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Papers

Assessment of Pressure Indicators on Protected Areas in the Amazon Coastal Zone - Pará

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Palavras-chave
RESEX
RAPPAM
Kernel Density

Resumo
The Marine Protected Areas (MPA), also known as RESEX (Extractive Reserves) in the Coastal Zone of Pará form a conglomerate of Protected Areas (PAs) and serve as a tool to combat the improper use of natural resources. This conglomerate of Protected Areas exhibits rich biodiversity and is home to approximately 5,000 families from traditional communities. This study aims to analyze the pressures occurring in 12 MPA in Pará. For this purpose, secondary vector-format data were used to identify pressure indicators, applying Kernel estimation for spatial analysis. To assess the degree of these pressures, the Rapid Assessment and Prioritization of Protected Areas Management (RAPPAM) methodology was used, which calculates the pressure level of activities in MPAs by measuring them in terms of "extent," "impact," and "permanence." The results indicate that the main pressures are fishing, wildfires, deforestation, tourism, and oil exploitation, with Araí-Peroba and Caeté-Taperaçu being the most pressured MPAs, while Soure and Mocapajuba are the least pressured. The study also revealed that the most significant pressures are related to wildfires and fishing and that enforcement and monitoring actions can minimize the identified impacts. The research indicates that pressures on PAs are directly linked to the legal status of these territories.

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INTRODUCTION

Protected areas are essential tools for providing services, livelihoods, and sustenance to local communities (Shaharum *et al.*, 2018), as well as mitigating greenhouse gases and protecting against disasters linked to sea level rise, protecting forests from deforestation pressures, and maintaining endemic species.

In recent decades, the inclusion of issues related to protected areas in the agenda of international conventions has stimulated the creation of many Protected Areas (Silva *et al.*, 2018). On a global scale, protected areas currently cover about 16.64% of terrestrial ecosystems and 7.74% of coastal waters (Chen *et al.*, 2023). In this context, Protected Areas (PAs) are a Brazilian strategy for protecting biodiversity, valuing traditional peoples, and controlling anthropogenic pressures on certain territories (Gomes *et al.*, 2022).

In 2000, Brazil established standards for the creation, implementation, and management of its protected areas through the (Sistema Nacional de Unidades de Conservação da Natureza (SNUC - National System of Nature Conservation Units, in English) – Law No. 9985/2000 (Brasil, 2000). The SNUC is a comprehensive system that incorporates classifications from the International Union for Conservation of Nature (IUCN), separating conservation units into two main groups: Integral Protection and Sustainable Use. The former aims to protect biodiversity, while the latter aims to conserve biodiversity, linked to varying degrees of exploitation and sociocultural maintenance.

Given these legal changes, there was a push to create more protected areas. Between 1990 and 2000, more than 15,900,347 hectares (ha) of protected areas were established in Brazil, contrasting with the 18,543,942 ha formed since the inception of protected areas up to 1990 (MMA, 2022).

Although the creation of protected areas is seen as progress, the global trend in biodiversity is declining, raising questions about the effectiveness of these territories in delivering conservation results (Gaveau *et al.*, 2009; Barber *et al.*, 2012; Yang *et al.*, 2019). In addition, the lack of regulation in the area surrounding protected areas - the buffer zone - contributes to deforestation in adjacent lands, altering the dynamics of development activities (Cuenca *et al.*, 2016; Rahman; Islam, 2021).

In this sense, the concept of effectiveness in PAs can be defined as the impact that this territory achieves, linked to the extent to which the policies for establishing these territories and their management contribute to socio-environmental changes (Assis *et al.*, 2021; Chen *et al.*, 2023); thus, evaluation components such as biodiversity, management processes, and achievement of objectives comprise metrics for effectiveness (Hockings *et al.*, 2000; DeFries *et al.*, 2007; Geldmann *et al.*, 2021). The creation of protected areas has long been used as a measure of the effectiveness of biodiversity conservation; however, this approach has flaws and inconsistencies (Massulo, 2019; Powlen *et al.*, 2021). Studies show that, on a global scale, only 18.7% of protected areas have been evaluated, and of these, 20% are effectively managed, with most areas considered “paper parks” (Geldmann *et al.*, 2013; Watson *et al.*, 2014; Chen *et al.*, 2023).

Considering the context assessment criteria of the Rapid Assessment and Prioritization of Protected Areas Management (RAPPAM) methodology, which analyzes pressures on Protected Areas, this study proposes to evaluate existing pressure indicators in 12 Marine Reservas Extrativistas (RESEXs) in the Paraense Coastal Zone.

RESEXs IN THE AMAZON

According to Article 18 of the SNUC (Brasil, 2000), RESEX is:

> “an area used by traditional extractive populations, whose subsistence is based on extractivism and, complementarily, on subsistence agriculture and small animal husbandry, and whose basic objectives are to protect the livelihoods and culture of these populations and ensure the sustainable use of the unit's natural resources.”

Thus, Marine RESEXs play a crucial role in protecting mangrove areas, supporting sustainable resources on which humans depend, and enhancing communities in sociocultural aspects, in addition to safeguarding them from climate impacts (Ferreira, 2013; Wang *et al.*, 2024).

The Marine RESEXs of the Paraense Coastal Zone cover approximately 400 km of territory and a mangrove area of 150,181.37 ha (Gonçalves; Andrade, 2024). This conglomerate of Protected Areas exhibits rich biodiversity and is home to approximately 5,000 families from traditional communities (Pimentel, 2019).

For the management of these areas, the SNUC (Art. 15, Paragraph 12) provides for the existence of a Deliberative Council that must be chaired by the body responsible for its administration and composed of representatives of public agencies, civil society organizations, and traditional populations residing in the area, as provided for in regulations and the act creating the UC (Gonçalves; Szlafsztein, 2023).

