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Challenges and strategies for SDG 14 in brazilian ports

Desafios e estratégias para o ODS 14 nos portos brasileiros

Desafíos y estrategias para el ODS 14 en los puertos brasileños

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Abstract

The port sector is integral to both global and local economies, managing a substantial share of international trade. Given their economic significance, ports are also prime locations for advancing sustainability, with many adopting measures aligned with this objective. The integration of the Sustainable Development Goals (SDGs) within the port sector provides a structured framework for sustainability, offering specific indicators to guide progress. This study assesses the implementation of the SDGs in the Brazilian port sector, focusing on SDG 14 (Life Below Water). The data were collected through interviews with eight respondents. The findings reveal that current practices align with recognised sustainability standards, particularly addressing SDG 14 targets 14.1, 14.2, and 14.5. Key initiatives include ISO 14001 certification, monitoring of aquatic life and water quality, waste management, and environmental education programmes. Voluntary socio-environmental projects, adherence to the UN Global Compact, and partnerships with academic and regulatory bodies further demonstrate a proactive commitment to sustainability. However, significant challenges

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persist, such as gaps in environmental noise monitoring, the conservation of Permanent Preservation Areas (PPAs), and the adoption of Environmental DNA (eDNA) for biodiversity monitoring. Enhanced environmental reporting standards and the adoption of SMART targets are recommended to strengthen SDG alignment. This study provides a comprehensive analysis of SDG 14 implementation in Brazilian ports, highlighting both successes and areas for improvement. As sustainability practices mature, Brazilian ports are well-positioned to contribute to the blue economy, balancing economic growth with marine conservation.

Keywords: Sustainable Development Goals. SDG 14. Sustainability. Blue Economy. Ports.

Resumo

O setor portuário é essencial para as economias globais e locais, gerenciando uma parcela significativa do comércio internacional. Dada sua relevância econômica, os portos também são locais estratégicos para promover a sustentabilidade, com muitos adotando medidas alinhadas a esse objetivo. A integração dos Objetivos de Desenvolvimento Sustentável (ODS) no setor portuário oferece uma estrutura organizada para a sustentabilidade, com indicadores específicos para orientar o progresso. Este estudo avalia a implementação dos ODS no setor portuário brasileiro, com foco no ODS 14 (Vida na Água). Os dados foram coletados por meio de entrevistas com oito respondentes. Os resultados revelam que as práticas atuais estão alinhadas com padrões de sustentabilidade reconhecidos, abordando particularmente as metas 14.1, 14.2 e 14.5 do ODS 14. As principais iniciativas incluem a certificação ISO 14001, monitoramento da vida aquática e da qualidade da água, gestão de resíduos e programas de educação ambiental. Projetos socioambientais voluntários, adesão ao Pacto Global da ONU e parcerias com instituições acadêmicas e reguladoras também demonstram um compromisso proativo com a sustentabilidade. No entanto, desafios significativos persistem, como lacunas no monitoramento de ruídos ambientais, conservação de Áreas de Preservação Permanente (APPs) e adoção de DNA Ambiental (eDNA) para monitoramento da biodiversidade. Recomenda-se o fortalecimento dos padrões de relatórios ambientais e a adoção de metas SMART para melhorar o alinhamento com os ODS. Este estudo oferece uma análise abrangente da implementação do ODS 14 nos portos brasileiros, destacando tanto os sucessos quanto as áreas para aprimoramento. À medida que as práticas de sustentabilidade amadurecem, os portos brasileiros estão bem posicionados para contribuir com a economia azul, equilibrando o crescimento econômico com a conservação marinha.

Palavras-chave: Objetivos de Desenvolvimento Sustentável. ODS 14. Sustentabilidade. Economia Azul. Portos.

Resumen

El sector portuario es fundamental para las economías globales y locales, gestionando una parte sustancial del comercio internacional. Dada su relevancia económica, los puertos también son puntos estratégicos para promover la sostenibilidad, con muchos adoptando medidas alineadas con este objetivo. La integración de los Objetivos de Desarrollo Sostenible (ODS) en el sector portuario proporciona un marco estructurado para la sostenibilidad, ofreciendo indicadores específicos para guiar el progreso. Este estudio evalúa la implementación de los ODS en el sector portuario brasileño, centrándose en el ODS 14 (Vida Submarina). Los datos se recopilaron mediante entrevistas con ocho participantes. Los resultados revelan que las prácticas actuales están alineadas con estándares reconocidos de sostenibilidad, abordando particularmente las metas 14.1, 14.2 y 14.5 del ODS 14. Las principales iniciativas incluyen la certificación ISO 14001, el monitoreo de la vida acuática y la calidad del agua, la gestión de residuos y los programas de educación ambiental. Los proyectos socioambientales voluntarios, la adhesión al Pacto Mundial de las Naciones Unidas y las colaboraciones con organismos académicos y regulatorios demuestran un compromiso proactivo con la sostenibilidad. Sin embargo, persisten desafíos significativos, como las deficiencias en el monitoreo del ruido ambiental, la conservación de las Áreas de Preservación Permanente (APP) y la adopción del ADN Ambiental (eDNA) para el monitoreo de la biodiversidad. Se recomienda reforzar los estándares de informes ambientales y adoptar objetivos SMART para mejorar el alineamiento con los ODS. Este estudio ofrece un análisis exhaustivo de la implementación del ODS 14 en los puertos brasileños, destacando tanto los logros como las áreas de mejora. A medida que las prácticas de sostenibilidad maduran, los puertos brasileños están bien posicionados para contribuir a la economía azul, equilibrando el crecimiento económico con la conservación marina.

