2018) and does not necessarily ensure that MPAs achieve their conservation objectives (Edgar et al., 2014). The Post-2020 Global Biodiversity Strategy, a new set of goals adopted by governments, includes a call to protect at least 30% of marine and coastal areas by 2030 (hereafter referred to as the 30 × 30 goal), further emphasizing the importance of expanding MPA coverage. The establishment of very large and remote MPAs, known as Large-Scale Marine Protected Areas (LSMPAs), was a strategy used by some signatory countries to reach conservation goals in the last decade (Leenhardt et al., 2013). The 30 × 30 goal is challenging mainly because this effort must go beyond numbers and strive for quality. Therefore, to meet the proposed conservation targets effectively it is necessary to consider key attributes of MPAs such as their level of protection and connectivity (Halpern, 2003; Edgar et al., 2014; Gill et al., 2017; Giglio et al., 2018).

Currently, approximately eight percent of global marine waters worldwide are under some form of protection (UNEP-WCMC and IUCN, 2024). Brazil has around 8,000 km of coastline, the longest in the South Atlantic Ocean, including eight marine ecoregions (Spalding et al., 2007), and a diversity of ecosystems. With a vast Exclusive Economic Zone (EEZ) covering 3.6 million km^2, the Brazilian coast sustains over 250 coastal cities and numerous fishing communities. Since 2018, Brazil's MPA network has covered more than 25% of its EEZ, however, it faces structural challenges, including insufficient spatial representation of ecosystems and taxa (Vilar and Joyeux, 2021), lack of management plans (Vilar et al., 2020), and inadequate resources for surveillance and enforcement (Gehardinger et al., 2011; Oliveira Júnior et al., 2016). The establishment of protected areas in Brazil's coastal regions began in 1961 with the creation of the Monte Pascoal National Park (classified as IUCN Category II – National Park) (Brasil, 1961). Eighteen years later, the country created its first MPA at the Rocas Atoll, categorized as IUCN Category Ia - Strict Nature Reserve (Brasil, 1979). Until 2018, Brazil had protected approximately 1.6% of its jurisdictional waters through MPAs, with only 8.9% of these MPAs classified under the most restrictive protection status (Ia IUCN category). Following the designation of four oceanic LSMPAs, the spatial coverage of protected marine waters surged to over 26% (MMA, 2018). This rapid expansion of Brazil's MPA network has been seen as an opportunity to meet global protection targets (Soares and Lucas, 2018). However, it was largely driven by political considerations in a top-down approach, rather than being based on technical factors (Giglio et al., 2018; Silva, 2019a).

Currently, Brazilian protected areas fall under the administration of federal, state, and municipal jurisdictions and are categorized into two main groups: 1) Full Protection (henceforth no-take; IUCN categories I to III), which aims to preserve biodiversity, being allowed with only the indirect use of its natural resources; and 2) Sustainable Use (referred to as partially protected; IUCN categories IV-VI), which aim to balance nature conservation with sustainable use of natural resources. No-take areas include Ecological Stations, Biological Reserves, Government Parks, Wildlife Refuges, and Natural Monuments. Partially protected areas encompass Sustainable Development Reserves, Extractive Reserves, Government Forests, Fauna Reserves, Environmental Protection Areas, Relevant Ecological Interest Areas, and Private Reserves of Natural Heritage (Brasil, 2000).

Given the global emphasis on meeting biodiversity conservation targets, such as the 30 × 30 initiative, it is crucial to evaluate the effectiveness of Brazil's MPA network. This study aims to analyze the trends in the expansion of MPAs in Brazil between 2002 and 2022, examining how well these areas fulfill their intended conservation goals. It seeks to assess whether the MPAs are effectively designed in terms of protection levels, management tools, ecosystem representation, and their potential to meet global conservation targets. By doing so, the study provides insights into the strengths and weaknesses of Brazil's marine conservation efforts and offers guidance for future policy improvements to enhance the ecological integrity of protected areas.

2. Material and methods

2.1. Indicators of change

To evaluate changes in the Brazilian MPAs network over twenty years (2002–2022), we employed a set of indicators adapted from Roberts et al. (2018), using data from: (i) number of MPAs and total protected area; (ii) number of legal acts (modifications to MPAs); (iii) size class distribution of MPAs; (iv) level of protection; (v) implementation of legal management instruments; and (vi) biodiversity representation and level of protection considering marine ecoregions (Fig. S1).

Data was collected from the Open Data Portal (Portal de Dados Abertos) (MMA, 2022), which compiles, updates, and provides data on Brazilian protected areas since 2018. We quantified all MPAs that entered or were removed from the Brazilian MPAs system to investigate trends in the number of MPAs and the total protected area between 2002 and 2022.

In addition to the creation of new MPAs, some previously established areas underwent legal modifications. These events, known as Protected Area Downgrading, Downsizing, or Degazettement (PADDD) (Mascia and Pailler, 2011), may be driven by various causes and can impact conservation efforts. We compiled information on legal acts to assess changes related to: (i) increase in the number, magnitude, or extent of human activities within a MPA (Downgrading); (ii) decrease in the size of a MPA through a legal boundary change (Downsizing); (iii) loss of legal protection for a MPA (Degazettement); (iv) increase in the size of a MPA (Upsizing); and (v) alteration in the category of protection of a MPA (Recategorization). We classified these events as "enacted" when legally executed by the government and "proposed" when formally under consideration but not yet enacted. Data on legal acts were obtained from the PADDDtracker-Brasil (WWF-Brasil, 2024).