These RESEXs are managed by the (Instituto Chico Mendes de Conservação da Biodiversidade (ICMBIO – Chico Mendes Institute for Biodiversity Conservation, in English) and by the Associação de Usuários e Moradores das RESEX (AUREMs – Associations of Users and Residents of Marine RESEXs, in English) (ICMBIO, 2014). In 2020, ICMBIO's management was restructured, and it now consists of Núcleos de Gestão Integrada (NGI – Integrated Management Centers, in English), which are structures adopted by the managing body to achieve gains in management efficiency and optimize resources, including physical structures and equipment. The same team is responsible for the administration of a group of Protected Areas located in the same region (ICMBIO, 2020).

Despite efforts to adopt best practices with marine RESEXs, these areas still face management challenges. They are vulnerable to environmental threats and conflicts between communities, which directly impact the effectiveness of these territories.

CONCEPT OF EFFECTIVENESS AND RAPPAM METHODOLOGY

According to Hockings *et al.* (2015), a protected area is considered adequate when it possesses the capacity and specific competencies to fulfill the functions for which it was established satisfactorily. Geldmann *et al.* (2015) complement this understanding by stating that a protected area can be considered adequate when it achieves its objectives concerning maintaining integrity and resilience, thereby ensuring the representativeness and viability of all levels of biodiversity organization.

The RAPPAM, developed in 2003 by the Worldwide Fund for Nature (Ervin, 2003), aims to conduct rapid and comprehensive assessments of the management of Protected Areas, regardless of their classification or location. According to Hockings *et al.* (2015), this method has been applied in over 1,800 protected areas across 57 countries.

The RAPPAM assessment framework is based on the framework proposed by Hockings (2000), which assesses the management of protected areas considering the alignment of goals and objectives, the context in which actions are carried out, planning and available resources, the processes implemented, and the results achieved (**Chart** 1).

Chart1- Summary of the IUCN Methodology

Evaluation Elements	Explanations	Criteria
Context	Where are we now?	Pressures and threats Vulnerability Context
Planning	Where do we want to be?	Legislation Planning
Entries	What do we need?	Resources
Processes	How do we do it?	Adaptation of the Management Process
Outputs	What are the results?	Management Results, Services, and Products
Results	What has been achieved?	Effects of Management on Objectives

Source: The authors (2025). Adapted from Hockings (2000).

In Brazil, the model has been used to assess management effectiveness solely from the perspective of managers, without considering the participation of other actors involved in managing protected areas, particularly those working under co-management arrangements (Brandão, 2021). Furthermore, although RAPPAM is a generalist method, it was initially developed for forest areas (Ervin, 2003).

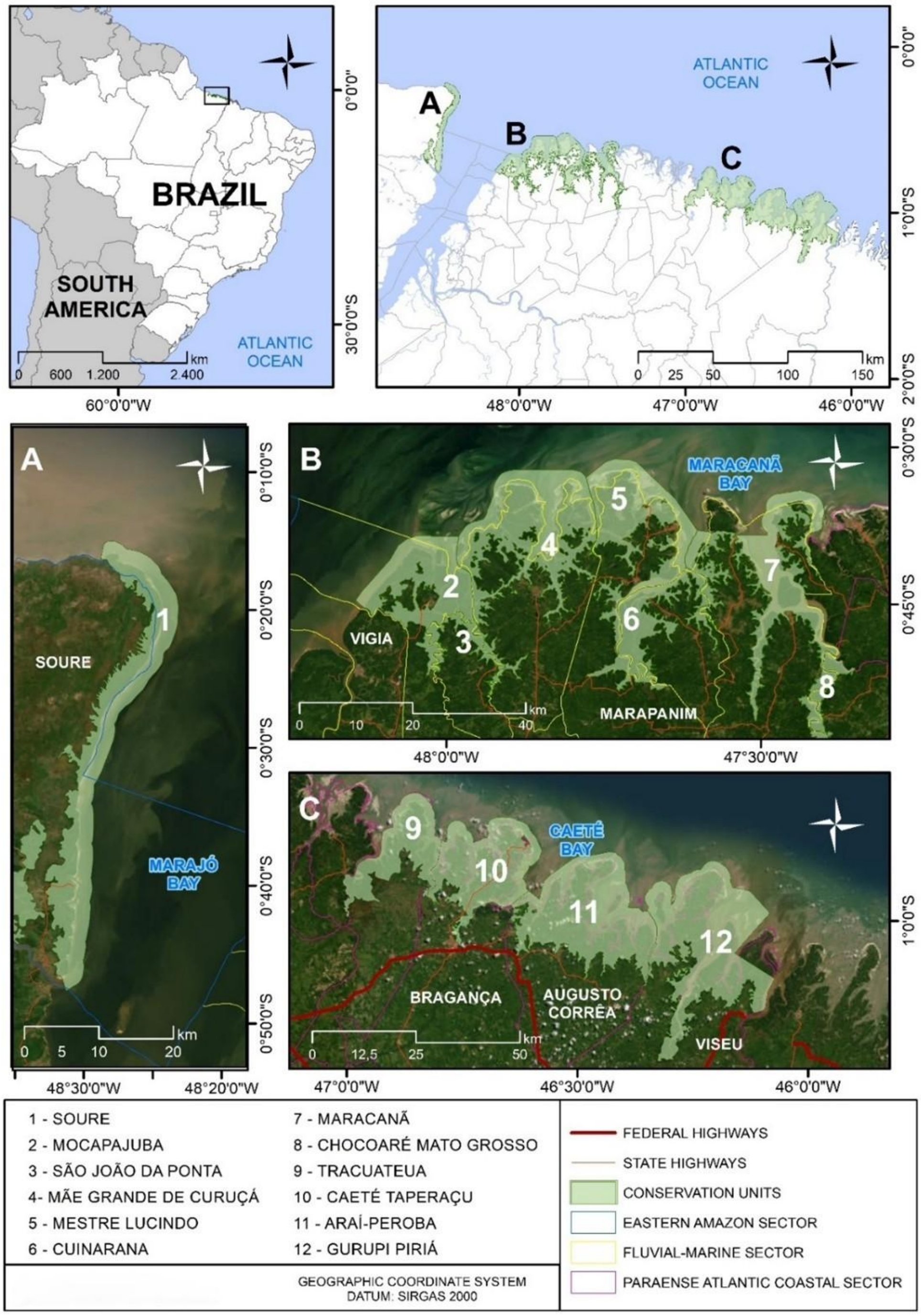
Studies on the management of Marine RESEXs in Brazil using RAPPAM have shown that assessment results can vary significantly when the perspectives of other actors and the specific characteristics of ecosystems are considered (Brandão, 2017; Giglio *et al.*, 2019).

