CONTRIBUTIONS TO MARINE SPATIAL PLANNING IN THE BRAZILIAN COASTAL REGION

CONTRIBUIÇÕES PARA O ORDENAMENTO ESPACIAL MARINHO NA REGIÃO COSTEIRA BRASILEIRA

CONTRIBUCIONES A LA PLANIFICACIÓN ESPACIAL MARINA EN LA REGIÓN COSTERA BRASILEÑA

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ABSTRACT

The role of the oceans has been fundamental for sustaining life on the planet. However, they are increasingly facing significant issues of the modern world: in many places, every cubic meter of the ocean bears multiple, often conflicting demands, leading to heightened competition for space and resources. In the future, this situation will become unsustainable. Therefore, it is essential to manage marine space to allocate and organize the activities taking place within it, that is, to develop Marine Spatial Planning (MSP). In this context, the work proposes zoning the main activities identified along the Brazilian coast, aiming to contribute to the country's marine spatial planning, which, with 5.7 million square kilometers (a coastline exceeding 10,000 kilometers), still lacks planning in this sector. The methodology considered various global literature examples and the legal framework, also

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supported by digital technologies based on Geographic Information Systems (GIS), which facilitated the spatialization of data, information, and complex spatial analyses. The results suggest a mapping and analysis of the primary activities in the Brazilian Coastal Zone, a proposed zoning for the Brazilian coastal region, also presenting a set of guidelines to contribute to the study and development of the topic, aiming to continuously improve the process.

Keywords: Brazilian coastal region. Marine spatial planning. GIS. Geoenvironmental Guidelines.

RESUMO

O papel dos oceanos tem sido fundamental para a sustentação da vida no planeta. No entanto, eles vêm enfrentando, cada vez mais, questões significativas do mundo moderno: em muitos lugares, cada metro cúbico do oceano suporta múltiplas demandas, frequentemente conflitantes, o que leva a uma crescente competição por espaço e recursos. No futuro, essa situação se tornará insustentável. Portanto, é essencial gerir o espaço marinho para alocar e organizar as atividades nele desenvolvidas, ou seja, elaborar o Ordenamento do Espaço Marinho (OEM). Nesse contexto, este trabalho propõe o zoneamento das principais atividades identificadas ao longo da costa brasileira, com o objetivo de contribuir para o planejamento espacial marinho do país, que, com 5,7 milhões de quilômetros quadrados (e um litoral que supera os 10.000 quilômetros), ainda carece de planejamento nesse setor. A metodologia considerou diversos exemplos da literatura mundial e o arcabouço legal, além do suporte de tecnologias digitais baseadas em Sistemas de Informação Geográfica (SIG), que facilitaram a espacialização de dados, informações e análises espaciais complexas. Os resultados apontam para um mapeamento e análise das principais atividades na Zona Costeira Brasileira, uma proposta de zoneamento da região litorânea, além da apresentação de um conjunto de diretrizes para contribuir com o estudo e o desenvolvimento do tema, visando ao aprimoramento contínuo do processo.

Keywords: Região costeira brasileira. Ordenamento do espaço marinho. SIG. Diretrizes geoambientais.

RESUMEN

El papel de los océanos ha sido fundamental para sostener la vida en el planeta. Sin embargo, cada vez enfrentan más problemas significativos del mundo moderno: en muchos lugares, cada metro cúbico del océano soporta múltiples demandas, a menudo conflictivas, lo que genera una creciente competencia por el espacio y los recursos. En el futuro, esta situación será insostenible. Por lo tanto, es esencial gestionar el espacio marino para asignar y organizar las actividades que se desarrollan en él, es decir, desarrollar la Planificación Espacial Marina (PEM). En este contexto, el trabajo propone el zonificación de las principales actividades identificadas a lo largo de la costa brasileña, con el objetivo de contribuir a la planificación espacial marina del país, que, con 5,7 millones de kilómetros cuadrados (y una línea costera que supera los 10.000 kilómetros), aún carece de planificación en este sector. La metodología consideró diversos ejemplos de la literatura mundial y el marco legal, además del apoyo de tecnologías digitales basadas en Sistemas de Información Geográfica (SIG), que facilitaron la espacialización de datos, información y análisis espaciales complejos. Los resultados sugieren un mapeo y análisis de las principales actividades en la Zona Costera Brasileña, una propuesta de zonificación para la región costera, y también presentan un conjunto de directrices para contribuir al estudio y desarrollo del tema, con el objetivo de mejorar continuamente el proceso.