To analyze trends in MPA size, each Brazilian MPA was categorized into six size classes adopted from Roberts et al. (2018): 1–10, 10–100, 100–1,000, 1000–10,000, 10,000–100,000, and >100,000 km^2. The proportion of MPAs in each size class was calculated. Considering that Brazilian MPAs allow different activities, we assessed the level of protection of each MPA group and category. Our analyses were based on similarities in the levels of protection between the Brazilian National System of Protected Areas and the IUCN categories (Table S1).

The implementation of a management plan and establishment of the management council are legal prerequisites crucial for enhancing MPA's effectiveness and are mandatory in Brazil (Brasil, 2000). We compiled information on the creation of MPA management plans and councils and estimated the average gap between the implementation of the management plan and the management council establishment. We gathered information about the existence of a management plan and council from the Management Analysis and Monitoring System (SAMGE; Sistema de Análise e Monitoramento de Gestão), an application tool for the analysis and monitoring of PAs management, developed by the Division of Management Monitoring and Evaluation (ICMBio, 2024). We also searched information regarding the creation and development dates on the web and extracted it from official acts and literature of the executive, legislative, and judicial branches of each public administration.

Finally, we assessed trends in the representation and level of protection of biodiversity in each of Brazil's eight marine ecoregions (Spalding et al., 2007). The MPA area of each marine ecoregion was described through spatial coverage categories (<1%, 1–10%, 10–25%, 25–40%, 40–55%, 55–70%, 70–85%, and 85–100%). The 10% protection target established by the Convention on Biological Diversity (CBD, 2010) served as a reference point to estimate "adequate" area-based protection and quantify changes in representation over time.

Proportions of each marine ecoregion were calculated based on the IUCN standardized classification to assess changes over time.

3. Results

3.1. Changes to the number of MPAs and total area protected

Between 2002 and 2022, a total of 87 MPAs were established in Brazil, with 53% being partially protected and 47% designated as no-take areas (Fig. S2). Of these 87 MPAs, 29.9% (n = 26) were created at the municipal administrative level, 36.8% (n =32) at the state level, and 33.3% (n = 29) at the federal level. The total number of MPAs increased from 108 to 195, resulting in 113 partially protected and 82 no-take MPAs. Currently, the Park category (IUCN's II) has the largest number of MPAs, while in the partially protected group, the Environmental Protection Area (IUCN's V) is the most representative category (Table S2). Over 935,000 km^2 of protected area were added to the Brazilian system, bringing the total protected area to 1,082,923.83 km^2 (Fig. 1). The most significant expansion of MPAs occurred in 2018 when 13 new MPAs were established, consisting of 8 partially protected and 5 no-take areas, contributing to a total protected area of 907,967.06 km^2 (Fig. 1). Coastal areas accounted for the vast majority (95.4%) of MPAs, with only four MPAs implemented offshore representing 93.6% of the total MPA area in Brazil.

3.2. Size distribution

Of the 87 MPAs created between 2002 and 2022, 72 (83%) were small (<100 km^2), 13 (15%) were medium-size (100–10,000 km^2), and 2 (2%) were large-size MPAs (>100,000 km^2) (Table 1). The proportion of smaller MPAs (<10 km^2) almost doubled, while the number of the other two small (10–100 and 100–1000 km^2) and medium (1000–10,000 and 10,000–100,000 km^2) size classes decreased over two decades (Table 1) The same happened to the medium size MPAs. Until 2018, Brazil had no large size (>100,000 km^2) MPA.

3.3. Trends in the number of legal acts

We identified 40 legal changes in the Brazilian MPAs system, with 33 already enacted and 7 proposed. Modifications to the size of existing MPAs were the most frequent legal change, with 24 MPAs being upsized (Fig. 3). Nine downsizing events were registered, four were proposed and five were enacted. Regarding recategorization events (n = 7), three were proposed and four were enacted (one upgrade and three downgrades; Table S3). No MPAs were degazetted in Brazil between 2002 and 2022 (Table S3).

3.4. Changes to the level of protection for marine biodiversity

We found that over the twenty years analyzed, there has been a similar increase (n = 41 and n = 46, respectively) in the number of no-take (categories Ia, II and III) and partially protected areas (categories IV, V and VI) designated (Table 3).

The IUCN Category II had the greatest increase in number, adding 24 new MPAs to the Brazilian MPAs network; however, these areas comprise only 0.1% of the total area. MPA's Category V experienced the largest growth, with expansion occurring in 2018 when the offshore Environmental Protected Areas of St. Peter and St. Paul and Trindade and Martim Vaz were established, being responsible for about 86% of the growth in the spatial coverage over the two decades (Table 3). Only one MPA has been incorporated into IUCN Category Ia (Fig. 4): the Guanabara Ecological Station, created in 2006, adding 19.36 km^2 to the total area. The proportions of IUCN Categories Ia, IV, and V have decreased in relation to the total network (4.5%, 0.7%, and 10.5%), while II, III, and VI have increased (2.1%, 6.8%, and 6.8%) over the years (Fig. 4).