METHODOLOGY

Study area

The 12 Marine RESEXs in the study are in the Eastern Marajó, Fluvial- Marine and Atlantic Coast sectors of the Paraense Coastal Zone, namely: Mãe Grande de Curuçá, São João da Ponta, Caeté-Taperaçu, Tracuateua, Araí-Peroba, Gurupi-Piriá, Chocoaré - Mato Grosso, Soure, Mocapajuba, Mestre Lucindo, and Cuinarana (Figure 1, Table 1). The Mocapajuba, Mestre Lucindo, and Cuinarana Resex were established in 2014, nine years after the creation of the others (Gonçalves; Szlafsztein, 2023).

Figure 1 - Paraense Coastal Zone Marine RESEXs:
A - Soure NGI; B - NGI of Salgado Paraense; C - NGI Bragantino



Source: DNIT (2020); MMA (2022); IBGE (2022). Elaborated by the authors (2025).

Table 1 - Information on the Marine RESEXs in the study area

RESEXs	Year Established	Municipality	Municipal area	Area of the Protected Area	Percentage of the municipality	Families
Soure	2001	Soure	3,517.318	274.64	8%	566
São João da Ponta	2002	São João da Ponta	195.918	34.09	17%	471
Mãe Grande Curuçá	2002	Curuçá	672.670	366.78	55%	564
Maracanã	2002	Maracanã	855.664	301.79	35%	281
Chocoaré Mato Grosso	2002	Santarém Novo	229.510	27.83	12%	280
Caeté Taperaçu	2005	Bragança	2,901.930	424.9	15%	562
Tracuateua	2005	Tracuateua	934.272	278.64	30%	227
Gurupi Piriá	2005	Viseu	4,915.873	740.41	15%	556
Araí-Peroba	2005	Augusto Corrêa	1,091.540	115.5	11%	294
Mocapajuba	2014	São Caetano de Odivelas	743.466	210.27	28%	564
Mestre Lucindo	2014	Marapanim	795.967	364.64	33%	282
Cuinarana	2014	Magalhães Barata	325.265	110.36	33%	304
Total	-	-	13,662.075	3150.25	23%	4951

Source: MMA (2022); Pimentel (2019). Elaborated by the authors (2025).

According to data from MapBiomas (2023), the Marine RESEXs of the Paraense Coastal Zone have 1,670.6 km² of mangroves, 22.5 km² of fields, 71.2 km² of pasture, and 2 km² of non-vegetated areas.

Data cataloging

In the "context" category of the RAPPAM method, pressures and threats affecting protected areas are analyzed. Pressures are considered activities that occur and cause concrete negative impacts on the natural resources that are the primary objective of the Protected Area. On the other hand, threats refer to the probability that these activities will occur or intensify in the future, indicating a risk to the integrity of the Protected Area (Ervin, 2003).

Primary and secondary data in various formats will be used to analyze pressures in the study area (Chart 2).

Chart 2- Source of data for analyzing pressure on PAs

Modality	Activity	Source	Data Type	Year
Land Use and Land Cover	Deforestation Livestock Urbanization Agriculture	Google Earth Engine Image Catalog	Raster	(GEE, 2024)
Use of fire	Wildfires	National Institute for Space Research	Vector	(INPE, 2024)
Tourism	Tourist Activity Points	Ministry of Tourism	Vector	(DATATOUR, 2024)
Energy matrix	Oil Blocks	National Petroleum Agency	Vector	(ANP, 2024)
Industrial Activity	Fishing activities	National Program for Tracking Fishing Vessels by Satellite	Vector	(PREPS, 2024)

Source: The authors (2025).

Kernel estimate

From the data grouping, a Kernel density estimate was performed to show spatial patterns of the catalogued pressures. Kernel density is a non-parametric method for estimating probability densities, defined by (Powell, 1996):

$$fx = \frac{1}{nh^2}\sum_{i=1}^{n} k\left\{\frac{x - x_i}{h}\right\}$$

Where:

n: is the number of points.
h: is the smoothing parameter.
k: is the kernel density function.
x: is the coordinate vector that defines the location where the function is estimated, and
xi: are the vectors that define the coordinates of each observation.

According to Koutsias *et al.* (2014), one issue to be defined is the data smoothing parameter, as this aspect depends on the purpose of using the Kernel estimate. For the present study, a 5 km interpolation is used for the coverage radius, incorporated into five classes (Chart 3) to understand the extent of the threats in the Protected Areas.