Palabras clave: Región costera brasileña. Planificación espacial marina. SIG. Directrices geoambientales.

INTRODUCTION

Oceans cover 71% of the Earth's surface and are vital for sustaining life (VISBECK, 2018). They regulate climate, provide food, support energy generation, and host diverse ecosystems, many of which remain unexplored due to deep-sea inaccessibility (AMBSDORF et al., 2017). Over 40% of the world's population lives in coastal zones up to 200 km from the shore, and in Brazil, this percentage reaches 80% (ARAÚJO FILHO et al., 2022; VIOLANTE et al., 2022). The interaction between oceans and society can be viewed as a sustainability cycle (AMBSDORF et al., 2017). Oceans offer essential services such as oxygen production, nutrient cycling, and carbon sequestration, benefiting human life and economies. In turn, human actions can either preserve or degrade ocean health. Responsible behaviors include reducing emissions, managing waste, and protecting sensitive zones. However, overfishing, pollution, and acidification threaten this balance.

Brazil plays a strategic role in marine sustainability due to its vast coastline and marine biodiversity. The Brazilian Exclusive Economic Zone (EEZ), known as the "Blue Amazon", covers about 3.6 million km², with potential expansion to 5.7 million km² (MARINHA DO BRASIL, 2023). This area holds major environmental and economic significance, mirroring the Amazon rainforest in its biodiversity and resource wealth. Nonetheless, as populations and industries expand along coasts, pressure on marine resources increases. This overuse raises challenges like pollution, habitat loss, and resource competition. Each cubic meter of the ocean may serve multiple, often conflicting, purposes (VISBECK, 2018). Without coordinated management, ocean degradation is likely to intensify.

Marine Spatial Planning (MSP) was developed as a strategy to address such challenges (BOYES et al., 2007). MSP is a framework for organizing and managing the use of marine spaces in a forward-looking and integrative manner. It aims to allocate space for multiple uses while minimizing conflicts and promoting sustainability. UNESCO defines MSP as a public process to balance ecological, economic, and social goals in marine areas through informed decision-making (EHLER & DOUVERE, 2009). Over the last two decades, MSP has gained prominence. More than 70 countries have initiated MSP processes, covering over half

of the world's EEZ area (SANTOS et al., 2019; SANTOS et al., 2020). While most are in early stages, countries like China and those in Northern Europe have made significant advances. The trend continues to grow, especially in developing regions such as Africa and South America.

In Brazil, MSP has not yet been formally adopted, primarily due to the vast size and complexity of its marine territory. Implementing a unified national MSP would cost an estimated R$30 million (VIOLANTE et al., 2022). To address this, the Blue Amazon was divided into four regions: North, Northeast, Southeast, and South. As of March 2023, BNDES had initiated a public selection process to support technical studies for implementing MSP in the South Region (BNDES, 2024). This initial phase is expected to be concluded within three years. The goal is to complete MSP development across the country by 2030, incorporating lessons from this pilot.

In line with the United Nations Sustainable Development Goals (SDGs), Marine Spatial Planning (MSP) is an essential tool for addressing the challenges that hinder their achievement. Although oceans and seas are often primarily associated with SDG 14 (Life Below Water), they are connected to all 17 SDGs (GRIGGS et al., 2017; UNESCO-IOC, 2022), some more directly than others. Specifically, the SDGs related to the environment and society benefit significantly from the implementation of MSP. For instance, in the context of SDG 7 (Affordable and Clean Energy), MSP can help identify suitable areas for developing ocean renewable energy sources, such as offshore wind energy, among others, contributing to the promotion of clean and renewable energy production.

Regarding renewable energy sources, several can be explored in the marine environment in an accessible and clean manner. These include ocean-based sources that utilize marine resources: wave energy, tidal energy, ocean currents, thermal gradients, and salinity gradients; as well as sources that exploit the ocean's physical space: offshore wind energy (the most developed source globally), offshore solar energy, and low-carbon hydrogen. The trend is for these technologies to advance further, contributing to a cleaner and more sustainable energy matrix and playing a fundamental role in the fight against climate change.