Palabras clave: Objetivos de Desarrollo Sostenible. ODS 14. Sostenibilidad. Economía Azul. Puertos.

Introduction

Ports serve as critical nodes in the global transport chain, fostering economic growth by facilitating the movement of people, goods, and commodities. They are among the primary systems for exporting products and resources on an international scale. In 2022, Brazil's port sector handled an impressive 1,206.8 million tonnes of cargo, consisting of 712.4 million tonnes of solid bulk**,** 304 million tonnes of liquid bulk, and 128.4 million tonnes of containerised cargo (ANTAQ, 2023). This remarkable volume underscores the strategic role of ports, not only within Brazil but globally, where they act as fundamental components of international trade flows.

Port activities and developments are frequently linked to significant socio-economic benefits, such as increased GDP and employment. However, these benefits come with considerable environmental costs, including air and water pollution, loss of marine biodiversity, and coastal ecosystem degradation. Expanding port facilities often necessitates extensive dredging, which disrupts sediment flows, degrades marine habitats, and threatens ecological stability (Nogué-Algueró, 2020).

In Latin America**,** port expansion is occurring at an unprecedented rate, bringing profound socio-ecological impacts that particularly affect marine ecosystems and the communities dependent on them. In response, stakeholders are increasingly advocating for marine democracy**,** a governance approach that integrates local ecological knowledge into environmental decision-making processes. By including community voices in port governance, this approach promotes more sustainable and inclusive management practices (Anbleyth-Evans, 2023).

At regional levels, tailored policies and investments are required to balance economic growth with environmental preservation. For instance, Poland's blue economy contributes nearly 6% of the national GDP**,** generating substantial economic benefits that extend beyond coastal areas through intersectoral linkages. This demonstrates the importance of regional policies that support infrastructure, innovation, and workforce development in the maritime sector (Mogila *et al*., 2023).

Given their economic and environmental significance, ports play a fundamental role in achieving the United Nations Sustainable Development Goals (SDGs)**.** Introduced in 2015, the SDGs provide a comprehensive framework to guide global sustainability efforts, targeting completion by 2030. The SDGs address diverse issues, including poverty eradication, climate

action, and environmental protection, promoting interconnected actions across economic, social, and environmental dimensions (Roma, 2019).

Lee *et al*. (2020) systematically examined the intersection between the SDGs and port operations, particularly within the context of the blue economy. Their findings highlight the prominence of SDG 14 (Life Below Water)**,** which focuses on conserving and sustainably using marine resources. Other SDGs closely linked to port operations include SDG 8 (Decent Work and Economic Growth)**,** SDG 9 (Industry, Innovation, and Infrastructure), and SDG 11 (Sustainable Cities and Communities) (Wang *et al*., 2020).

Caliskan (2022) analysed sustainability reports from 33 European ports, identifying SDG 9 as the most frequently mentioned (32 ports), followed by SDG 12 (31 ports), SDG 13 (30 ports), and SDGs 11 and 17 (28 ports). Notably, SDG 14 also featured prominently, reflecting its critical importance within the port sector. In contrast, SDGs 5, 2, and 1 were the least represented, demonstrating disparities in focus across sustainability initiatives.

Sustainable Development Goal 14 (SDG 14) aims to conserve and sustainably use oceans, seas, and marine resources for sustainable development. Ports, due to their direct interaction with the marine environment, are key agents in achieving SDG 14. Efficient environmental management practices are essential, including waste management, marine pollution mitigation, and biodiversity conservation programmes (International Maritime Organization, 2017). Within this context, ports are uniquely positioned to implement actions such as monitoring aquatic biota**,** assessing water and sediment quality**,** minimising dredging impacts**,** reducing underwater noise, and supporting research on marine ecosystems. These initiatives are vital for promoting sustainable port operations that balance economic development with environmental stewardship (Caliskan, 2022).

Understanding how ports implement the Sustainable Development Goals (SDGs)**,** particularly SDG 14**,** is essential for advancing sustainable practices within the sector. The Brazilian port sector's alignment with SDG 14 reflects a commitment to fostering sustainable development and supporting the growth of the blue economy through strategic initiatives. This paper examines the progress of SDG implementation in Brazilian ports, with a particular focus on SDG 14 (Life Below Water). By analysing these efforts, the study aims to provide valuable insights into the actions undertaken and the challenges encountered by Brazilian ports in advancing the SDGs. Additionally, it addresses the environmental, social, and economic impacts associated with port activities, contributing to a broader understanding of the sector’s role in sustainable development.