Chart 3 - Classification of pressures on protected areas

Class	Description
Low pressure	Low pressure density
Medium Low Pressure	Presents Medium Low-Pressure Density
Medium Pressure	Medium Pressure Density
Medium High Pressure	Medium High-Pressure Density
High pressure	Presents High-Pressure Density

Source: The authors (2025). Adapted from Koutsias (2014).

RAPPAM methodology

RAPPAM is a recognized method for evaluating the effectiveness of protected area management, with 16 evaluation modules and a specific section for evaluating existing pressures in Protected Areas (Aburaki; Mwalyosi, 2018).

For this article, we used the descriptions of the protected areas in the Paraense Coastal Zone found in the AUREMs (2023) document, which describes the pressures on protected areas.

Each Pressure identified received a score for each of the indicators on a scale of 1 to 4, with 1 representing the lowest score and 4 the highest score (**Chart 4**).

Chart 4 - Assigning values to analyze the degree of pressure on the PAs

Indicator	**Value**			
	1	2	3	4
Extension	Localized	Spread	Diffused	Throughout
Impact	Mild	Moderate	High	Strong
Permanence	Short term	Medium term	Long term	Permanent

Source: The authors (2025). Adapted from Ervin (2003).

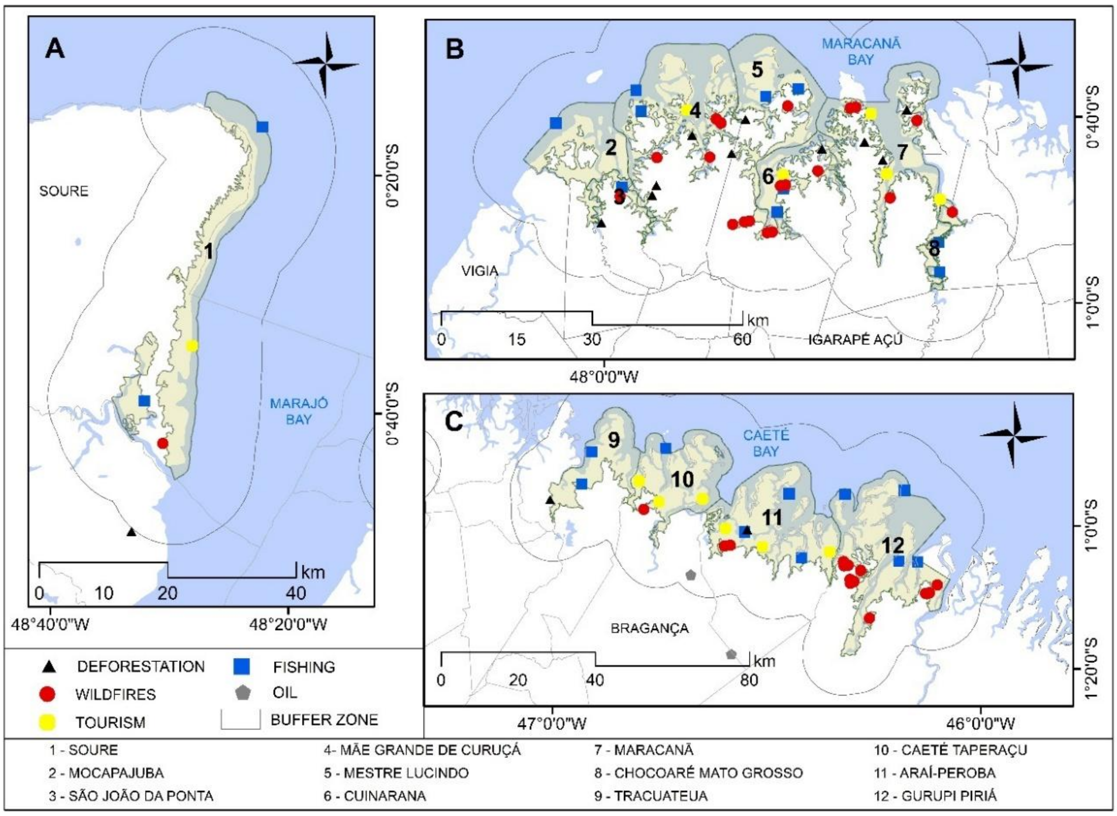
The degree of each pressure was obtained by multiplying the scores on the indicators of "extension," "impact," and "permanence". When applying the scale values to the three indicators, the lowest possible degree is 1, and the highest possible degree is 64. The degree serves as a metric of the pressure's impact on the Protected Area. For classification, a degree of 1 to 3 is considered light, 4 to 9 is considered moderate, 12 to 24 is considered high, and 27 to 64 is considered severe (Ervin, 2003).

RESULTS

The pressures on RESEX areas include fishing, tourism, wildfires, deforestation, and oil extraction. These pressures affect the entire mosaic of PAs (Figure 2).

The PAs most potentially affected are a) the Araí-Peroba RESEX, which faces all five types of threats listed; b) the Cuinarana, Mãe Grande de Curuçá, and Caeté Taperaçu RESEX, which face four types of threats listed; c) the Soure, Mocapajuba, São João da Ponta, Maracanã, Mestre Lucindo, and Chocoaré Mato Grosso Marine RESEX, with three types of threats; and d) the Gurupi-Piriá and Tracuateua RESEXs, with two types of threats identified (Chart 5).