3.5. Trends in the implementation of legal management instruments

Overall, 50.8% of the MPAs in Brazil have a management plan, 71.3% have a management council, and 46.7% have both. Regarding administrative jurisdictions, 22.5% of municipal MPAs have a management plan and 4% have created a management council. MPAs managed by state authorities have 23.1% and 36.9% of their

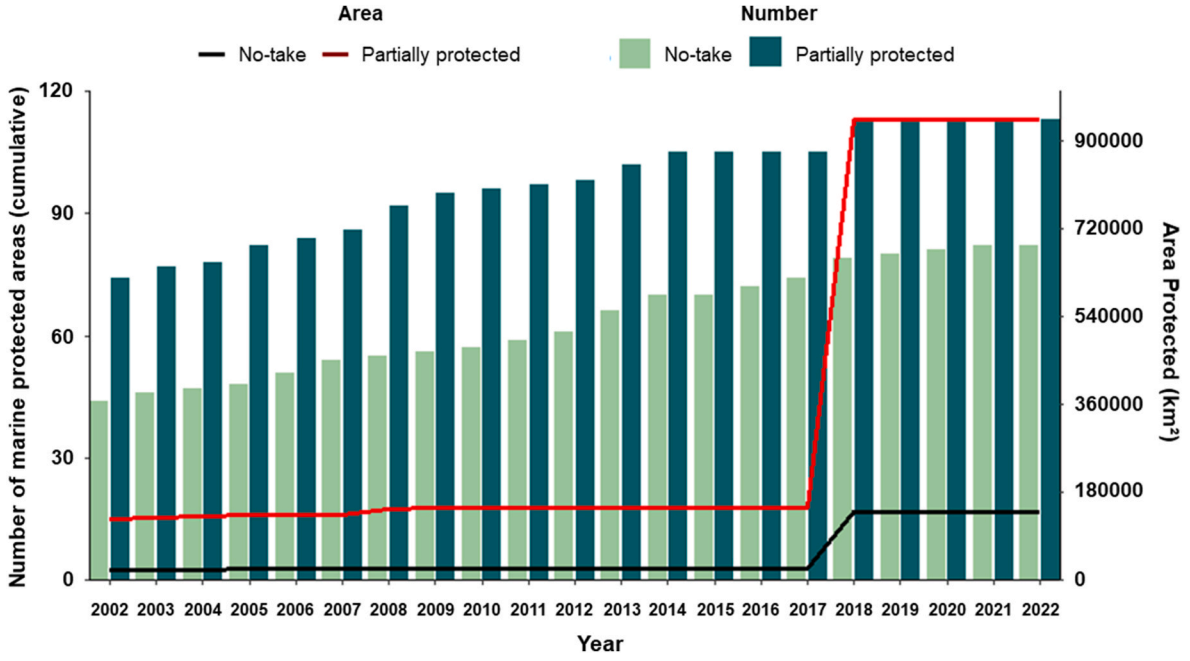

Fig. 1. Accumulated number (bars) and area (red and black lines) of marine protected areas in Brazil from 2002 to 2022. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Fig. 2. Changes in the size class distributions of marine protected areas in Brazil from 2002 to 2022.

Table 1
Changes in the proportion (%) in size class distribution of marine protected areas over the years.

Size class (km²)	Size category	1961–2001	2002–2022
0–10	Small	15.7	31.0
10–100		29.6	27.6
100 -1000		35.2	24.1
1000–10,000	Medium	16.7	12.6
10,000–100,000		2.8	2.3
>100,000	Large	0	2.3

management plans elaborated and management councils created, respectively, while those managed by federal authorities have these percentages at 21% and 32.3%. Between 2002 and 2022, 85 (85.8%) management plans were elaborated, and 130 (93.5%) management councils were created. Most of the management plans and management councils created during this period belong to state MPAs (Fig. 5; Table S4).

Regarding the management group, federal no-take MPAs had more management plans and management councils established (Figs. S2a–b). In the group of partially protected MPAs, the state MPAs had the highest number of management plans and management councils created (Figs. S3a–b). Between 2002 and 2022, the IUCN category II represents the no-take group with the highest percentage of implemented management plans (61.7%) and councils (54.7%), while among the partially

