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Adaptive capacity of vulnerability in tropical estuaries: challenges and directions for environmental governance and democracy

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Capacidade adaptativa da vulnerabilidade em estuários tropicais: desafios e direcionamentos da gestão e democracia ambiental

RESUMO

Objetivo - identificar os principais aspectos da capacidade adaptativa da vulnerabilidade, frente a riscos ou exposições à ameaças ambientais e antrópicas em estuários tropicais, destacando os principais desafios e direcionamentos da gestão e democracia ambiental para esse ecossistema.

Metodologia – a primeira etapa metodológica se deu por meio de uma Revisão Bibliográfica Sistemática, a qual permitiu a identificação, seleção e análise crítica de estudos relevantes sobre vulnerabilidade, gestão e democracia ambiental em estuários tropicais. A segunda etapa envolveu uma análise de conteúdo, a fim de categorizar e interpretar os principais achados das publicações selecionadas.

Originalidade/relevância – a pesquisa preenche uma lacuna teórica relacionada à integração entre democracia ambiental e gestão territorial em estuários tropicais, tema ainda pouco explorado sob uma perspectiva sistêmica e de múltiplas escalas. Ainda, as articulações entre as temáticas contribuem para o avanço do conhecimento em políticas públicas ambientais e na governança de ecossistemas costeiros complexos, como os estuários.

Resultados - três aspectos principais foram identificados: (I) a importância do envolvimento dos atores sociais na criação de uma gestão ambiental integrada e justa; (II) os desafios na proteção dos estuários, que exigem compreensão de suas vulnerabilidades em diferentes escalas espaciais e temporais; e (III) o desenvolvimento de uma gestão territorial que incorpore monitoramento eficiente e ferramentas de modelagem adaptadas às especificidades locais (ambientais e sociais).

Contribuições teóricas/metodológicas - a relevância da democracia ambiental como elemento cerne para a resiliência socioecológica em estuários tropicais, enfatizando a necessidade da participação ativa das comunidades tradicionais na tomada de decisões.

Contribuições sociais e ambientais – socialmente tem-se a valorização do conhecimento tradicional e o fortalecimento das capacidades comunitárias para atuação em processos decisórios. Ambientalmente, a pesquisa direciona caminhos para uma gestão mais sensível às especificidades ecológicas dos estuários, favorecendo políticas públicas mais justas, eficazes e sustentáveis frente as vulnerabilidades ambientais.

PALAVRAS-CHAVE: Gestão integrada. Justiça social. Participação comunitária.

Adaptive capacity of vulnerability in tropical estuaries: challenges and directions for environmental governance and democracy

ABSTRACT

Objective – To identify the main aspects of adaptive capacity in relation to vulnerability, considering risks or exposure to environmental and anthropogenic threats in tropical estuaries, while highlighting key challenges and directions for environmental management and democracy in this ecosystem.

Methodology – The first methodological stage consisted of a Systematic Literature Review, which enabled the identification, selection, and critical analysis of relevant studies on vulnerability, management, and environmental democracy in tropical estuaries. The second stage involved content analysis in order to categorize and interpret the main findings of the selected publications.

Originality/relevance – This research addresses a theoretical gap concerning the integration of environmental democracy and territorial management in tropical estuaries, a topic still underexplored from a systemic and multi-scalar perspective. Furthermore, the articulation between these themes contributes to the advancement of knowledge in environmental public policy and the governance of complex coastal ecosystems such as estuaries.

Results – Three main aspects were identified: (I) the importance of involving social actors in the creation of integrated and equitable environmental management; (II) the challenges of protecting estuaries, which require understanding their vulnerabilities at different spatial and temporal scales; and (III) the development of territorial management that incorporates efficient monitoring and modeling tools adapted to local (environmental and social) specificities.

Theoretical/methodological contributions – The study highlights the significance of environmental democracy as a central element for socio-ecological resilience in tropical estuaries, emphasizing the need for the active participation of traditional communities in decision-making processes.

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Social and environmental contributions – Socially, the study promotes the recognition of traditional knowledge and the strengthening of community capacities for engagement in decision-making. Environmentally, the research offers pathways toward a management approach that is more sensitive to the ecological specificities of estuaries, fostering public policies that are more just, effective, and sustainable in the face of environmental vulnerabilities.