Another highly relevant factor is that we are currently in the Decade of Ocean Science for Sustainable Development (2021-2030): "The Ocean Decade," established by the UN to promote advances related to the oceans that support the health and sustainability of seas and oceans, mobilizing public, private, and civil society actors. The actions of the "Ocean Decade" encourage reflection on urgent and necessary measures for the use and protection of coastal and marine spaces worldwide (UN, 2021).

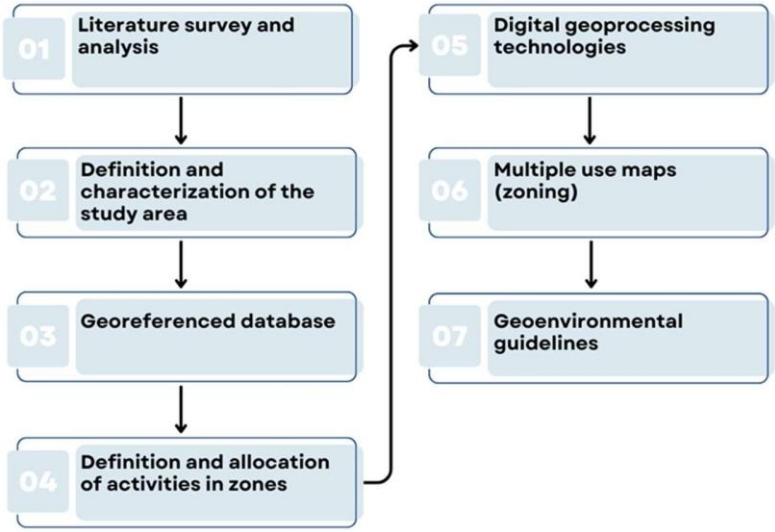
Marine Spatial Planning (MSP) has become a global trend, with Northern Europe and China implementing and reviewing MSP across their entire marine areas, while Oceania and the United States have partially adopted it (Frazão Santos et al., 2019). Brazil has not yet developed an official MSP. However, between December 2022 and March 2023, the National Bank for Economic and Social Development (BNDES) supported a technical study to implement a Pilot MSP Project in the Southern Marine Region of Brazil (BNDES, 2023). This initiative is expected to promote further research and help tailor MSP implementation in Brazil based on the experience of more advanced countries.

The goal of this article, contributing to Marine Spatial Planning in Brazil, is to propose zoning for the various and different activities in Brazil's marine space.

METHODOLOGY

The methodology adopted is divided into seven stages (Figure 1). Initially, an extensive literature review was conducted, supported by a meta-analysis of over 150 scientific articles, to consolidate the theoretical framework on the subject. Subsequently, the study area was defined, focusing on the most relevant socio-economic, geobiophysiographic, and environmental aspects of the Brazilian coast.

Figure 1. Methodological Flowchart of the research.



Next, spatial data on socio-economic, geobiophysiographic, and environmental topics were collected and organized into a georeferenced database. This data includes information on maritime space use and resources, such as fishing, environmental protection, tourism, offshore energy, navigation, among others – which helped to allocate the multiple activities into zones. A Geographic Information System (GIS) was developed using ArcGIS 10.6.1, which facilitated data integration, information georeferencing, map production, and complex spatial analyses.

The kernel density methodology was used as a spatial analysis tool, which employs a statistical interpolation method to estimate density curves and represent the intensity of a specific phenomenon. This method was applied to activities with high frequencies that made it challenging to interpret information across the entire study area.

Based on the literature and different MSP models consulted, as well as identified regulatory measures, a multi-use zoning scheme for the Brazilian coastal region was developed, establishing differentiated levels through specific zones.