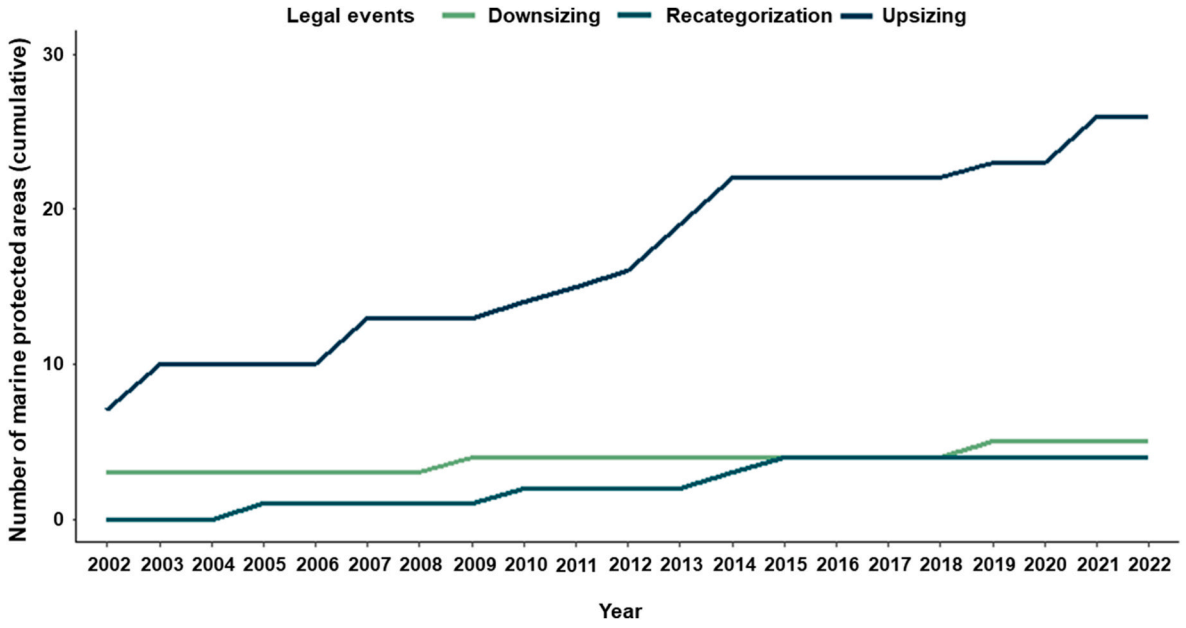

Fig. 3. Trends in the number of upsizing, downsizing and downgrading enacted events in marine protected areas of Brazil between 2002 and 2022.

Table 3
Assigned IUCN category, number of marine protected areas designated, area added (km^2) and proportion of total area expanded (%) between 2002 and 2022. IUCN = International Union for the Conservation of Nature. MPA = marine protected area.

IUCN category	Designated MPA	Area added (km^2)	Proportion of total area expanded (%)
Ia (Strict Nature Reserve)	1	19.36	0.002
II (National Park)	24	1305.44	0.1
III (Natural Monument or Feature)	16	116,169.31	12.4
IV (Habitat or Species Management Area)	4	42.95	0.004
V (Protected Seascape)	21	807,062.52	86.2
VI (Protected Area with Sustainable Use of Natural Resources)	21	11,849.65	1.3

protected group, category V exhibits the highest implementation percentages (73.1% and 70.3%), respectively Table S4).

Overall, the development of management plans, the primary guiding management document, has been taking three times longer (average = 18 years) than the stipulated time frame in Brazilian legislation (5 years). Over the past two decades, the management plans has taken ~9 years to be developed. Concerning administrative jurisdictions, state-managed MPAs take longer to create their management plans. The management plans of more restrictive MPAs take 7 years on average, while partially protected ones take 10 years to be created. However, there has been a decrease in the average time for the implementation of management plans for all administrative jurisdictions and management groups between 2002 and 2022.

3.6. Trends in marine ecoregion representation and level of protection

Among Brazil's eight marine ecoregions, four have less than 10% of their areas under any form of protection, while two have between 10% and 25% protected. Notably, two offshore ecoregions—St. Peter and St. Paul, and Trindade and Martim Vaz—are fully protected, with 100% of their areas under conservation (Table 4).

The growth of the Brazilian MPAs in different marine ecoregions over time varied. There was an increase in the number of MPAs in the Southeastern (n = 32), Eastern (n = 20), Amazon (n = 15), and Northeastern (n = 15) ecoregions. In contrast, there was less growth in the St. Peter and St. Paul (n = 2), Trindade and Martim Vaz (n = 2), Rio Grande (n = 1), and no increase in Fernando de Noronha and Rocas Atoll ecoregions. Although the increase in the number of MPAs in St. Peter and St. Paul, as well as Trindade and Martim Vaz, was smaller, these two ecoregions experienced the most significant spatial expansion: 40% (431,304.70 km^2) and 43.5% (471,480.96 km^2), respectively. In terms of protection categories, these oceanic areas are predominantly classified under Category V of the IUCN, which is one of the least restrictive protected area categories (Fig. S2).

Between 2002 and 2022, the spatial coverage of partially protected MPAs expanded, with most of the area added in five of Brazil's eight marine ecoregions falling under MPAs created in category V. The Southeastern ecoregion was the only one to establish new MPAs across all categories. Despite this, the greatest increase in the number of new MPAs occurred in the no-take group, while the MPAs from the partially protected group accounted for 91.5% of the total expanded area (Fig. S4).

4. Discussion

By assessing changes in spatial patterns, implementation of formal management tools, level of protection and ecosystem representation of the Brazilian MPAs over two decades, our findings revealed that i) Brazilian MPAs were mostly implemented in coastal areas and with a small size (0–1000 km^2); ii) most of MPAs are within partially protected categories and disproportionately distributed in both number and spatial coverage over the marine ecoregions; and iii) formal management tools are lacking in MPAs from all administrative jurisdictions. Similar trends in protected habitat and MPAs size have been observed in other regions of the world. Most of MPAs in the Mediterranean Sea also are coastal, small in area, and characterized by fragmented protection efforts, with only about 6% of the marine area protected, and most MPAs being smaller than 50 km^2, underscoring a global challenge of creating larger, more ecologically meaningful protected areas (Giakoumi et al.,