KEYWORDS: Integrated management. Social justice. Community participation.

Capacidad adaptativa de la vulnerabilidad en estuarios tropicales: desafíos y orientaciones para la gestión y la democracia ambiental

RESUMEN

Objetivo – Identificar los principales aspectos de la capacidad adaptativa frente a la vulnerabilidad, considerando los riesgos o exposiciones a amenazas ambientales y antrópicas en estuarios tropicales, destacando los principales desafíos y orientaciones para la gestión y la democracia ambiental en este ecosistema.

Metodología – La primera etapa metodológica consistió en una Revisión Bibliográfica Sistemática, que permitió la identificación, selección y análisis crítico de estudios relevantes sobre vulnerabilidad, gestión y democracia ambiental en estuarios tropicales. La segunda etapa implicó un análisis de contenido con el fin de categorizar e interpretar los principales hallazgos de las publicaciones seleccionadas.

Originalidad/relevancia – Esta investigación aborda una brecha teórica relacionada con la integración entre democracia ambiental y gestión territorial en estuarios tropicales, un tema aún poco explorado desde una perspectiva sistémica y multiescalar. Además, la articulación entre estas temáticas contribuye al avance del conocimiento en políticas públicas ambientales y en la gobernanza de ecosistemas costeros complejos como los estuarios.

Resultados – Se identificaron tres aspectos principales: (I) la importancia de la participación de los actores sociales en la construcción de una gestión ambiental integrada y justa; (II) los desafíos en la protección de los estuarios, que requieren la comprensión de sus vulnerabilidades en diferentes escalas espaciales y temporales; y (III) el desarrollo de una gestión territorial que incorpore un monitoreo eficiente y herramientas de modelización adaptadas a las especificidades locales (ambientales y sociales).

Contribuciones teóricas/metodológicas – El estudio resalta la relevancia de la democracia ambiental como elemento central para la resiliencia socioecológica en estuarios tropicales, subrayando la necesidad de una participación de las comunidades tradicionales en los procesos de toma de decisiones.

Contribuciones sociales y ambientales – A nivel social, se destaca la valorización del conocimiento tradicional y el fortalecimiento de las capacidades comunitarias para actuar en los procesos decisorios. A nivel ambiental, la investigación señala caminos hacia una gestión más sensible a las especificidades ecológicas de los estuarios, promoviendo políticas públicas más justas, eficaces y sostenibles frente a las vulnerabilidades ambientales.

PALABRAS CLAVE: Gestión integrada. Justicia social. Participación comunitaria.

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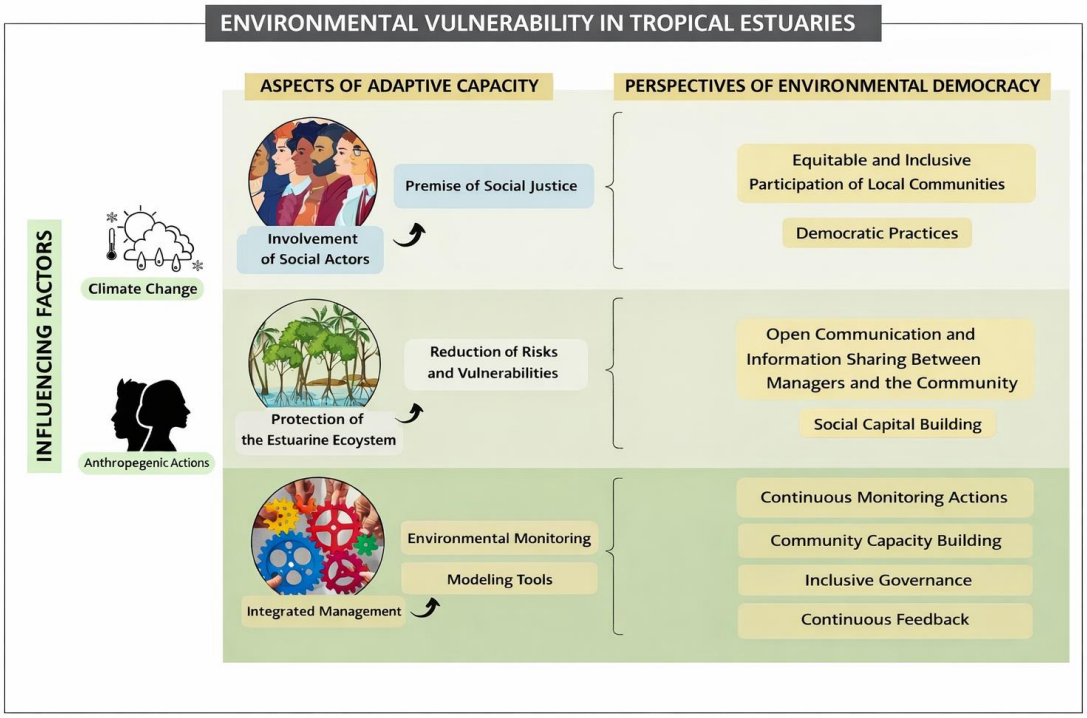
GRAPHIC ABSTRACT