Literature Review

Ports serve as critical nodes in the global transport chain, fostering economic growth by facilitating the movement of people, goods, and commodities. They are among the primary systems for exporting products and resources on an international scale. In 2022, Brazil's port sector handled an impressive 1,206.8 million tonnes of cargo, consisting of 712.4 million tonnes of solid bulk**,** 304 million tonnes of liquid bulk, and 128.4 million tonnes of containerised cargo **(**ANTAQ, 2023). This remarkable volume underscores the strategic role of ports, not only within Brazil but globally, where they act as fundamental components of international trade flows.

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This paper examines the progress of SDG implementation in Brazilian ports, with a particular focus on SDG 14 (Life Below Water). By analysing these efforts, the study aims to provide valuable insights into the actions undertaken and the challenges encountered by Brazilian ports in advancing the SDGs. Additionally, it addresses the environmental, social,

and economic impacts associated with port activities, contributing to a broader understanding of the sector's role in sustainable development.

Method

This study is characterised as an exploratory and descriptive field study, employing a qualitative methodology. The research focused on managers of public ports and terminals located in Brazil. It is important to note that during the administration of the questionnaire, participants remained anonymous, ensuring the confidentiality of individual responses.

To gain a deeper understanding within the framework of Sustainable Development Goal (SDG) 14, two distinct questionnaires were developed. The first focused on specific data related to SDG 14, while the second explored the broader targets associated with this goal. This methodological approach was designed to yield a comprehensive and nuanced view of how ports and terminals contribute to achieving the Sustainable Development Goals. Key themes covered in the questionnaires included environmental policy, environmental agendas, socio-environmental studies conducted and planned, environmental monitoring practices, and environmental impact assessments, among others.

The first questionnaire focusing on specific SDG 14 data consists of 14 questions, with 5 open-ended and 9 closed-ended or mixed questions. The second questionnaire addressing SDG 14 targets consists of 9 questions, with 5 open-ended and 4 closed-ended or mixed questions (Table 1).

Table 1

Key Questions from the SDG 14 Specific and Goals Questionnaires

Questionnaire: SDG 14 – Specific	Questionnaire: SDG 14 – Goals
1. Which of these monitoring activities has the port/terminal already executed, is currently executing, or plans to execute in its areas of influence? Options: Aquatic biota; Water quality; Marine sediment quality; Exotic species; Compensation for fishing activity; Ballast water control; Shoreline; Environmental DNA; Underwater noise; Mangrove or Permanent Protection Area. 2. Does the port/terminal have programmes and/or actions aimed at preserving the coastal zone, especially Permanent Protection Areas? 3. What actions does the port/terminal take to reduce marine pollution and the impact of port operations on local marine life? 4. Does the port/terminal implement any additional controls for monitoring ballast water exchange? If yes, please detail the process. 5. If the port/terminal conducts an aquatic biota monitoring programme, what are the sampled groups and the monitoring frequency? 6. Does the port/terminal monitor for the identification of invasive exotic species? If yes, please detail the process. 7. Does the port/terminal perform dredging? If yes, please detail the type and whether the impacts of the activity on aquatic biota have been identified and are monitored. 8. Does the port/terminal have any programmes focused on fishing activity? If yes, please detail the programme. 9. How is the port/terminal addressing the issue of sustainable fishing and the conservation of marine life in its operations? 10. Does the port/terminal have any programmes/systems to subsidise fishermen affected by its activities? If yes, please detail the programme. 11. Does the port/terminal have a system for recording environmental incidents and events? If yes, please detail the process. 12. How are the results of the port/terminal's environmental monitoring and/or management actions reported? Options: Environmental compliance report; Annual environmental performance report; Integrated report. 13. Does the port/terminal execute any other environmental programmes or actions not linked to a licence and/or environmental authorisation? If yes, please specify. 14. Comments for researchers.	1. Does the port/terminal have an environmental agenda aimed at achieving the SDGs? 2. Are there partnerships or agreements with other companies or entities to achieve the Sustainable Development Goals? If yes, please detail the initiatives. 3. What actions is the port/terminal implementing to contribute to SDG 14? 4. What are the main challenges faced by the port/terminal in implementing SDG 14? 5. Does the port/terminal have clear goals for achieving SDG 14? If yes, what are these goals? 6. If there are related goals for SDG 14, what is the expected timeframe for achieving them? 7. If there are actions for achieving the SDG 14 goals, what is the level of implementation/compliance? 8. Indicate, in ascending order, the priority environmental actions for the port/terminal. Options: Air quality; Ballast water; Port-city relationship; Water quality; Energy efficiency; Noise; Waste (port and ships); Port development; Dredging operations. 9. Comments for researchers.

The study targeted 20 ports and terminals with the highest levels of activity in 2022. Participation requests were issued via email correspondence, using contact information available on the websites of the selected port facilities, and supplemented by official requests

via the FalaBR platform for public ports. Responses were collected between 21st August and 15th November 2023, resulting in a sample of eight respondents. Collected responses were subjected to a comprehensive analysis, with results aggregated around specific keywords or core concepts to maintain respondent anonymity and confidentiality.

Results

The study conducted with Brazilian ports allowed for a comprehensive and in-depth evaluation of SDG 14 (Life Below Water) and its implementation. Additionally, the first question explored which Sustainable Development Goals (SDGs) were prioritised by the participating ports. This assessment encompassed a broad range of SDGs, underscoring the multidimensional role of ports in driving economic growth, promoting environmental stewardship, and fostering social development.