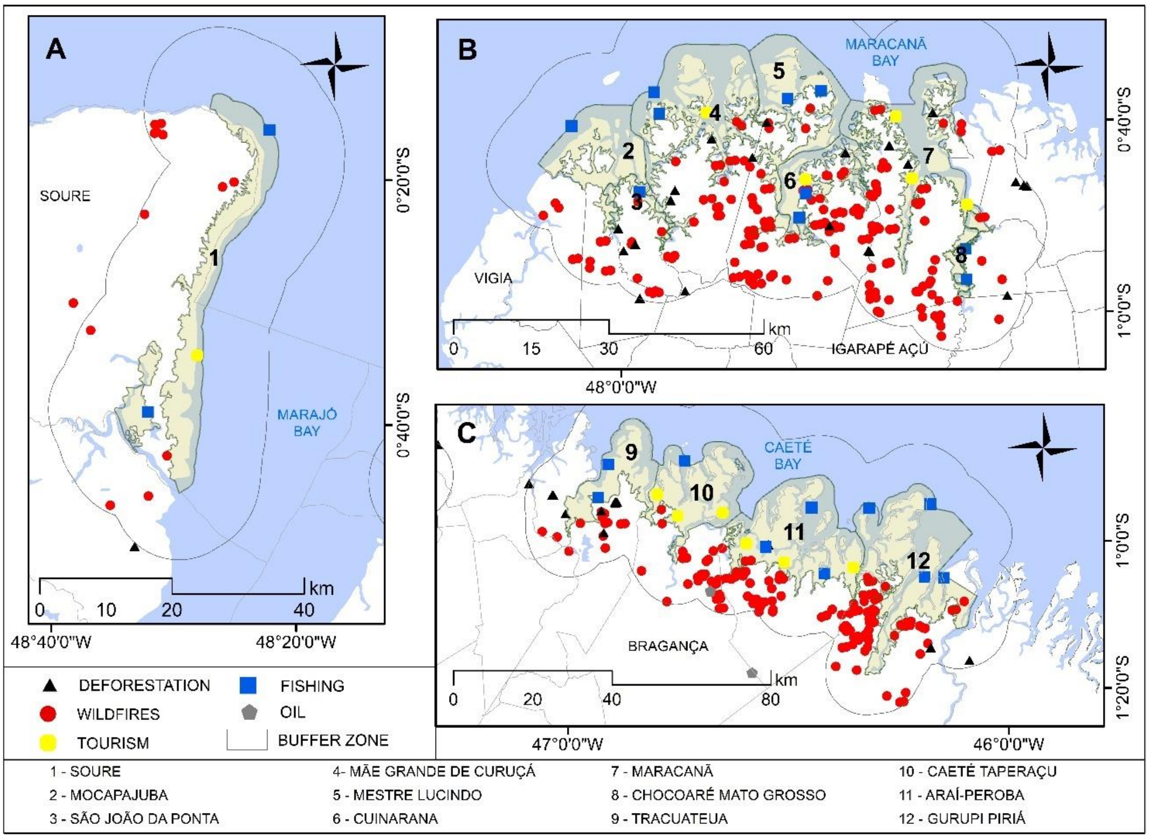
Figure 2 - Representation of the pressures on Marine RESEXs



Source: INPE (2024); DataTour (2024); ANP (2024); PREPS (2024); MMA (2022). Elaborated by the authors (2025).

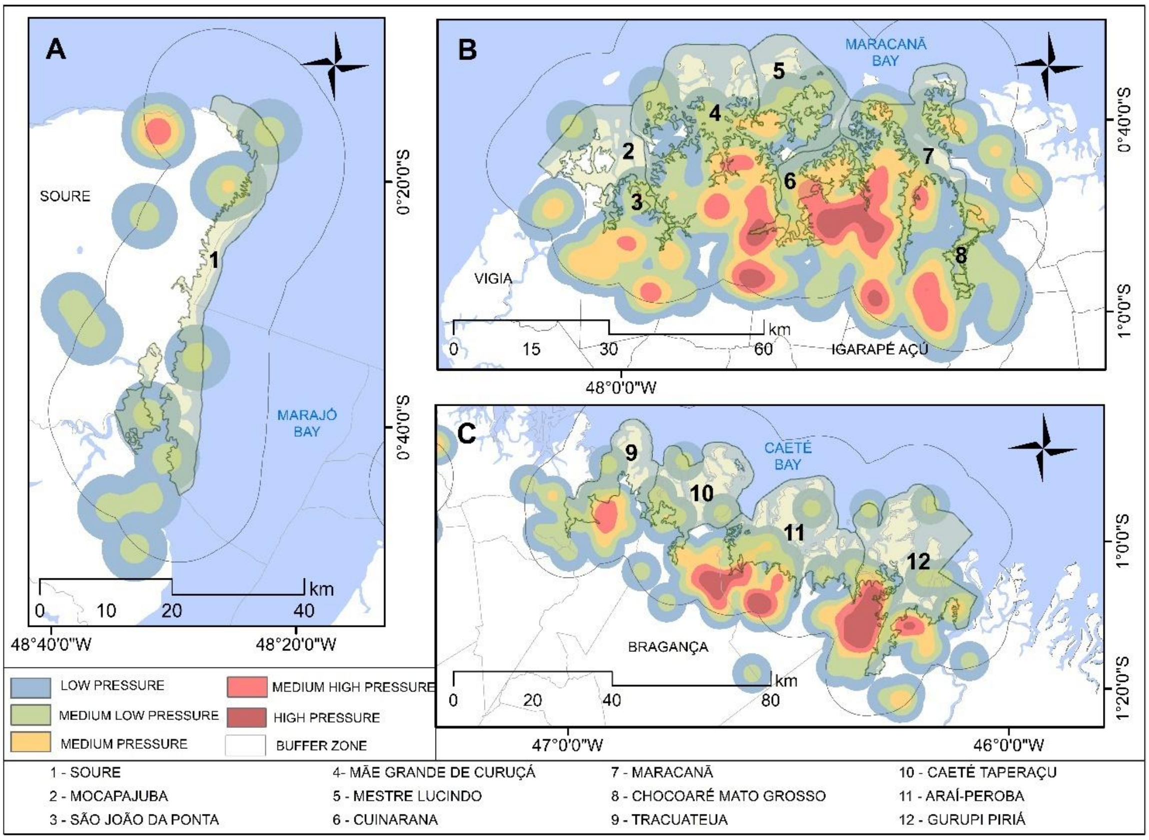
Considering the importance of the Buffer Zone, in addition to analyzing existing pressures within the Marine RESEXs in the Paraense Coastal Zone (Figure 5), an analysis was conducted considering a 5 km Buffer Zone (Figures 3 and 4). According to the SNUC (Brasil, 2000), Buffer Zones must be defined in the Management Plan for the Protected Area, establishing potentially impactful human activities within a radius of 3 to 10 km.