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1 INTRODUCTION

Tropical estuaries are one of the most productive and complex ecosystems in the world, considered a transition zone between marine and terrestrial environments (Alongi, 2022). Estuaries are fundamental for maintaining biodiversity, providing fishing resources, coastal protection, among other environmental functions (Day et al., 2012; Wolanski et al., 2019). Despite their great ecological importance, these environments face significant pressures from climate change and urbanisation, which affect the balance and productivity of the ecosystem, making them increasingly environmentally vulnerable (Kennish, 2002; Alongi, 2012).

Ellison (2015, p.116) indicated that vulnerability is "an inclusive concept for analysing the socio-ecological response coupled with environmental change, defined as the propensity or predisposition to be adversely affected"; further taking into account the three components of vulnerability: exposure, sensitivity, and adaptive capacity. This is one of the most accepted concepts when working in estuarine environments (Fongnzossie et al., 2022; Thurman et al., 2022; Montefiore et al., 2023).

Environmental vulnerability in tropical estuaries is directly related to exposure to anthropogenic pressures and climate change, which increases the need for effective adaptation mechanisms. According to Adger (2006), the vulnerability of a system will depend both on the magnitude of the threat/risk and on the adaptive capacity of local communities to respond to these changes. Furthermore, Gallopín (2006) points out that adaptive capacity involves not only technological solutions, but also the integration of local knowledge and the active participation of communities in the establishment of public policies.

Further, the adaptive capacity of tropical estuaries is associated with responses to the effects of stresses/stressors (Turner et al., 2003). These responses are successfully implemented in relation to environmental variability, including behavioural adjustments to both resources and possible technologies (Adger, 2006). Thus, the adaptive capacity of communities in estuarine regions to respond to environmental changes will depend on several factors, including access to information, equity in decision-making, and inclusive governance (Adger, 2010; Berkes, 2006).

In this context, the implementation of environmental democracy, which may involve active and effective participation of local communities in environmental decision-making, emerges as a good prospect for promoting the sustainability of tropical estuaries (Carayannis; Campbell; Grigoroudis, 2021; Barrett et al. 2022). According to Parola (2017), environmental democracy is based on the principles of public participation, access to information, and access to justice in environmental matters. Furthermore, environmental democracy considers the equitable distribution of decision-making oportunities, access to environmental information, and the meaningful participation of all social actors interested in the environmental governance process (Newing; Fritsch, 2009).

In tropical estuaries, the environmental democracy approach is fundamental to envisioning vulnerability mitigation measures, as well as strengthening ties between many communities and the environment in which they live (Martin et al., 2020; Booi; Mishi; Andersen,

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2022). Thus, the inclusion of these communities in environmental governance can improve the effectiveness of conservation policies and reduce socio-ecological vulnerability (Lemos; Agrawal, 2006).

This study aimed to identify the main aspects of the adaptive capacity of vulnerability in the face of risks or exposure to environmental and anthropogenic threats in tropical estuaries, highlighting the main challenges and directions for environmental management and democracy for this ecosystem.

2 METHODOLOGY

The main aspects that enable adaptive capacity in the face of risks or exposure to environmental and anthropogenic threats in tropical estuaries were identified with a Systematic Literature Review (SLR). This methodological procedure sought to answer the following question: 'What are the current challenges, presented in scientific publications and productions, related to the management of estuarine regions and environmental democracy?'