The findings indicate that SDG 14 (Life Below Water) and SDG 8 (Decent Work and Economic Growth) emerged as top priorities, reflecting a dual focus on environmental protection and economic resilience (see Figure 1). This prioritisation underscores the sector's recognition of the critical balance needed between ecological sustainability and socio-economic growth, an approach particularly relevant in the context of the blue economy. Ports play a pivotal role in fostering and advancing the blue economy, which emphasises sustainable use of ocean resources for economic growth, improved livelihoods, and marine ecosystem health. By prioritising SDG 14, these ports reinforce their commitment to protecting marine life, a cornerstone of the blue economy, while SDG 8 signals their investment in creating sustainable job opportunities and economic stability.

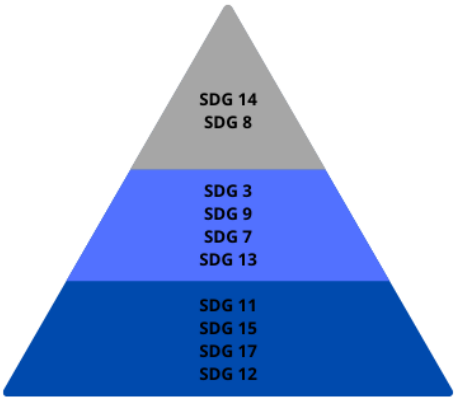
Figure 1 presents a pyramid illustrating the hierarchy of SDG prioritisation within the Brazilian port sector, where the base represents lower-priority SDGs and the apex highlights SDG 8 and SDG 14 as primary concerns. This finding resonates partially with the results of Wang *et al*. (2020), who identified SDGs 8, 9, 11, and 14 as high priorities, particularly in relation to port infrastructure and workforce engagement. The distinct emphasis on SDGs 8 and 14 in the Brazilian context can be attributed to the close interaction between port terminals, ocean ecosystems, and employment needs. In addition, the work of Caliskan (2022) underscores the relevance of SDGs 11, 12, 13, and 17, further suggesting that the sector's SDG priorities reflect a nuanced adaptation to local economic and environmental contexts.

In this framework, it is essential to consider the maturity level of SDG implementation practices within port terminals, as these can influence both the breadth and depth of the blue economy's integration into port operations. As SDG initiatives mature, ports are likely to become more active contributors to the blue economy, bolstering economic development while safeguarding ocean health and promoting sustainable practices.

This study reveals that a substantial 83.3% of respondents have developed environmental agendas explicitly focused on, or contributing to, SDG 14 (Life Below Water). In addition, half of the respondents reported forming partnerships or agreements with a range of institutions to meet these environmental goals. These collaborations span municipal environmental agencies, universities, local education departments, water and sewage service providers, waste recycler associations, and regulatory bodies such as the Office of the Comptroller General. One respondent notably indicated membership in the UN Global Compact, with active participation in the Water and Ocean Action Platform (aligned with SDGs 6 and 14) and broader involvement in platforms focused on Communication and Engagement, Climate Action, Anti-Corruption, and the Brazilian Alliance for Ocean Culture.

Figure 1

SDG primarily in accordance with the respondents



Participation in committees, working groups, and environmental programmes is widely recognised as vital for fostering closer engagement with critical issues, such as those addressed by the UN Global Compact and the Water and Ocean Action Platform. Notably, only one respondent reported engagement with the Brazilian Alliance for Ocean Culture, a network established in 2021 under the Ministry of Science, Technology, and Innovations. This alliance brings together a diverse array of social actors committed to implementing local

actions aligned with the national and global goals of the Ocean Decade, reflecting a collective drive towards sustainable ocean governance.