Figure 3 – Representation of Pressures on Marine RESEXs



Source: INPE (2024); DataTour (2024); ANP (2024); PREPS (2024); MMA (2022). Elaborated by the authors (2025).

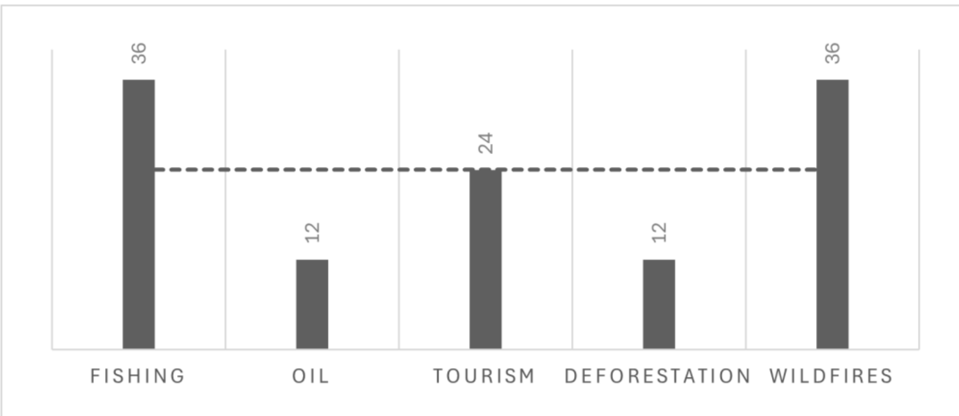
Figure 4 - Pressure Kernel Density



Source: INPE (2024); DataTour (2024); ANP (2024); PREPS (2024); MMA (2022). Elaborated by the authors (2025).

In general, when applying the RAPPAM methodology to analyze the degree of pressure on the cluster of conservation units, oil activities, tourism, and deforestation are found to exert a high degree of pressure. Fishing and wildfires are identified as exerting a severe degree of pressure (Figure 5 and Table 2).

Figure 5—Degree of pressure on RESEXs in the Paraense Coastal Zone



Source: The authors (2025).

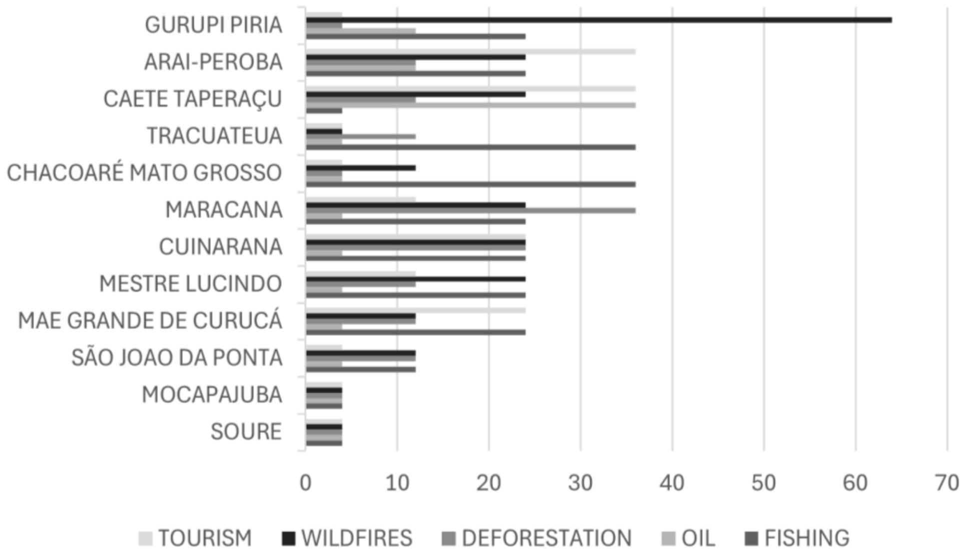
Table 2 – Assessment of the degree of pressure of each activity in the RESEXs of the Paraense Coastal Zone

Indicator	Pressure				
	Fishing	Wildfires	Tourism	Deforestation	Oil
Extension	4	4	2	2	1
Impact	4	4	3	2	3
Persistence	3	3	4	2	4

Source: The authors (2025).

When applying the methodology individually to the RESEXs studied, the Soure and Mocapajuba RESEXs show the lowest levels of pressure. In contrast, the Gurupí Piria, Araí-Peroba, Caeté Taperaçu, and Tracuateua RESEXs show the highest levels. Among the most common pressures on conservation units are fishing, tourism, and wildfires (Figure 6, Chart 5).

Figure 6 - Degree of pressure by RESEX in the Paraense Coastal Zone



Source: The authors (2025).