The SLR was conducted using the Web of Science and SCOPUS databases. These databases were selected because they are among the largest and most important repositories of scientific journals (Archambault et al., 2009; Albach; Medeiros, 2020). The time frame of 2018 to 2024 for the SLR was chosen due to the higher concentration of publications on the subject, according to results identified by Nascimento and Hanai (2022).

The following equation was established using search strings in the databases: "estuar*" OR "tropical estuar*" AND "vulnerab*" OR "environm* vulnerab*" OR "aquatic vulnerab*" AND "management" AND "enviromen* democrac*".

As criteria for inclusion of results, publications relevant to integrated coastal zone management, environmental planning, and tropical estuary conservation were considered. In addition, studies addressing environmental democracy in estuaries were included, taking into account social participation and environmental citizenship, environmental justice, participatory environmental governance, and socio-environmental conflicts in estuarine areas.

In addition to the SLR, a content analysis was performed following the guidelines of Bardin (2016), establishing groupings considering the approach to aspects of the adaptive capacity of estuaries and their respective directions for management and environmental democracy. Furthermore, the author highlights the need to create categories that are exclusive, thus giving aspects of exclusivity, in addition to incorporating all the content obtained from the review.

3 RESULTS AND DISCUSSION

3.1 Aspects of adaptive capacity and environmental vulnerability in tropical estuaries

3.1.1 Involvement of social actors and protection of the estuarine ecosystem

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There are many challenges in managing tropical estuarine regions given their environmental vulnerabilities. One of them, according to Harris et al. (2022), is the high population density in these regions, since in addition to environmental problems, there are those associated with human actions. Thus, one of the advances in management must come from solutions that place human beings at the centre, since they are the main drivers of environmental vulnerabilities.

Wu et al. (2018) state that the coastal zone is the most populous and dynamic region on the planet due to the high degree and speed of urbanisation. As a result, it has become one of the most vulnerable in the world due to the high stress caused by anthropogenic activities and the consequences of climate change. The outcomes of estuary urbanisation are felt by the resident population on different scales, especially in relation to subsistence use, as evidenced by Moura, Bezerra and Lapa (2025) when investigating the Mangrove Park in the city of Recife, Pernambuco (Brazil).

Harris et al. (2021) propose the premise of **social justice**, which brings information and professionalisation to the most vulnerable communities living around estuaries. The distinguishing feature of this approach is raising awareness and transforming attitudes, leading to knowledge and the need for improvements to the environment. And by improving the environment, their quality of life will consequently improve. Thus, these actors themselves develop and suggest improvements for the estuaries, contributing to a significant improvement in the chain of environmental impacts generated by themselves (e.g., illegal waste disposal, predatory fishing, discharge of effluents into water bodies).

Corroborating the premise of Harris et al. (2022), Montefiore et al. (2023) assume that **direct access to local scientific knowledge** simplifies the understanding of the behaviour and threats inherent in the system that underpins the assessment, development and implementation of policies and technologies aimed at mitigating the adverse impacts of environmental vulnerabilities. Thus, having humans allied with the adaptive capacity of the system becomes fundamental to promoting improvements to estuaries.

Emphasising the most vulnerable communities, Addo et al. (2020) highlight the need to develop strategies aimed at **reducing risk and, consequently, exposure to vulnerabilities,** understanding their various levels and influencing factors. These strategies, in turn, are based on past knowledge of various estuaries.

Risks are higher in coastal communities in cities in developing countries, which consequently suffer from a lack of location-specific data and systems that can provide early warning of environmental risks and hazards (Addo et al., 2020). As a result, local management begins to develop and implement public policies with a systemic view, involving vulnerable communities and estuaries, thereby reducing potential vulnerabilities to the environment and communities. To this end, it is necessary to understand the levels and factors that aggravate environmental vulnerability.

3.1.2 Integrated management of tropical estuaries

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For good management of estuarine regions, it is essential to understand the ecosystem services present there, as well as to continuously monitor environmental quality and how these environments respond to climate change. To this end, Laurino et al. (2021) emphasise that it is often not necessary to use sophisticated technologies to manage an environment well, as many solutions can be found in nature itself. These solutions can be used to minimise the impacts of climate change or even to increase local productivity.