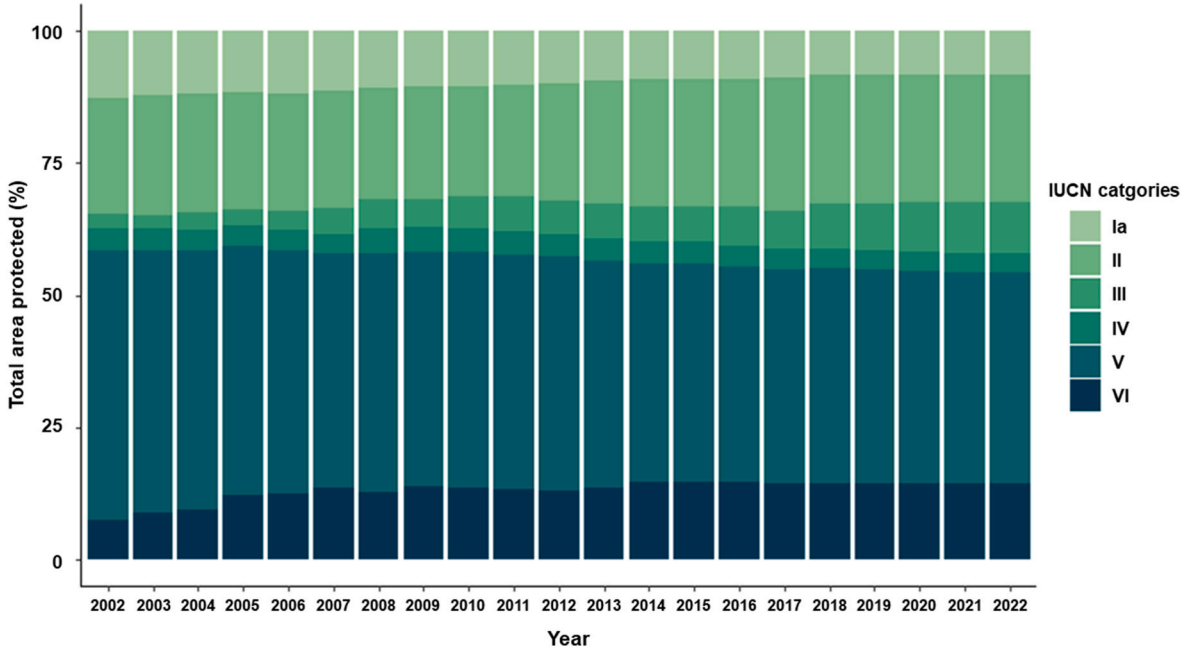

Fig. 4. Changes in the proportion of the network within each IUCN MPA category between 2002 and 2022. IUCN = International Union for the Conservation of Nature. The names of IUCN categories are described in Table 3.

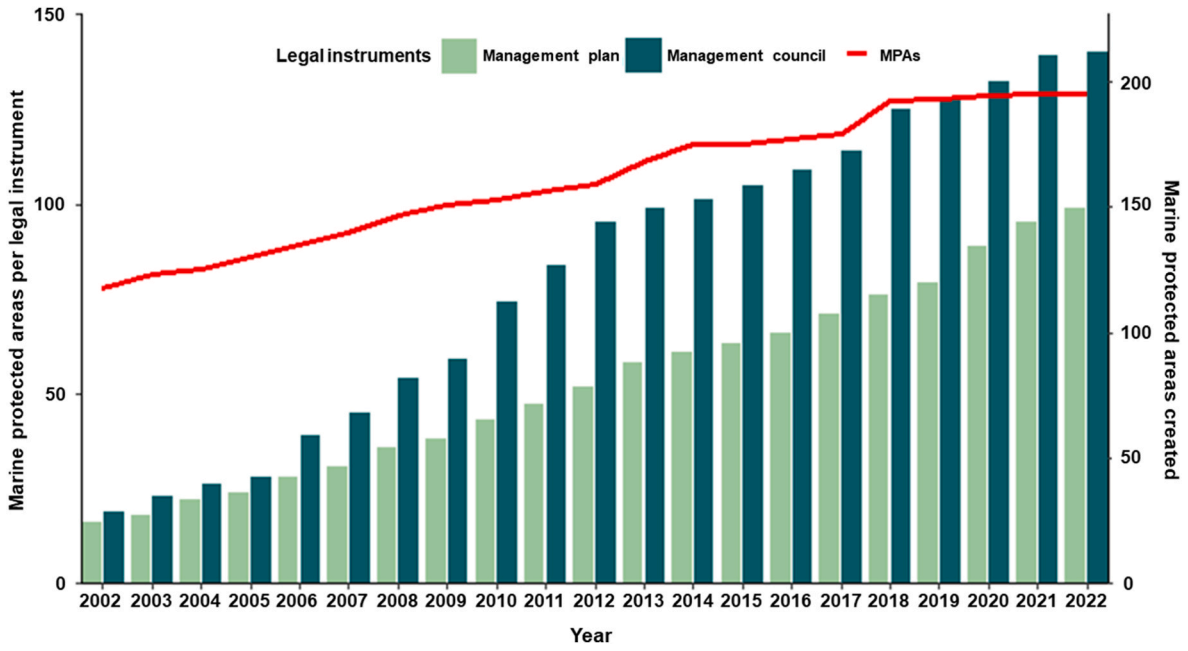

Fig. 5. Change in the number of management plans and councils across the Brazilian marine protected areas network between 2002 and 2022. The red line indicates the total number of MPAs in each year. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Table 4
Proportion of each Brazilian Marine Ecoregion protected.