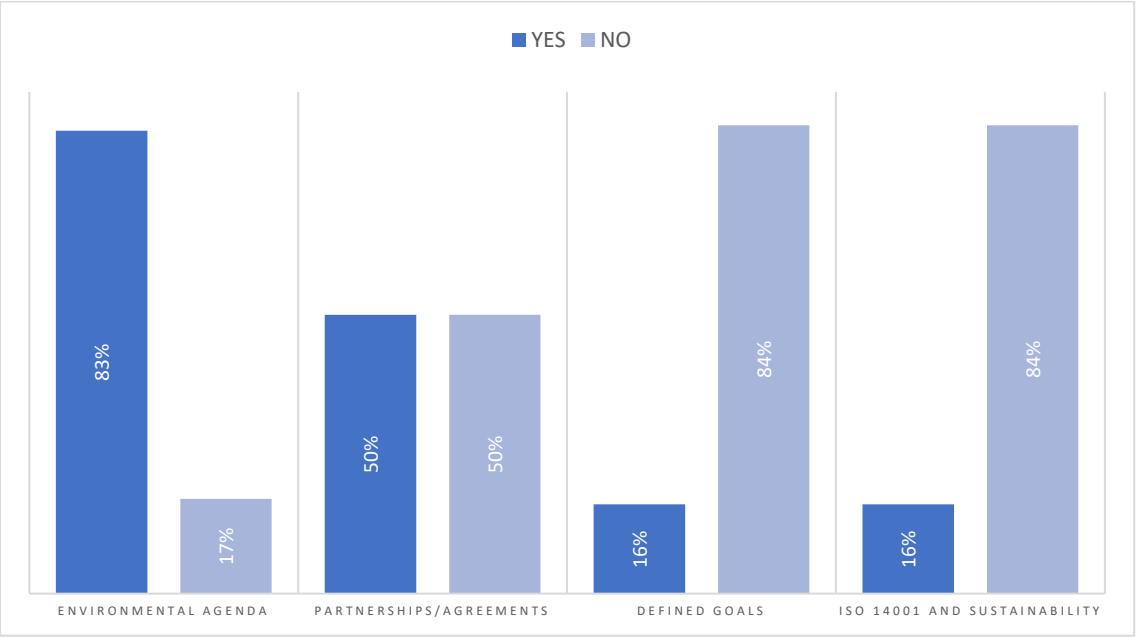
In terms of specific actions undertaken by ports and terminals to advance SDG 14, responses highlighted a variety of marine environmental monitoring activities. These include the tracking of aquatic biota and marine sediments, environmental management of dredging activities, waste control for vessels, monitoring of invasive species, and regular inspections related to port operations. Additionally, several initiatives aimed at supporting fishing communities were reported. These findings are consistent with the observations of Cunha *et al*. (2023) regarding sustainability practices documented in Brazilian port sustainability reports. However, an observed increase in actions linked to SDG 14 suggests either an underrepresentation of such initiatives in sustainability reports or a lack of explicit linkage between these activities and SDG 14, highlighting a potential area for improved reporting.

Regarding ISO 14001 and ISO 45001 certifications, only one respondent reported having obtained these certifications, in addition to implementing energy efficiency projects, acquiring a meteorological station, monitoring greenhouse gas emissions, and investing in green area preservation.

The study also uncovered a gap in the explicit association between ISO 14001 certification and port sustainability practices aimed at SDG 14 within sustainability reports. Additionally, the association with ISO 45001, which primarily focuses on occupational health and safety management, emerged as an indirect link to SDG 14. This suggests potential areas of overlap between environmental and safety objectives that may not be immediately apparent yet underscore a holistic approach to sustainable development within the port sector (see Figure 2).

Figure 2

Adhesion of ports and terminals to sustainability actions



When examining the obstacles to implementing initiatives aligned with SDG 14, five out of six participants in the study identified a range of critical challenges. These included a shortage of financial resources, the need for specialised training and development of personnel responsible for executing and supervising these initiatives, insufficient staffing levels, a lack of effective coordination between government entities and the economic sector, and the absence of appropriate environmental licensing for port operators. Respondents also highlighted additional complexities related to the scale and operational dynamics of ports, such as the extensive physical size of port facilities, the multiplicity of stakeholders involved, the necessity of fostering cultural change, high turnover rates in leadership positions, and the need for sustained support from these leaders to drive sustainability efforts. Collectively, these factors represent significant management challenges that hinder the effective implementation of SDG 14.

In terms of specific targets for SDG 14, only one respondent reported having established measurable targets, integrated into the Strategic Planning 2021–2025 and the Environmental Agenda 2021–2023**.** This agenda includes two SDG 14-related targets: the updating of the Individual Emergency Plan (IEP) for the Organised Port, in compliance with the Brazilian Institute of the Environment and Renewable Natural Resources (IBAMA) by

2022, and the promotion of initiatives aimed at water protection and partnerships aligned with the Ocean Decade by 2023.

Additionally, one respondent cited a timeframe of five to ten years for the broader implementation of these targets, although without specifying clear goals for SDG 14. This may suggest an ongoing process of developing more precise targets. The single response detailing specific SDG 14 targets indicated an implementation rate of 80%, with full achievement projected within a five-year timeframe.