Chart 5 - Pressure indicators present in each RESEX

RESEXs	Fishing	Tourism	Deforestation	Wildfires	Oil
Soure	x	x	-	x	-
São João da Ponta	x	-	x	x	-
Mãe Grande Curuçá	x	x	x	x	-
Maracanã	x	x	x	x	-
Chocoaré Mato Grosso	x	x	-	x	-
Caeté Taperaçu	-	x	-	x	x
Tracuateua	x	-	x	-	-
Gurupi Piriá	x	-	-	x	-
Araí-Peroba	x	x	x	x	x
Mocapajuba	x	-	-	x	-
Mestre Lucindo	x	-	x	x	-
Cuinarana	x	x	-	x	-

Source: The authors (2025).

DISCUSSION

The creation of the Paraense Coastal Zone Marine RESEXs involves a timeline that began in 2001, with a process inspired by the first Marine RESEX created in Brazil, in 1992, in Santa Catarina (Pimentel, 2019). According to Gonçalves and Szlafsztein (2023), in addition to environmental conservation factors, the creation of conservation units in the Paraense Coastal Zone is influenced and supported by local communities. According to Zangh *et al.* (2025), these territories are a pillar of social change, thus affecting the health, well-being, culture, and relationships of community members.

Although most of the Marine RESEXs in the Paraense Coastal Zone were created more than 20 years ago, few have a Management Plan. This document is required under Article 27 of the SNUC. It is one of the mandatory requirements for implementing and managing a Protected Area, which must be approved within a maximum period of five years from the date of the PA creation.

The absence of a Management Plan is the result of a lack of resources and infrastructure limitations (Moraes *et al.,* 2017), thus negatively impacting protected areas, influencing management processes, threat mitigation, conflict reduction between communities, and other associated factors (Gonçalves; Szlafsztein, 2023; West *et al.,*2022). According to AUREMs (2023), the main pressures found in the Paraense Coastal Zone that affect the PAs, in addition to management-related problems, are oil activities, deforestation, fishing, tourism, and wildfires. According to Geldmann *et al.* (2019), a study conducted on a global and temporal scale found that pressures exerted on conservation areas have increased in recent decades, primarily in tropical regions characterized by low Human Development Indexes. This issue is also related to the absence of mechanisms and resources to address initial pressures.

In this sense, due to the legal loophole in the Marine RESEXs of the Paraense Coastal Zone, assessing their environmental context becomes of paramount importance. In the following sections, each pressure on the assessed protected areas is discussed.

Tourism

The RESEXs areas that face pressure from tourism are Soure, Mãe Grande Curuçá, Maracanã, Chocoaré Mato Grosso, Caeté Taperaçu, Araí-Peroba, and Cuinarana, with high pressure (24) in the coastal zone. In several countries, tourism is often used as an auxiliary livelihood strategy for biodiversity conservation in PAs, such as community-based tourism, mainly in marine RESEXs (Stone; Nyaupane, 2015; Stone *et al.,* 2021).

Thus, tourism activities aim to replace traditional income-generating activities and eventually reduce poverty and mitigate threats to biodiversity (Pham, 2020).

Although the primary objective of tourism activities is positive, research in the literature presents both positive and negative assessments of this type of activity. In Brazil, the potential for growth in tourism activities has a significant impact on coastal environments, particularly in untouched areas such as the Amazon coast, where tourism can harm the environment, as well as conflicting interactions with the local economy and the well-being of visitors (Pereira *et al.,* 2018).

A study conducted by Pereira *et al.* (2024) highlighted socio-environmental conflicts in tourist areas adjacent to and within the Soure and Caeté-Taperaçu Marine RESEXs, where adjacent sites are not protected and affect the areas surrounding the PAs. In recreational areas within the protected area, a significant enforcement effort is underway by the management agency (Figure 7).

Figure 7 – Tourism in the Soure RESEX: A – Sign marking the boundary of the Soure RESEX; B – Barra Velha beach, area surrounding the Soure RESEX; C – Pesqueiro beach, area surrounding the Soure RESEX; D – Erosion at Pesqueiro beach

Source: The authors (2025).

In addition to environmental issues, coastal tourism, particularly in the private sector, often overlooks the traditional practices of local communities and neglects sustainable recreational options, thereby generating social and environmental conflicts that compromise the quality of life for inhabitants (Almeida; Jardim, 2018).

Fishing

All PAs in the study, except Marine RESEX Caeté Taperaçu, list fishing as a threat to the coastal zone, demonstrating a high degree of pressure (12) and severe pressure (36). Commercial fishing exerts considerable pressure on marine ecosystems, and exploitation requires effective management systems to control excessive species mortality resulting from fishing (Alós; Arlinghaus, 2013). A fact that is not so well recognized is that recreational fishing activities in many coastal areas are intense, reaching fishing mortality rates similar to or even higher than those of industrial fishing (Figueira; Coleman, 2010).

Given this finding, PAs are presented as a strategy to mitigate this environmental problem. However, such measures often create conflicts between communities and other stakeholders because access to fishing ecosystems becomes restricted or prohibited (Fenberg *et al.*, 2012; Pimentel, 2019). Thus, managers may be inclined to implement less stringent management alternatives, using traditional regulatory measures such as catch limits based on species size, daily or weekly catch limits, annual quotas, and partial seasonal closures, rather than implementing more stringent controls (Ihde *et al.*, 2011).

In addition to the issue of recreational and commercial fishing, traditional communities perceive that protected areas are home to more abundant or larger fish due to fishing restrictions (Denny; Babcock, 2004; Lester; Halpern, 2009). This perception increases fishing pressure in marine reserves (Figure 8).

Figure 8 – Fishing Pressure in RESEX Cuinarana: A. - Fishing boats in the Cuinarana RESEX; B - Abandoned boats in the community of Santo Antônio in the Cuinarana RESEX

Source: The authors (2024).