Laurino et al. (2021) suggest using bioindicators to monitor estuarine regions, as well as monitoring ecosystem services, since nature itself and the animals that inhabit it begin to give 'signals' when changes occur in their balance, especially with regard to climate change. Thus, this management approach supports local decision-making in response to global challenges.

Another major contemporary challenge for management is related to adaptations to and mitigation of climate change. In this regard, Raw et al. (2023) emphasise that estuarine ecosystems can and should potentially be used to respond to climate needs, since these environments are effective carbon sinks. The authors recommend the inclusion of these environments in public policies that guide responses to climate change.

Following the same line of thought as Laurino et al. (2021), Alves et al. (2020) reiterate that in-depth knowledge of the site is required, as well as the **monitoring of existing environmental vulnerabilities**, among which the authors highlight coastal erosion, which directly affects the local economy. This is because, within this factor, there are variables that are often not identified (regional climatic differences, coastal dynamics, tidal ranges, etc.). According to the authors, the natural geomorphology of coastal environments is and should be definitively associated with management and public policies, since regional differences strongly influence vulnerability. In addition, Machado and Albino (2023) highlight that awareness of local peculiarities and the understanding that coastal zones are not homogeneous are fundamental for effective management.

The need to carry out effective environmental monitoring often poses challenges for decision-makers. Tsai (2022), when conducting temporal monitoring of the Zengwun estuary in Taiwan, verified that the accuracy and continuity of information related to the coast and estuaries are fundamental for sound management and, consequently, for the conservation of these environments. However, what is desirable often does not reflect reality, resulting in data limitations and scarcity for decision-makers. In addition to conducting monitoring activities, standardisation of sampling designs (such as indices of use and periodicity) is required to ensure data accuracy and their subsequent applicability in the respective study areas.

With regard to **management models and tools** that consider environmental vulnerability in tropical estuarine regions, the main studies identified by the SLR highlight the use of geoprocessing to map climate change impacts, such as flood risks and sea-level rise (Al-Nasrawi et al., 2018; Khalil et al., 2020; Van Copellone; Temmerman, 2020; Imani et al., 2021; Ennouali et al., 2023; Sunkur et al., 2024). Geographic Information Systems (GIS) have proven to be an essential tool for scenario simulations and projections, enabling the use of a wide range of databases and the exploration of different scenarios across defined spatial and temporal scales.

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These GIS-based modelling tools provide valuable support for decision-makers, offering greater autonomy in the analysis of their study areas. However, the implementation of such tools is not always straightforward, as it requires consideration of local specificities. The replication of models from other regions without due caution may encounter obstacles related to data suitability and reliability, as well as failing to accurately reflect the specific needs of each locality.

Another important challenge is the need for continuous environmental monitoring, which is essential to ensure the provision of ecosystem services. To implement integrated and effective management, it is crucial to understand all factors that compose the ecosystem, encompassing both natural dynamics and anthropogenic pressures that affect these regions.

Environmental vulnerability in tropical estuaries occurs with greater incidence in developing countries. Thus, aspects related to adaptive capacity and corresponding management approaches must incorporate the communities surrounding these regions, as previously outlined. Based on this premise, Mattah et al. (2023), when studying socio-economic vulnerability in the Volta estuary in Ghana, found that community conditions directly interfere with the estuarine region. The implications are mainly related to basic sanitation, as domestic effluents are discharged directly into the water body, compromising the region's water quality.

The discharge of domestic effluents into water bodies ultimately becomes one of the most significant problems in estuaries. In this context, Montefiore et al. (2023) verified that government programmes and local environmental agencies in the United States use tools to monitor water quality in order to understand and reduce the effects of excessive nutrient loading in the estuarine plume. However, the major highlight of this process lies in the fact that planning and actions occurred through access to scientific knowledge, providing decision-makers with a broader range of information.

Furthermore, Montefiore et al. (2023) emphasise that scientific research provides improved strategies for estuarine management. If the various social actors within a given estuarine watershed had access to information and scientific research, the likelihood of minimising the effects of environmental vulnerabilities—particularly with regard to water quality—would be greater, offering potential resources for the implementation of effective actions in estuarine environments.

Nascimento, Hanai and Guilherme (2021), when conducting a study in the Capibaribe estuary, Brazil, demonstrated that it is fundamental to identify the main problems affecting the estuarine region, as well as their cascading effects on the locality. The identification of such issues contributes to the development of an environmental monitoring plan, as the evidence can be reliably used by decision-makers.