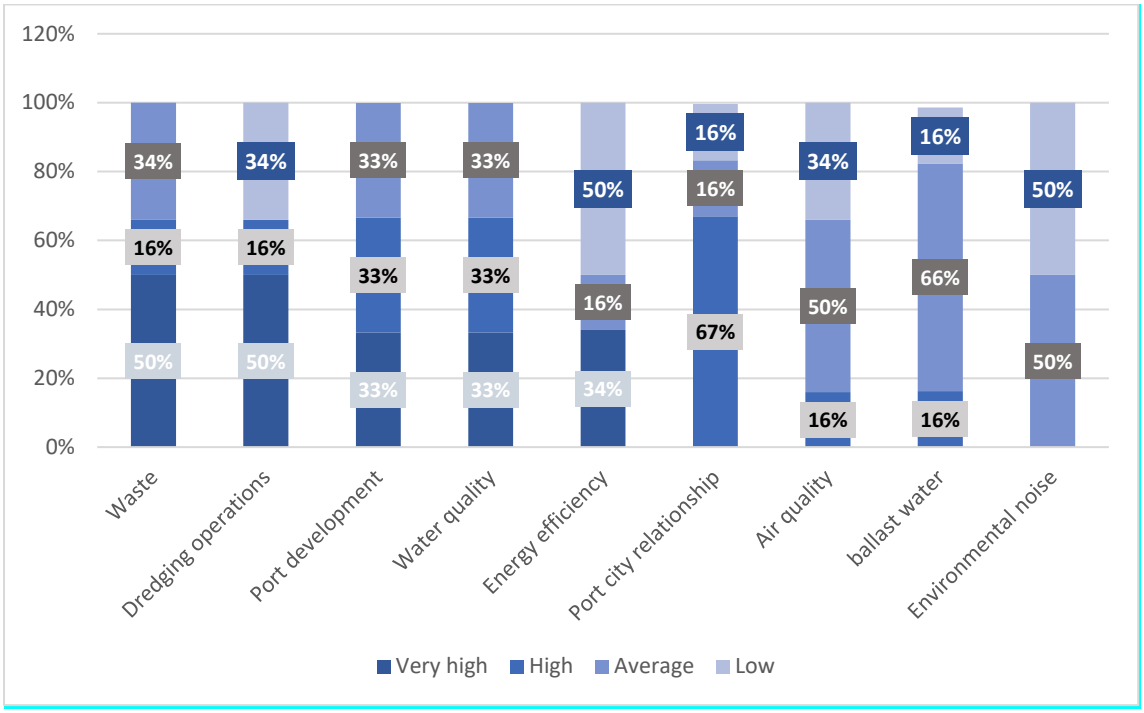
As Virto (2018) suggests, the adoption of SMART (Specific, Measurable, Attainable, Relevant, and Time-bound) targets is essential for the effective implementation of SDG 14. However, the study observed that at least five out of the ten SDG 14 targets (specifically, targets 14.1, 14.2, 14.3, 14.7**,** and 14.b**)** currently lack scheduled implementation timelines or defined success metrics. Importantly, while SDG 14 targets are globally oriented, it is crucial for countries to adapt these targets to local and regional contexts to ensure relevance and feasibility.

Regarding priority actions, the research evaluated nine specific items, inviting participants to rate each on a scale from “very high” to “low” priority. Waste management emerged as a primary concern, with 50% of respondents assigning it a “very high” priority, 16% rating it as “high”, and 34% considering it of “medium” importance. Dredging operations also stood out, with 50% of respondents categorising them as “very high” priority, 16% as “high”, and 34% as “low”. In contrast, actions related to environmental noise received the lowest priority, with an even split between “medium” (50%) and “low” (50%) ratings.

The emphasis on waste management aligns with the findings of Zulfiqar and Butt (2021), who emphasise that effective waste management directly supports SDGs 6 (Clean Water and Sanitation) and 11 (Sustainable Cities and Communities). In addition to these goals, waste management practices contribute substantially to the preservation of coastal ecosystems, the conservation of marine biodiversity, and the prevention of ocean pollution. This is directly relevant to SDG 14, as it aligns with at least three of its targets: 14.1 (reducing marine pollution), 14.2 (protecting marine ecosystems), and 14.5 (conserving coastal and marine areas).

Figure 3

Priority environmental actions for the ports/terminal



Although most respondents reported implementing measures to mitigate the impacts of dredging, the data reveal a significant discrepancy regarding underwater noise monitoring: only one respondent confirmed ongoing monitoring, while another indicated it had been conducted in the past. Three participants stated they had never performed underwater noise monitoring, and three others reported that it was planned.

It is crucial to highlight that underwater noise, generated by both dredging activities and maritime traffic, has substantial impacts on marine biological communities, particularly in port regions inhabited by cetaceans. These impacts include behavioural changes, disruptions in communication, and alterations to migration routes (Boas, 2015). Similarly, studies such as that by Maroja *et al*. (2023) demonstrate that elevated underwater noise levels affect fish communities, altering their movement patterns.

In terms of the broader scope of environmental monitoring—whether already conducted, in progress, planned, or never performed—the research encompassed ten different types of monitoring, all of which are currently being carried out by at least one port or port terminal. The most frequently conducted monitoring activities among the ports include assessments of aquatic biota, water quality, marine sediment quality, and invasive species.

However, only one port or terminal reported monitoring underwater noise, environmental DNA (eDNA), and mangrove or other Permanent Preservation Areas (PPAs).

Environmental DNA (eDNA) represents a valuable tool for biodiversity monitoring in aquatic ecosystems, enabling species detection without the need for physical samples. High-throughput sequencing of eDNA allows for a detailed characterisation of microbial communities, offering a rigorous approach to understanding ecological dynamics within ballast water samples (Gerhard & Gunsch, 2019).