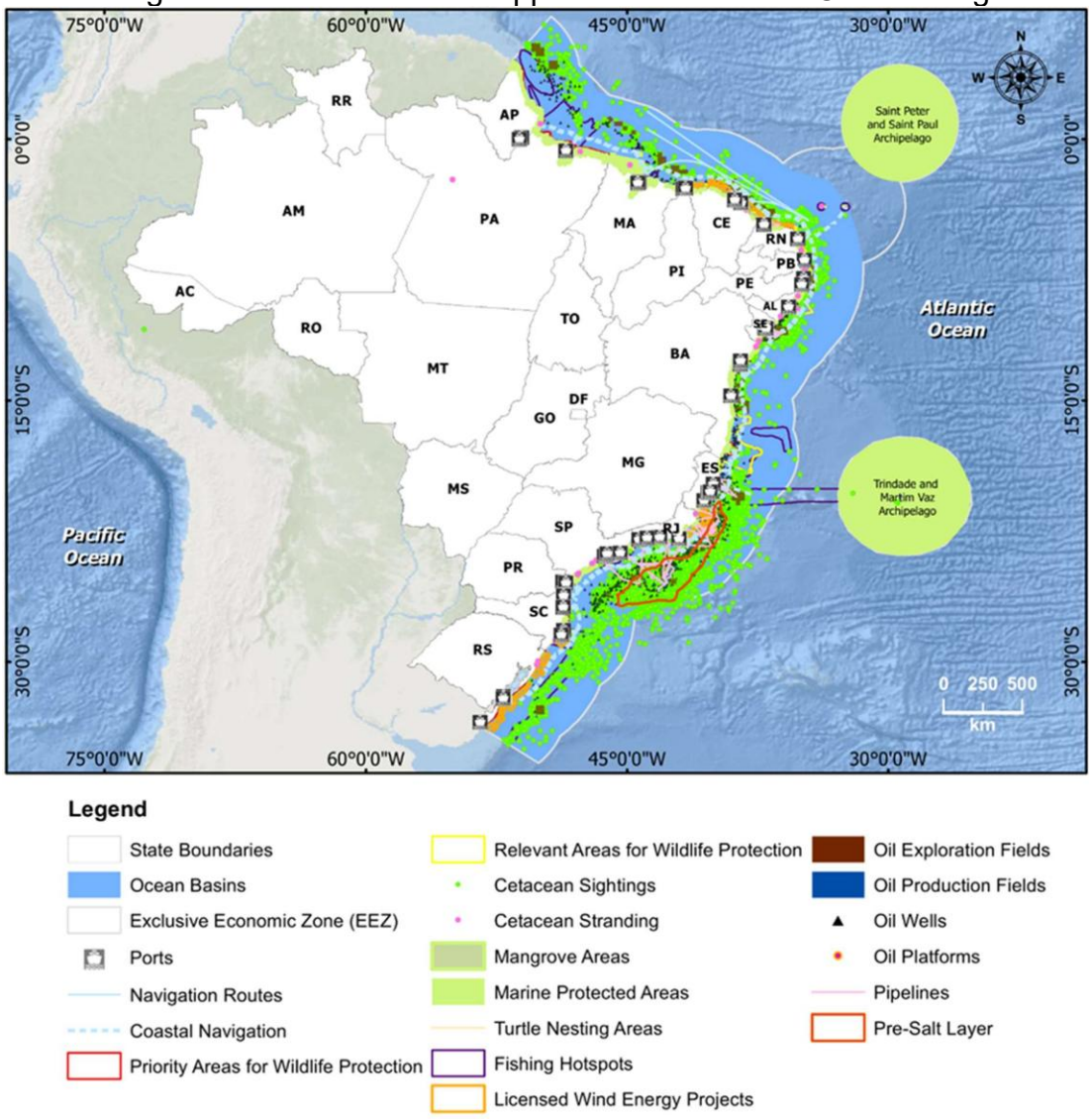
After analyzing the results, recommendations and guidelines were proposed, offering a set of ideas and challenges for the management and spatial organization of Brazil's marine space, as well as pathways for future work, contributing to the discussion and enhancement of the topic.

RESULTS AND DISCUSSIONS

The results illustrate the proposed zoning scheme and its main constraints, showing where activities are permitted, restricted, or prohibited according to existing legal regulations.

Initially, the predominant activities along the Brazilian coast were mapped (the results are depicted in Figure 2). This figure highlights the importance of the Brazilian Coastal Region and illustrates the high frequency of activities and resources that characterize the region's significant complexity, making marine space management particularly challenging.

Figure 2. Main Activities Mapped in the Brazilian Coastal Region.



PROPOSED ZONING FOR THE BRAZILIAN MARINE SPACE

The proposed zoning, based primarily on English Nature (1994), Gubbay (1996) and Gubbay & Laffoley (1996), identifies the zones where each activity or use can occur (Figure 3). The color code represents the management

arrangements and different levels of protection in each zone. The blue color represents zones where any activity could occur, subject to current legislation; the green and orange colors refer to zones with increasing levels of restrictions.