For example, research conducted in the Philippines by Bobiles *et al.* (2016) demonstrates the similarity in fishing pressure between areas adjacent to and within the Protected Area, based on the perceptions of its users. Kauano *et al.* (2017) demonstrate that the organization of traditional communities with assistance from enforcement agencies can mitigate illegal fishing activities.

Oil

The PAs that face pressure from oil activities are the Caeté Taperaçu Marine RESEX and the Araí-Peroba Marine RESEX. However, even though only two of the twelve RESEXs studied are pressured by oil, exhibiting a high degree of pressure (12), this factor poses a medium- and long-term threat to the entire coastal zone of Pará. Studies indicate that this is due to the proposed oil exploration and future exploitation in the equatorial margin, which covers the states of Amapá, Pará, and Maranhão, regions that are particularly vulnerable to this practice (Andrade *et al.*, 2018; Parente *et al.*, 2021).

For AUREMs (2023), the lack of regulation and other legislation for PAs is a concern at a socio-environmental level for this emerging activity.

Thus, in the long term, oil activity is a pressure point in coastal regions, where vulnerability to oil spills reflects sensitivity, exposure, and adaptive capacity in terms of biological, geological, and socioeconomic resources, whether affected by small or large events (Nelson *et al.*, 2015; Nelson *et al.*, 2018; Monteiro *et al.*, 2020; Silva *et al.*, 2022).

In this sense, a study proposed by Dalton and Jin (2010) that analyzes oil spills in protected areas highlights the problem of regulating oil activities and the damage caused to PAs. This confirms that resources within these areas are no longer protected against oil spills than those outside their boundaries.

Nunes *et al.* (2023) assess the oil spill that occurred on the Southwest Atlantic coast of Brazil in 2020, pointing to approximately 1,009 reports of oil slicks. Of these, 480 were located within the boundaries of PAs and 346 in their buffer zones, causing ecological disturbance and, consequently, socioeconomic concerns.

Deforestation and Wildfires

Deforestation and wildfires are often closely linked. In the Protected Areas studied, wildfires exert severe pressure (36), except the Tracuateua Marine RESEX, which did not show signs of wildfires. Deforestation presents a moderate degree of pressure (12), with the São João da Ponta, Mãe Grande Curuçá, Maracanã, Tracuateua, Araí-Peroba, and Mestre Lucindo Marine RESEXs standing out.

The loss of tropical forests poses a significant threat to biodiversity and ecosystem functioning, potentially leading to climate change and disruption of local livelihoods (Boillat *et al.*, 2022).

Regarding PAs, despite the expansion of protected areas since the 1990s, these territories remain under constant threat from anthropogenic activities, including settlement encroachment, land-use and land-cover changes, mining, livestock farming, agriculture, and logging (Wade *et al.*, 2020). According to Jones *et al.* (2018), approximately one-third of the world's protected areas are under human pressure.

Within the context of drivers, agricultural expansion drives forest loss, and such expansion and activities are linked to global demand for meat and fodder (Armenteras *et al.*, 2017).

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Another factor associated with the expansion of deforestation is wildfire, which, according to Ramalho *et al.* (2021), poses one of the greatest threats to Protected Areas. Despite enforcement and monitoring programs, the issue persists unabated.

In the Amazon, deforestation rates have increased significantly recently, rising by 34.4% from 2018 to 2019 and 21.9% from 2020 to 2021 (INPE, 2021). These movements have historically been associated with land grabbing and occupation, large enterprises, and, above all, the weakening of environmental policies. (Athayde *et al.,* 2022; Conceição *et al*., 2021).

Buffer Zone

Generally, when applying the extension to the Buffer Zone, Marine RESEXs exhibit considerable pressure indices. An additional factor is the absence of a Management Plan in most of the Protected Areas in the Pará Coastal Zone. In contrast, the Soure and Caeté-Taperaçu Marine RESEXs showed the lowest pressure indices, a factor associated with the existence of a Management Plan and the maturation of management tools.

According to Almeida-Rocha and Peres (2021), special attention should be given to areas surrounding PAs to reduce the impacts of anthropogenic activities and edge effects. To this end, some countries have established regulations for buffer zones, which are areas subject to land-use restrictions, to act as a protective barrier and mitigate the harmful effects of human activities while also promoting livelihoods for neighboring human populations (Lima; Ranieri, 2018).

According to Lima and Ranieri (2018), the presence of a management plan in Protected Areas, as well as the regulation of Buffer Zones, is essential for the success and mitigation of anthropic pressures.

Thus, it is evident that legal management factors and conservation practices are closely associated.

FINAL CONSIDERATIONS

An analysis of pressures on the 12 Protected Areas reveals that the activities exerting the most significant pressure are fishing, oil extraction, wildfires, deforestation, and tourism, underscoring the need for stricter control of these activities in the region. The conservation units that presented the highest degree of pressure are those that are behind schedule with their management plans and other legal aspects, indicating that management is not effectively associated with conservation practices. Management, human, and economic resources are still obstacles to the effectiveness of RESEX in the Amazon Coastal Zone.

The study suggests enforcement and monitoring actions, which are essential for minimizing impacts on PAs. Ultimately, the method employed in the Marine RESEXs enabled the identification of pressures and threats, thereby contributing to a more profound understanding of existing social, economic, and environmental relationships.

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Carolina da Silva Gonçalves: Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Writing – Original Draft and Writing – review & editing. Márcia Aparecida da Silva Pimentel: Supervision and Writing – review & editing. Milena Marília Nogueira de Andrade: Conceptualization, Investigation, Supervision and Writing – review & editing.