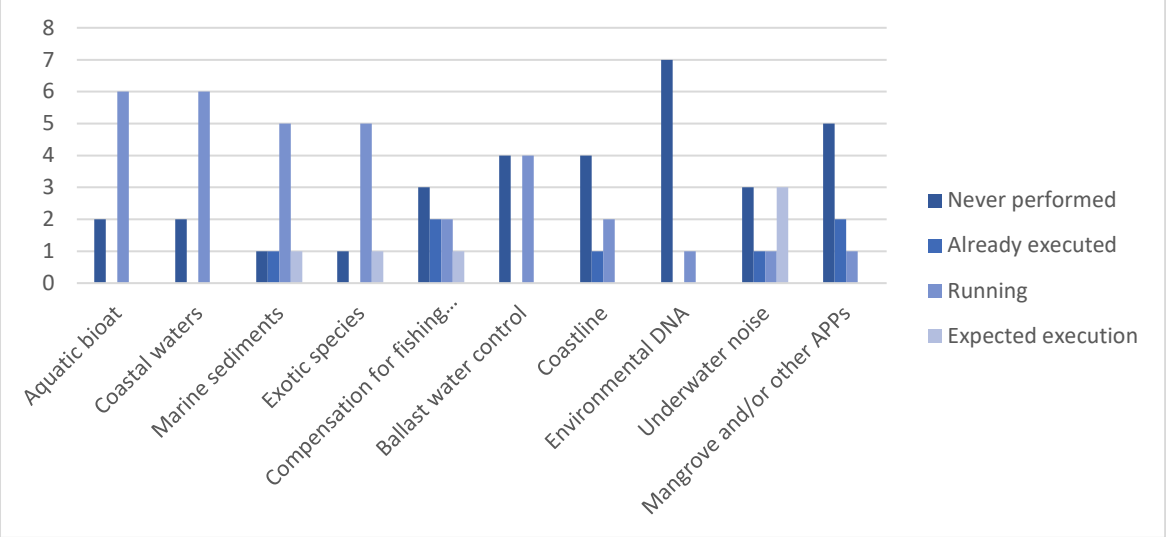
eDNA involves the molecular identification of species through DNA sequencing, providing significant advantages in terms of quality, quantity, and speed in obtaining environmental information. Unlike traditional species collection and identification methods, this technique does not require extensive taxonomic knowledge and is less dependent on morphological conditions or life cycles (Xiao *et al*., 2022). However, the effectiveness of this technique relies on the existence of a comprehensive reference DNA database, the development of which could benefit other sectors of society, including academic institutions and regulatory bodies.

In the context of SDG 14 for the port sector, integrating eDNA methodologies with existing environmental practices could significantly contribute to the development of local public policies focused on species conservation and the rapid identification of environmental impacts.

Regarding eDNA, 87.5% of respondents indicated they had never conducted this form of monitoring, highlighting an area with significant potential for expansion and improvement in port environmental practices (Figure 4).

Figure 4

Environmental monitoring carried out by ports/terminal



The data collected in this study indicate that key marine environmental impacts are integrated into existing environmental programmes within the ports' environmental management plans, in compliance with the regulatory requirements imposed by environmental licensing bodies. While these programmes are mandated as part of environmental licensing, there remains significant scope for adopting advanced methodologies that could enhance monitoring effectiveness and improve data quality. For instance, Environmental DNA (eDNA), a promising tool for biodiversity monitoring, was reported as being utilised by only one respondent in this study.

Regarding the preservation of coastal zones, specifically Permanent Preservation Areas (PPAs)**,** 50% of respondents reported specific actions targeting these areas. However, such actions appear to be embedded within broader environmental programmes rather than implemented as dedicated monitoring initiatives. This lack of targeted efforts to protect PPAs, such as mangroves**,** coupled with the absence of coastal line monitoring, highlights opportunities for improvement.

Mangroves are vital ecosystems, providing coastal protection, carbon sequestration, and essential habitats for marine biodiversity. Their ecological significance is well-documented (Barbier *et al.*, 2011), and Brazil, home to approximately 7% of the world's mangroves (FAO, 2007), holds substantial ecological and socioeconomic value in these ecosystems. Despite their importance, mangrove monitoring remains insufficient, underscoring the need for robust coastal ecosystem monitoring to ensure effective

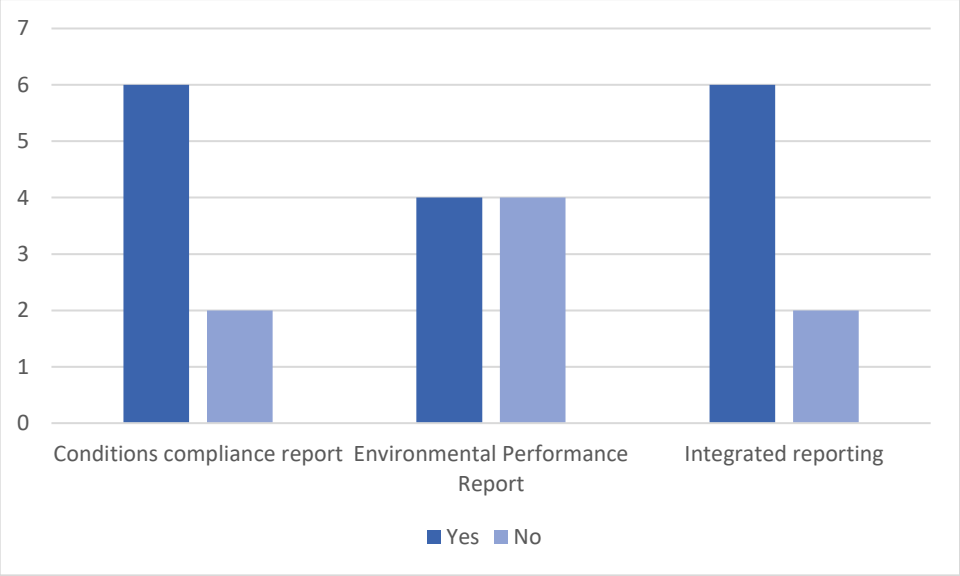
environmental management, particularly in regions vulnerable to sea level rise and pollution (Schmidt & Gomes, 2016).