To enhance comprehension and facilitate the analysis of the proposed zoning map (Figure 4), zones were defined where various activities are grouped. Through a detailed analysis of a representative set of Marine Spatial Planning (MSP) examples from around the world, including their zoning, and adapting to Brazilian realities based on current legislation and prevalent local activities, three main types of zones were suggested. Each zone offers a progressively higher level of environmental protection and active management. The proposed zones, listed from the least to the most protection, are:

- General Use Zone (GUZ), with subzones of Minimum Management (MMZ) and Directed Management (DMZ);
- Conservation Priority Zone (CPZ); and
- Exclusion Zone (EZ), with subzones of Limited Exclusion (LEZ) and Significant Exclusion (SEZ). A description of each zone is presented below:

GENERAL USE ZONE (GUZ)

Zone 1A - Minimum Management Zone (MMZ): Initially, activities occurring in this zone are already permitted by national legislation. In other cases, activities may occur legally, subject to consents and licenses issued by relevant authorities, provided proposals are deemed technically viable and environmentally sustainable—becoming Zone 1B (see below);

Zone 1B - Directed Management Zone (DMZ): This zone defines areas within Zone 1A where an authorization, license, or consent has been granted for an activity or development according to relevant legislation controlling that activity. Activities in this zone are subject to regional, national, and international regulations and are managed and/or monitored by relevant authorities. Such activities may restrict other developments.

CONSERVATION PRIORITY ZONE (CPZ)

This zone includes all areas designated for their conservation value, including Marine Protected Areas, Mangrove Areas, Fish-Bird-Cetacean Areas, and Turtle Nesting Areas. Activities in this region are not automatically restricted but are generally subject to higher levels of control, assessment, and monitoring. An activity may be legally permitted if developers can demonstrate that their

proposals will not have a significant detrimental effect on the conservation status of the site.

Exclusion Zone (EZ)

Zone 3A - Limited Exclusion Zone (LEZ): This subzone involves activities that impose a temporary exclusion zone affecting other activities using the same marine space. For example, fishing protection areas where legislation defines areas that are seasonally or permanently closed to specific types of fishing. This provides protection to target species, ensuring their continued existence, though it does not restrict other activities in the area.

Zone 3B - Significant Exclusion Zone (SEZ): This subzone contains legally permitted activities requiring a significant exclusion zone around them for health and safety reasons to avoid collisions and offer development protection. Zoning includes both the activity and the safety area. Examples include safety zones of 500 meters around oil and gas platforms and wind turbines. As more developments occur at sea, this zone will likely increase in size. The zone would be reduced if developments were completed, abandoned, or decommissioned.

Figure 3. Distribution of Activities and Justification for Zoning.