Marine Ecoregion	Proportion protected (%)		Percentage of spatial coverage protected
	1961–2001	2002–2022	
Rio Grande	0.1	0.1	<1%
Fernando de Noronha and Rocas Atoll	0.6	0.7	
Northeastern	1.1	2.0	1–10%
Eastern	1.8	2.7	
Southeastern	5.1	10.2	10–25%
Amazon	19.5	21.4	
St. Peter and St. Paul	0	100	85–100%
Trindade and Martim Vaz	0	100	

2018). Likewise, the uneven distribution of MPAs across Brazil's marine ecoregions mirrors patterns seen in other nations. In Southeast Asia, for instance, marine protection is highly concentrated in coastal zones with higher economic or touristic value, leaving deep-sea and pelagic ecosystems significantly underrepresented (White et al., 2014). In contrast, countries like Australia, through the establishment of the Great Barrier Reef Marine Park, have made strides in creating expansive MPAs encompassing various marine habitats, from coral reefs to deeper ocean zones. This broader ecosystem representation is often lacking in most countries, including Brazil.

The distribution of MPAs in Brazil remains unbalanced, despite meeting quantitative targets. Over the past two decades, more than 95% of MPAs were established in coastal waters, yet this covers only 5% of the country's total marine area. Indeed, these coastal areas, rich in biodiversity and crucial ecological processes, face heightened human pressures due to their proximity to the continent (McCauley et al., 2015; Halpern et al., 2019; Scherer et al., 2024). Nearshore ecosystems, such as coral reefs and mangroves, are particularly vulnerable to human impact compared to larger and deeper ones (Halpern et al., 2019). Therefore, expanding the spatial coverage of coastal MPAs is in fact crucial for conserving marine biodiversity, promoting sustainable fisheries, enhancing ecosystem services, supporting tourism, and strengthening climate change resilience (Fernandes et al., 2019; Halpern et al., 2019; Lester et al., 2009; Worm et al., 2006). However, protecting coastal areas poses unique challenges due to conflicts, diversity of stakeholders, and complex legal and regulatory frameworks, especially when compared to open ocean regions (Ban et al., 2014; Halpern et al., 2019). Despite these challenges, the higher percentage of MPAs being established in coastal regions reflects a significant national effort to develop a cohesive MPA network in these areas. However, the complexities of coastal management may also contribute to the low rate of formal management plan implementation within these MPAs.

Coastal nations, including Brazil, have established Large-Scale Marine Protected Areas (LSMPAs) to help meet conservation targets. In 2018, Brazil significantly expanded its MPA coverage with the designation of two offshore LSMPAs, accelerating its marine conservation efforts (Silva, 2019b). When effectively designed, implemented, and managed, LSMPAs reflect a strong commitment to conservation. Ecologically, these expansive areas can support the recovery of fish populations in surrounding waters (Medoff et al., 2022) by providing ample habitat for larvae dispersal and essential spaces for early life stages (De Santo, 2013). LSMPAs also help protect interconnected ecosystems, allowing biologically connected habitats to be managed cohesively (Wilhelm et al., 2014). Additionally, LSMPAs often encompass deep-sea and pelagic environments absent in smaller MPAs, protecting a diverse range of large and migratory species, such as tuna, sharks, cetaceans, and sea turtles (Toonen et al., 2013). LSMPAs have demonstrated effectiveness, particularly in no-take zones, by accommodating multiple uses while still providing broad conservation benefits (Edgar et al., 2014). This protection helps preserve marine biodiversity by shielding distant marine areas from the anthropogenic disturbances common in coastal development sites (Spalding et al., 2013). Despite their role in meeting specific objectives, the Brazilian LSMPAs may not comprehensively address all ecosystem commitments, reflecting the country's recent prioritization of LSMPAs creation to fulfill international targets rather than emphasizing effective and systematic biodiversity conservation. Political considerations influenced the establishment of these LSMPAs (Giglio et al., 2018), and the benefits to biodiversity conservation are very reduced in comparison with the design proposed through science-based planning (Francini-Filho et al., 2018; Pinheiro, 2018). In contrast to LSMPAs, smaller MPAs excel at providing targeted protection in high-use areas, such as coastal regions. While smaller

MPAs can be sufficient for sustaining certain fisheries (Green et al., 2014), networks of very small no-take zones (<1 km^2) have proven particularly effective at safeguarding fish communities from direct fishing pressure, leading to notable increases in the abundance and biomass of targeted species (Rolim et al., 2019). To meet conservation goals effectively, a diverse range of MPA sizes and classifications must be implemented, with both large and small MPAs playing crucial roles in different protection contexts (Jones and De Santo, 2016; Zupan et al., 2018). As such, MPA design tailored to the specific ecological and socioeconomic context is essential for ensuring long-term sustainability and conservation success (Lester and Halpern, 2008).