In terms of reducing marine pollution and minimising the impact of port operations on local marine life, respondents reported a variety of approaches. These include environmental education for crew members, monitoring of supply operations, waste management, and technological investments. Environmental education emerged as a key measure, targeting both internal and external audiences, often facilitated through collaborations with academic institutions and marine fauna rescue programmes. Additionally, in support of sustainable fishing practices, ports reported initiatives to engage with local fishing communities, promoting the monitoring of fishing activities to safeguard artisanal fishing—an activity with significant socioeconomic importance (Castro & Almeida, 2012).

Ballast water management was also addressed, with one respondent highlighting the implementation of additional controls in alignment with Brazilian Navy regulations **(**NORMAM-20**).** Pereira *et al*. (2014) emphasise the importance of verifying ballast water data reported by ships, noting identified weaknesses in reporting accuracy, particularly in the Amazon Bay.

Figure 5

Method of reporting monitoring and/or actions carried out by ports/terminal.



In this study, respondents were asked about the implementation of environmental programmes or initiatives beyond those required by their operating licences. Seven out of

eight respondents reported undertaking at least one voluntary environmental initiative. These actions included socio-environmental projects aimed at empowering local communities through courses and training, monitoring of environmental noise generated by port operations and surrounding areas, implementation of environmental education programmes, and the provision of tariff discounts through the Port Efficiency and Sustainability Index for terminals demonstrating effective initiatives to reduce greenhouse gas emissions and diversify energy sources.

Additional initiatives encompassed the sponsorship of socio-environmental projects, adherence to the UN Global Compact**,** including active engagement in its platforms and working groups, programmes focused on the rescue and rehabilitation of marine fauna, and enhanced chemical management practices. These voluntary actions underscore a proactive commitment by ports and terminals to adopt environmental practices that surpass regulatory requirements, reflecting an integrated and responsible approach to sustainability. The inclusion of such programmes indicates a more holistic perspective on environmental management, where socio-environmental and economic factors are carefully balanced in alignment with sustainable development principles.

Conclusions

This article sought to identify and analyse the strategies employed by the Brazilian port sector in adopting and implementing the Sustainable Development Goals (SDGs), with particular emphasis on SDG 14 (Life Below Water)**.**

The findings indicate that current practices are closely aligned with recognised sustainability standards for ports, specifically addressing targets 14.1, 14.2, and 14.5 of SDG 14. Key actions include obtaining ISO 14001 certification, monitoring aquatic life, water quality, and sediment conditions, implementing waste management measures, and developing environmental education programmes.

Environmental initiatives within ports extend well beyond regulatory requirements, with many ports engaging in socio-environmental projects, environmental education, and forming partnerships with academic and regulatory institutions. These voluntary efforts, coupled with adherence to the UN Global Compact**,** highlight a proactive and comprehensive approach to sustainability. However, significant gaps remain in critical areas, including environmental noise monitoring**,** targeted conservation of Permanent Preservation Areas

(PPAs) such as mangroves, and the broader adoption of Environmental DNA (eDNA) for biodiversity monitoring. Strengthening initiatives in these areas could enhance the sector's environmental management framework, enabling more robust ecosystem conservation and improved data quality.

The study identified key challenges to advancing SDG 14 initiatives**,** such as financial constraints, limited staffing, and the need for specialised training. Addressing these challenges will require improved coordination between government and economic sectors, underpinned by sustainable financing mechanisms. Adopting the SMART framework for setting specific, measurable targets for SDG 14 could further support alignment between port practices, local environmental needs, and regulatory standards.

Additionally, the findings suggest a need for improved environmental reporting practices to promote transparency and support informed decision-making. Establishing indicators and reporting standards could streamline reporting processes and facilitate more effective monitoring of sustainability outcomes. One notable challenge is the limited involvement of environmental licensing authorities in port and terminal sustainability initiatives. Enhancing the training of managers and operators, as well as increasing participation in committees and specialised technical groups, emerged as essential steps.

Another significant challenge lies in the lack of clear, specific targets for SDG achievement, highlighting the need to integrate these targets into the environmental policies of ports and terminals. Improving port quality management systems using Total Quality Management principles and Industry 4.0 innovations could also play a crucial role in advancing these efforts.

A limitation of this study is the relatively low participation rate of eligible ports. Nonetheless, the questionnaire distribution strategy proved effective, yielding sufficient data for analysis. Future research could benefit from comparing Brazilian ports with international counterparts to identify innovative initiatives and strategies for advancing SDG 14 in Brazilian ports.

The ongoing maturation of SDG practices within the Brazilian port sector positions these ports to become significant contributors to the blue economy**,** fostering both economic growth and marine conservation in alignment with global sustainability goals. This study underscores the potential of Brazilian ports to serve as international benchmarks in balancing economic resilience with environmental responsibility, reflecting the transformative power of sustainability initiatives in the maritime sector.

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