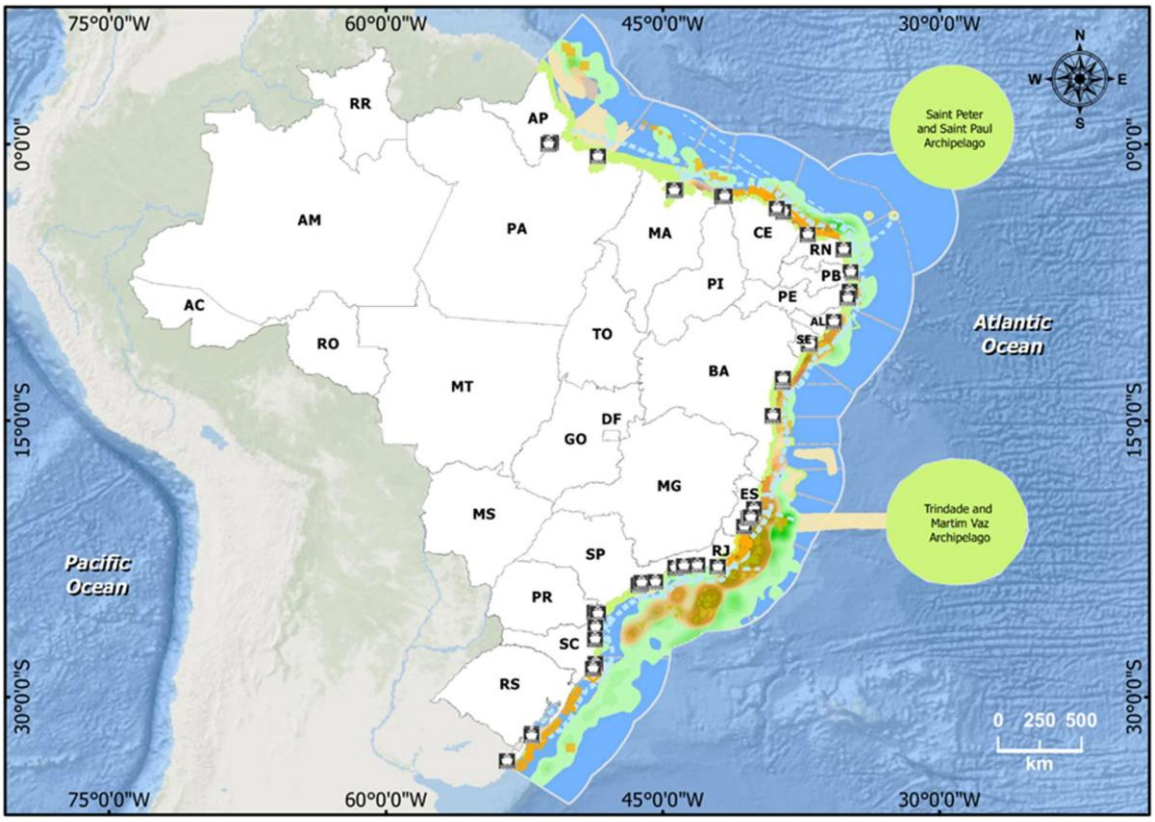
Activity	Zone		Justification
Windfarm Safety Zones	3B. Significant Exclusion Zone	3. Exclusion Zone	Restricted access zone (equivalent to exclusion) established for safety reasons per activity. Total exclusion of all other activities within a maximum radius of 500 m.
Windfarm Developments			
Oil & Gas Surface Structures			
Oil & Gas Wells			
Oil & Gas Pipelines			Excludes activities such as dredging sediment from the bed of water bodies, 250 m on each side.
Fishery Protected Areas	3A. Limited Exclusion Zone		Seasonal or annual restricts imposed on gear / quota or target species. Does not prevent other activities using the sea area.
Turtle Nursery Areas			
Mangrove Areas	2. Conservation Priority Zone		By definition, these areas form a series of marine protected areas.
Marine Protected Areas			
Priority and Relevant Wildlife Areas			
Port Infrastructure - Navigation	1B. Targeted Management Zone	1. General Use Zone	Designated areas for shipping movements.
Tourism	1A. Minimal Management Zone		All other activities can take place in this zone if they are legally permitted. There is potential for the development of activities in this zone. This zone is already used for navigation, recreation, research, study and fishing.
Remainder of the Coastal Area			

The proposed multi-use zoning scheme for the Brazilian coastal region is illustrated on the map in Figure 4. This map indicates the geographic extent of the zones, revealing the patterns of multi-use zoning created by applying existing regulations, which either permit, limit, or prohibit activities in specific geographic areas.

For those activities with high frequencies, which made it challenging to interpret information across the entire study area, the kernel density methodology was applied. This spatial analysis tool uses a statistical interpolation method to estimate density curves and represent the point intensity of a particular phenomenon. Kernel density curves were primarily applied in Zones 2B and 3B, addressing the following activities: cetacean strandings and sightings, and oil platforms and wells, respectively.

Potentially, all activities can occur in Zone 1A; however, as one progresses through the colored zones, there are increasing levels of legislative control. Therefore, activities were mapped based on the zone where they are most legally restricted.

Figure 4. Proposed Zoning for Marine Spatial Planning of the Brazilian Coastal Region.



Legend

State Boundaries
Ocean Basins
Ports
Z1A: Minimal Management Zone
Z1B: Targeted Management Zone
Z2: Conservation Priority Zone

Cetaceans density: stranding and sighting (Z2)
100%
0%

Density of oil platforms and wells (Z3B)
100%
0%

Z3A: Limited Exclusion Zone
Z3B: Significant Exclusion Zone

GEOENVIRONMENTAL GUIDELINES

Marine spatial planning is crucial for coastal and marine management, aiming to balance human activities with environmental conservation. For Brazil, with its vast coastline and rich marine biodiversity, the development of robust geoenvironmental guidelines is essential. To continually improve this process, the following guidelines are proposed:

- Ecosystem and Biodiversity Analysis
  Ecosystem Mapping: Conduct a detailed survey of different types of marine and coastal ecosystems, including coral reefs, mangroves, seagrass beds, and pelagic areas.