Relying solely on area-based targets as the primary indicator of MPA progress may obscure important metrics beyond MPA size and location. In addition, neglecting qualitative conservation aspects (e.g. management equity and effectiveness) creates uncertainty about achieving desired biodiversity outcomes (Collen and Nicholson, 2014; Svancara et al., 2005), potentially allowing marine biodiversity loss and its severe consequences to persist. For example, the development of Brazil's MPA system has been uneven in terms of protection levels, with a disproportionate number of MPAs created across different IUCN categories and management groups. Between 2002 and 2022, the MPAs expansion in Brazil followed the global trend, in which the designation of partially protected areas was the most applied conservation strategy (UNEP-WCMC and IUCN, 2024), being half (~53%) of Brazilian MPAs belonging to this category of protection. Despite the small difference between the number of no-take and partially protected MPAs created (n = 5), the spatial coverage of partially protected areas expansion was almost seven times bigger than no-takes. Yet, a single category (Environmental Protection Area - EPA) was responsible for 86% of the growth in spatial coverage. While the establishment of partially protected areas has substantially bolstered the MPA network, there are concerns about the effectiveness in preventing illegal activities, particularly fishing, within their boundaries. Studies suggest that both coastal (Nunes et al., 2023) and offshore (Magris, 2021) partially protected areas are not effectively deterring illegal fishing activities in Brazil, highlighting shortcomings in management strategies. The level of protection was recognized as a key factor affecting biodiversity in MPAs with different levels, fish biomass was notably higher within no-take compared to partially protected areas in Brazil (e.g. Illari et al., 2017; Motta et al., 2021; Rolim et al., 2019, 2022). Additionally, the effectiveness of EPAs in Brazil has been compromised by governance limitations such as weak inter-institutional communication, cross-jurisdictional coordination and recurrent conflicts from the northeastern (Almeida et al., 2016) to the southeastern coast (Macedo and Medeiros, 2021; Macedo et al., 2013).

No-take MPAs have been extensively studied and consistently shown to deliver stronger conservation outcomes compared to partially protected MPAs (Lester and Halpern, 2008; Sala and Giakoumi, 2017; Ferreira et al., 2022). Partially protected areas are typically less effective due to the allowance of certain extractive activities, leading to more complex regulations that can be harder to understand, enforce, and comply with (Roberts et al., 2020). Despite their ecological advantages, no-take MPAs have faced diminishing support from decision-makers, primarily due to conflicts with resource users (Costello and Ballantine, 2015). Given the widespread adoption of partially protected MPAs, rigorous monitoring is essential to determine under what conditions they can achieve conservation success. Although their effectiveness remains debated, these areas can offer both ecological and social benefits when they function as buffer zones around no-take MPAs or support sustainable fishing practices (Zupan et al., 2018; Di Lorenzo et al., 2020). To justify their costs and distinguish them from open-access areas, these MPAs must meet their ecological objectives, as social outcomes are often contingent on ecological success. Regardless of MPA type, strengthening regulations and establishing robust governance mechanisms are critical to maximizing conservation outcomes (Magris et al., 2021).

While the increase in MPA coverage in Brazil is recognized as a great conservation success, the distribution of MPAs between the different marine ecoregions is unbalanced. MPA networks should ensure sufficient representation of both species and ecosystems. The coverage of marine ecoregions is a metric generally used to assess ecological representation (e.g., Gannon et al., 2019), which is one of the qualitative elements of Aichi Target 11. We show that trends in MPAs expansion have remained insufficient to promote adequate spatial protection (>10%) in all marine ecoregions in Brazil between 2002 and 2022. Since 2002, the number of marine ecoregions reaching 10% coverage has increased from one to four. Historically, deficiencies in the representation of species and ecosystems in protected area networks were attributed to shortcomings in planning techniques (Pressey, 1994; Stewart et al., 2003). Despite improving conservation prioritization methods (Moilanen et al., 2009; Wilson et al., 2006), half of Brazil's marine ecoregions continue to have inadequate protection in terms of protection coverage. The percentage of ecoregion coverage under protection and the distribution of protection levels within each ecoregion appear to follow a similar pattern in the Mediterranean (Claudet et al., 2020). Thus, planning the expansion of MPAs should consider the effects of climate change (Frazão Santos et al., 2020) because species will probably shift their occurrence range to subtropical regions.

MPAs are the cornerstone of Brazil's conservation efforts; however, the country has also launched other initiatives to safeguard its marine ecosystems. These include the Blue Amazon Program, Fisheries Co-Management Programs, the National Plan for the Conservation of Endangered Species, and Marine Spatial Planning (Maretti et al., 2019). Such initiatives complement MPAs and advance Brazil's marine conservation objectives by targeting various facets of ecosystem protection and sustainable resource management. However, we verified that more than 50% of MPAs in Brazil lack both a management plan and a management council, leaving marine biodiversity threatened despite surpassing conservation goals. Studies evaluating the effectiveness of MPAs show positive results for MPAs that have both management instruments while MPAs that have only one of the two management instruments (management plan or management council) did not show significant conservation outcomes (e.g., Ferreira et al., 2022). In some cases, MPAs where management councils are legally established are not active, as observed with the EPA of Pratigi (Antoza-Barrios and Schiavetti, 2007).