In summary, establishing and implementing strategies for the management of tropical estuaries requires an integrative approach that must be grounded in scientific evidence, providing rigourous proposals formulations and actions aimed at system adaptation. According to Dada, Almar and Morand (2024), these strategies can and should be composed of different methods to address the various vulnerabilities. Furthermore, according to Roy et al. (2023), a set of strategies for analysing vulnerability facilitates the generation of consistent and useful

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data, enabling decision-makers to establish strategies for impact minimisation and sustainable local development.

Based on the main challenges related to estuarine management identified in the literature, Table 1 presents the possible adaptations to be undertaken, their emphasis, and their respective management approaches aimed at minimising environmental vulnerability.

Table 1 - Summary of aspects of adaptive capacity associated with environmental vulnerabilities, with respective emphases and directions.

ASPECTS OF ADAPTIVE CAPACITY	EMPHASIS	DIRECTIONS	SOURCES
Involvement of social actors	Social justice	Adopt integrated environmental management that includes human beings, seeking social justice that favours a marked reduction in environmental impacts on estuaries.	Addo *et al.* (2020); Harris *et al.* (2022)
Protection of estuaries	Reduction of risks and vulnerability	Design and develop actions that seek to understand vulnerabilities at different scales, incorporating their complexities, favouring a marked reduction in environmental and social vulnerability, given that estuaries suffer greatly from urban pressure.	Wu *et al.* (2018); Addo *et al.* (2020); Machado e Albino (2023); Raw *et al.* (2023)
Integrated management	Environmental monitoring	Emphasise in the integrated management plan the need to understand environmental complexities. To this end, long-term environmental monitoring is necessary. This enables decision-makers to understand the real needs of the estuary, as well as to identify the main causes of environmental vulnerability.	Alves *et al.* (2020); Laurino *et al.* (2021); Nascimento, Hanai, Guilherme (2021); Tsai (2022); Montefiore *et al.* (2023)
	Modelling tools	Use tools that are relevant to the location of application, since each model has certain peculiarities and simple replication can affect data accuracy. Furthermore, it is necessary and essential that they be developed by specialists.	Al-Nasrawi *et al.* (2018); Khalil *et al.* (2020); Imani *et al.* (2021); Ennouali *et al.* (2023); Sunkur et al. (2024)

Source: Own authorship (2025)

3.2 Perspectives of Environmental Democracy for minimising vulnerability

The perspectives of environmental democracy for minimising vulnerability in tropical estuaries are increasingly being recognised as fundamental strategies for addressing the environmental and social threats that affect these ecosystems. Environmental democracy, which emphasises the equitable and inclusive participation of traditional local communities in environmental decision-making, can play a key role in reducing the vulnerability of estuarine

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populations (Reed et al., 2020). This discussion is essential when observing contexts in which centralised and exclusionary governance has proven insufficient and inadequate with regard to local needs and environmental pressures (Bursztyn, 2018).

The vulnerabilities identified in tropical estuaries are intensified by a range of factors, including climate change, pollution, and the degradation of natural resources, as previously discussed. Thus, the inclusion of communities in environmental governance processes through democratic practices can enhance the adaptive capacity of these environments, enabling them to respond more effectively to environmental changes and natural disasters (Armitage; Loë; Plummer, 2012). This community participation promotes and ensures that environmental policies are informed by local knowledge, which is essential for identifying specific vulnerabilities and for implementing mitigation strategies that are appropriate to local needs (Díaz et al., 2019).

Environmental democracy also contributes to the building of social capital, a critical factor in reducing vulnerability. This capital refers to networks of trust and cooperation within a community and is strengthened when communities are actively involved in the management of their natural resources (Adger, 2010). In tropical estuaries, where there is a direct relationship between local communities and the ecosystem, inclusive governance can enhance social cooperation and facilitate the implementation of sustainable practices that may reduce exposure to environmental risks (Pomeroy et al., 2017).

Another important aspect of environmental democracy perspectives is the improvement of environmental justice. Communities in tropical estuaries often face significant inequalities in access to resources and participation in decision-making processes. Environmental democracy seeks to correct these disparities by ensuring that all groups, especially marginalised and vulnerable ones, have a voice in the policies that affect their lives (Schlosberg; Collins, 2014).