  Identification of High Biodiversity Areas: Identify and protect areas with high biodiversity and endemism, including critical habitats for threatened and migratory species.

- Environmental Impact Assessment:
  Impact Modeling: Use modeling techniques to predict and assess the impacts of human activities (such as fishing, tourism, and mineral exploration) on marine ecosystems.

  Continuous Monitoring: Establish monitoring programs to assess environmental changes and implement mitigation measures as needed.
- Integrated and Participatory Management:
  Community Engagement: Involve local communities, particularly those directly dependent on marine resources, in the planning and management process.

  Interinstitutional Coordination: Promote cooperation between different levels of government and institutions to ensure an integrated approach to marine resource management.

  Sectoral Integration: Foster coordination among government sectors involved in marine management, such as environment, fisheries, transport, and energy.

  Management Instruments: Utilize a combination of management tools, such as zoning, environmental licensing, creation of protected areas, and management plans.
- Marine Spatial Planning and Land Use:
  Marine Zoning: Create marine zones with different categories of use and protection, such as conservation areas, sustainable fishing zones, and development areas.

  Land Use Plans: Develop and implement marine land use plans that consider the environmental, social, and economic characteristics of coastal and marine areas.
- Protection and Restoration of Critical Areas:
  Protected Areas: Establish and expand marine protected areas to conserve critical habitats and threatened species. Ecological Restoration: Implement ecological restoration projects to recover degraded ecosystems and enhance the resilience of marine systems.
- Research and Innovation:
  Research Support: Support scientific research to better understand marine ecosystems and the impacts of human activities on them.

  Technology and Innovation: Promote the use of innovative technologies for environmental monitoring and sustainable management of marine resources.

- Education and Awareness:
  Awareness Campaigns: Conduct educational campaigns to raise public awareness about the importance of marine conservation and sustainable practices.

  Educational Programs: Implement educational programs in schools and communities about the marine environment and best practices for sustainable use.
- Risk Management and Climate Change Adaptation:
  Risk Assessment: Identify and assess risks related to climate change, such as sea level rise and ocean acidification, and develop adaptation strategies.

  Climate Action Plan: Integrate climate mitigation and adaptation actions into marine management plans.

  Future Scenarios: Consider the impacts of climate change on marine ecosystem dynamics and species distribution.

  Adaptation Measures: Include climate adaptation measures in zoning, such as creating ecological corridors and protecting vulnerable coastal areas.
- Specific Issues:
  Marine Protected Areas: Establish a representative network of marine protected areas with various levels of protection.

  Fishing: Implement ecosystem-based fisheries management measures, such as defining exclusion zones for fishing and controlling fishing capacity.

  Aquaculture: Promote sustainable aquaculture development, avoiding conflicts with other activities and minimizing environmental impacts.

  Maritime Transport: Minimize risks of accidents and pollution associated with maritime transport by establishing safe routes and anchorage areas.

  Oil and Gas Exploration: Regulate oil and gas exploration to prevent spills and other environmental impacts. Tourism: Promote sustainable tourism, avoiding degradation of marine ecosystems and ensuring water quality.
- Challenges and Opportunities:
  Scientific Knowledge: Increase investment in research and development to generate knowledge about Brazilian marine ecosystems.

  Capacity Building: Train public managers and civil society for integrated coastal and marine zone management.

  International Cooperation: Strengthen international cooperation to address transnational marine management challenges.

CONCLUSION

Developing an effective marine spatial planning (MSP) scheme is a complex and challenging process, but it is crucial for ensuring the conservation of marine biodiversity and the sustainable use of natural resources.

In order to improve this study, a more detailed approach in specific regions of the country is necessary to highlight local representativeness and demonstrate their importance and complexities. In this context, the following regions are notable:

- The Brazilian Equatorial Margin (BEM), located in the North region, is currently emerging as a new frontier for offshore oil exploration;
- The Northeast region, with its potential for ocean renewable energy exploration, particularly wind and solar power;
- The Southeast region, which has the largest area of ocean resource exploitation, especially oil, and
- The South region, characterized by its larger territorial dimension and less intensive use of marine resources.

Ultimately, the proposed guidelines can contribute to ensuring that marine spatial planning in Brazil is conducted sustainably and efficiently, promoting the conservation of natural resources and the well-being of coastal communities.

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