Although the number of MPAs is increasing, many remain "paper parks"—areas that lack the necessary regulations, management, and enforcement to achieve meaningful biodiversity conservation. Strengthening these elements is crucial to avoid fostering a false sense of security in marine conservation efforts. In Brazil, a significant portion of MPAs falls into this category, where inadequate management obstructs the achievement of conservation goals (Slezak, 2014). Research has shown that effective enforcement is directly linked to positive socio-ecological outcomes, such as the recovery of key fish populations (e.g., Guidetti et al., 2008). Despite some progress, key challenges remain in protecting marine biodiversity, including a lack of representativeness in MPA design, the absence of comprehensive management plans, insufficient monitoring of conservation status, and weak enforcement. These issues are not exclusive to Brazil and affect coastal areas globally (e.g., Fraschetti et al., 2018). Similarly, Brazil's terrestrial protected areas, which cover 30.42% of the land (UNEP-WCMC, 2024), also struggle with issues of "paper park" status. Inadequate management, enforcement, and financial resources reduce their effectiveness, while land-use pressures—particularly deforestation, agricultural expansion, and illegal logging—pose severe threats. For example, the Amazon, one of the most critical ecosystems in the world, continues to experience high levels of deforestation, even within protected zones (Lopes and Tsuyuki, 2024). Like MPAs, terrestrial reserves suffer from slow implementation of management plans and insufficient monitoring, leaving them vulnerable to exploitation and degradation.

While there has been progress in reducing the time required to implement management plans, it still takes an average of nine years—almost double the timeframe set by Brazil's National System of

Protected Areas. This delay underscores the urgent need for more efficient governance mechanisms to ensure MPAs deliver meaningful conservation outcomes. Similar to the Mediterranean, where 95% of MPAs provide inadequate protection for biodiversity (Claudet et al., 2020), Brazil faces comparable challenges. The lack of robust management plans and enforcement severely limits the effectiveness of its MPAs, emphasizing the importance of improving not just the quantity but the quality of protection. Only through stronger governance and strategic management can MPAs realize their full potential as effective tools for marine conservation.

Over the two decades, no-take MPAs under federal jurisdiction have had a higher proportion of management plans and management councils implementations. For the partially protected group, MPAs under state administration have shown a higher proportion of management plan and council implementations. The disparity in implementing formal management tools across administrative jurisdictions significantly impacts the effectiveness and scope of marine conservation. Most of the cases of MPA successes in Brazil have been described to federal MPAs (e.g., Ferreira et al., 2022) since areas under this jurisdiction likely have more management infrastructure and less influence of political turnover. Brazilian legislation grants distinct competencies to each level of government in marine resource management and the establishment of protected areas, resulting in unequal distribution of authority and responsibility. Federal laws establish guidelines for marine conservation and MPAs, but practical implementation and management often fall to state and municipal governments. This decentralization can lead to inconsistencies in conservation policy application, resulting in gaps in protection coverage and fragmented ecosystem management approaches.

The poor coordination between administrative jurisdictions can hinder integrated management approaches and efficient resource allocation for marine conservation. Overlapping competencies and unclear responsibilities can result in conflicts of interest, duplication of efforts, and resource wastage, undermining conservation efforts and protection objectives. Thus, promoting coordination and collaboration between administrative jurisdictions is essential for an integrated and effective approach to implementing and managing Brazilian MPAs.

5. Conclusion

Brazilian MPAs are predominantly small, partially protected, concentrated in coastal regions, and unevenly distributed across ecoregions. Additionally, many lack formal management tools. While increasing MPA coverage may suggest greater regulation of marine resources, this does not necessarily translate into effective biodiversity conservation. To improve conservation outcomes, it is critical to look beyond area-based targets. Upgrading existing partially protected MPAs to stricter protection levels, including the establishment of more no-take zones, may be more beneficial than simply expanding MPA coverage.

The delays in developing and implementing management plans, coupled with institutional and financial limitations, further inhibit MPAs from achieving their intended conservation goals. To address these issues, MPAs must be designed with key features that ensure their effectiveness, and their long-term sustainability must be supported through robust management and compliance measures. Collaborative efforts are essential to enhance coordination across administrative jurisdictions, strengthen governance frameworks, and allocate adequate resources to support MPA management.

Ensuring the long-term success of Brazil's MPAs requires a holistic and integrated approach that balances ecological conservation with social and economic development. To meet its 30 × 30 conservation goals, Brazil must address key gaps in governance, management, and enforcement within its marine protected areas. Strengthening these areas is essential for fully realizing their potential to safeguard biodiversity, bolster climate resilience, and sustain vital ecosystem services. With these improvements, Brazil has the opportunity to solidify its position as a global leader in conservation, provided it can overcome the existing challenges that currently undermine the effectiveness of its protected areas.

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil (CAPES) – Finance Code 001. FB was supported by CNPq (310,639/2021–2).

Competing interest and funding

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

CRediT authorship contribution statement

Nayla S. Patrizzi: Writing – review & editing, Writing – original draft, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Vinicius J. Giglio:** Writing – review & editing, Visualization, Validation, Supervision. **Fernanda Rolim:** Writing – review & editing, Conceptualization. **Francisco Barros:** Writing – review & editing, Supervision, Project administration, Funding acquisition.

Declaration of competing interest

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

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ocecoaman.2024.107509.

Data availability

Data will be made available on request.

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