The successful application of environmental democracy in tropical estuaries requires a commitment to community capacity-building and the creation of institutional mechanisms that facilitate and promote effective participation (Bäckstrand et al., 2010). This perspective includes strengthening local capacities for resource management, ensuring access to information, and creating deliberative spaces in which local voices can be heard and respected. Furthermore, it is essential that environmental policies are flexible and adaptive, allowing for adjustments based on continuous feedback from the communities involved (Folke et al., 2005).

With regard to risk and vulnerability reduction, environmental democracy contributes to open communication and information sharing between environmental managers and communities, enabling more efficient responses to environmental threats. Parola (2017) highlights that community involvement in decision-making processes helps to ensure that adaptation strategies are more equitable and effective, as they take into account the specific needs of the most vulnerable groups.

In terms of environmental monitoring, public participation tends to strengthen surveillance and control actions in estuaries. According to Smit and Wandel (2006), integrating local communities into monitoring activities results in more detailed and continuous knowledge of ecosystem changes, thereby increasing adaptive capacity to environmental change. One alternative for promoting integration between community, environment, and science is the use

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of Citizen Science. According to Silva and Hanai (2025), this approach constitutes a strategic tool in the formulation of public policies aimed at the preservation and conservation of biodiversity across different ecosystems and can be particularly effective in the context of tropical estuaries.

In the development of adaptive tools, such as modelling and territorial management technologies, environmental democracy ensures that these tools are adjusted to local realities. According to Adger (2006), adaptive governance that incorporates social participation and local knowledge results in technological solutions that are more closely aligned with environmental and social specificities. Thus, the relationship between environmental democracy and adaptive capacity in tropical estuaries is oriented towards the creation of participatory processes that strengthen adaptation and environmental management policies, promoting more robust resilience in the face of climatic and anthropogenic threats.

4 CONCLUSIONS

As a structural component of vulnerability, recognising and considering the adaptive capacities of estuaries in the face of exposure or risk are fundamental for identifying the main challenges of territorial management in tropical estuaries.

Four main aspects related to adaptive capacity were identified, namely: (I) the involvement of social actors surrounding these regions, so that integrated management can be developed with social justice within its scope; (II) the challenges associated with protecting the estuarine ecosystem, since it is necessary to understand risks and vulnerabilities across different scales; (III) the development of integrated management that encompasses environmental complexities through effective environmental monitoring; (IV) the adoption of appropriate modelling tools that incorporate local peculiarities in order to obtain accurate data that will support decision-makers.

Thus, understanding the three aspects mentioned is fundamental for establishing guidelines aimed at mitigating existing environmental vulnerabilities in tropical estuaries, in order to implement integrative management.

With regard to the perspectives of environmental democracy for tropical estuaries, it was observed that they are promising, offering a fundamental pathway for reducing vulnerability and promoting the sustainability of these ecosystems and their socio-environmental services. By integrating the equitable participation of local communities into environmental governance, environmental democracy strengthens the adaptive capacity and resilience of populations that depend on these complex and dynamic environments. This is particularly fundamental when considering the various contexts of environmental vulnerability, such as climate change, in which decisions must be made based on data and information derived from both scientific knowledge and local knowledges.

Furthermore, environmental democracy promotes social justice by ensuring that the voices of the groups involved are heard. This approach not only supports the effectiveness of environmental policies, but also contributes to social cooperation and the fair distribution of benefits and demands associated with natural resource management. Thus, for these perspectives to materialise, it is essential to invest in community capacity-building, institutional

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strengthening, and the creation of mechanisms that support continuous and meaningful community participation.

In summary, the implementation of environmental democracy in tropical estuaries represents an integrative and inclusive approach that not only mitigates vulnerability, but also promotes a more sustainable and equitable future for the populations that depend on estuarine ecosystems.

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AUTHOR CONTRIBUTION

NASCIMENTO, R.C.M. contributed to the conception and design of the study, data curation, formal analysis, investigation, methodology, initial draft writing, review, and final editing.
HANAI, F.Y. contributed to the conception and design of the study, critical review of the draft, revision and final editing, supervision.

CONFLICT OF INTEREST

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