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ABANDONED VESSELS IN GUANABARA BAY AND THEIR ENVIRONMENTAL IMPLICATIONS

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ABSTRACT

Moving, wrecked, abandoned, and drifting vessels drastically impact everything from coastal habitats to fishery resources, tourism, and recreation. Recently, the ship São Luís, stationed in Guanabara Bay, collided with the Rio-Niterói Bridge. This accident brought up the problem of marine pollution from water traffic. This study aims to evaluate the risks of accidents and the environmental contamination from abandoned vessels in this estuary. The methodology included a broad bibliographic compilation of studies on this relevant body of water, such as metal pollution, endocrine disruptors, paints, microplastics, emissions, ballast water, garbage, oil, and cargo residues. The results point to significant risks for the bay. In this case, specific legislation is a must, especially with the development of practical strategies, monitoring, and environmental management plans for this important ecosystem.

Keywords: Water pollution; Marine accidents; Ecological risks.

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INTRODUCTION

Maritime transportation, especially in the era of globalization, accounts for approximately 90% of the different types of cargo transported worldwide (Eronat *et al*., 2019; Harlaftis, 2020). However, maritime safety is a global concern, mainly due to the risks of serious accidents with human, economic, social, and environmental losses (Liu *et al*., 2021; Lan *et al*., 2023). Small, medium, or large vessels represent different pathways of pollution released into water bodies. These contaminants include petroleum products, paints, plastics and microplastics, ballast water, and trace metals (Amara *et al*., 2018; Baptista Neto *et al*., 2020; Gaylarde *et al*., 2021; Vacholz *et al*., 2022; Nascimento *et al*., 2022; Santos *et al*., 2022).

Specifically, anti-fouling paints or biocides that prevent the development and attachment of fouling organisms are highly harmful to biota (Terlizzi *et al*., 2001). According to Gaylarde *et al*. (2021), paint fragments in the oceans mainly arise from marine activities. Non-aqueous paints are considered plastics belonging to the polymer family (Gorni, 2003). Paint fragments can also release, by carriage, other types of contaminants into the aquatic environment (Yebra *et al.*, 2004; Koutsaftis & Aoyama, 2007).

According to Alencar (2021), the increase in the circulation of ships in Guanabara Bay is impressive. In 2009, the port of Rio received 1,568 ships, and, in an increasing spiral between 2009 and 2014, the increase in the number of vessels was around 231% (Alencar, 2021). Besides ships, platforms, and tug boats, other types of vessels that contribute to pollution are associated with the anthropic occupation of their surroundings. Such factors are determinants of its continuous pollution degree, with cumulative and synergistic effects that severely interfere with the quality of marine life in the bay (Silva *et al.*, 2018).

Considering that abandoned or drifting vessels range from risks of collisions (which may cause human losses) to serious ecological impacts on the bay, in this context, mitigating actions by the competent agencies and other social actors that work together in the preservation of this important estuary are essential and urgent (Benjamin & Figueiredo, 2020; Ocampo & Pereira, 2019). In addition, over the years, fishery resources, tourism, and recreation have been drastically affected (Dagola *et al.*, 2022). Therefore, assessing the impacts of abandoned boat accidents in this ecosystem is a topic of broad environmental relevance.

METHOD

For this work, a broad literature review was carried out. The research was conducted in databases such as Capes journals, Scielo, Google Scholar, Ensp/Fiocruz, and ScienceDirect.

Study area

The Guanabara Bay watershed is one of the most expressive areas in the country in terms of social, economic, and cultural aspects. It is located between latitudes 22°40' and 23°00' S and longitudes 043°00' and 043°20' W (Kjerfve *et al.*, 1997). It has an enormous population contingent and intense urbanization, with 16 municipalities around it (Amador, 2012). The hydrographic region in which it is inserted measures approximately 4,000 km², and its water mirror is around 384 km². It has 59 km² of islands and 91 rivers and channels (Amador, 1997). Rio de Janeiro city grew along the bay's margins due to its geomorphology and drainage network, which ensured good penetration in addition to clean waters and an excellent self-depuration system responsible for recycling the volume of urban discharges at the time.

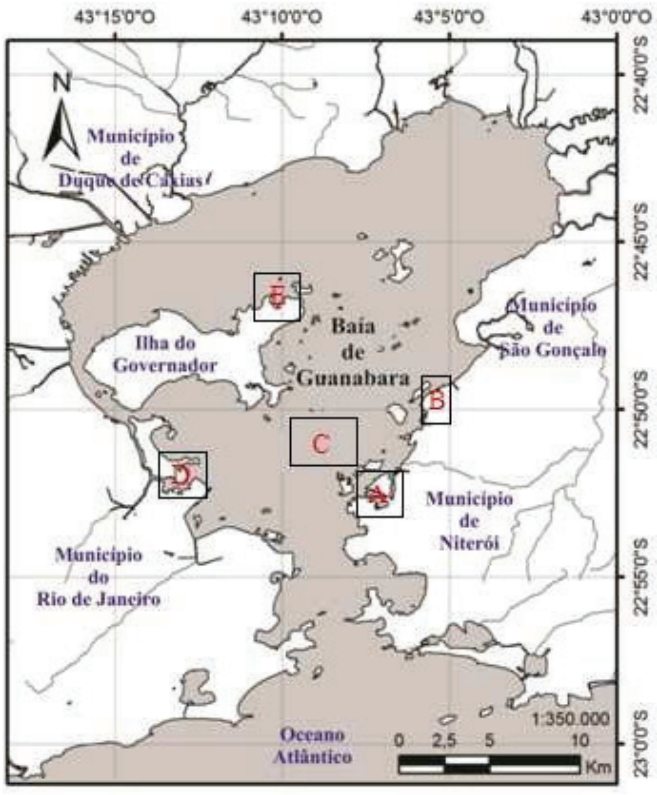

Figure 1. Map of the location of Guanabara Bay: locations of abandoned vessels A = Niterói Port, B = São Gonçalo, C = Inland Bay, D = Rio de Janeiro Port, and E = Ilha do Governador.
Source: The authors

According to studies, during the last 100 years, the surrounding catchment area has been greatly modified by anthropic activities such as deforestation and disorderly

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occupation (Amador 2012; Fonseca *et al.*, 2013). The bay's surroundings are home to several industries, including oil refineries, marine oil terminals, ports, fishing activities, solid waste dumping sites, and agricultural activities. Mainly in the northeast region of its drainage basin, several pollutants are introduced, responsible for the contribution of sewage dumping, metals, nutrients, hydrocarbons, organochlorines, pharmaceuticals, and sediments (Amador, 2012). Associated with this, there is an enormous contingent of slums without access to basic sanitation, a fact that directly affects the bay (IBGE, 2014).

The current environmental degradation of this estuary has promoted severe socio-environmental impacts and much damage to fishing activities, a social problem for several communities that made a living from fishing. In addition, tourism, which, before the industrial and population expansion of the metropolitan region, was a sector of relative importance, is currently practically nonexistent (Soares-Gomes *et al.*, 2016). The domestic sewage discharge into the bay without any treatment is another serious obstacle to be solved, mainly because the pollution can cause damage to the conservation and ideal conditions for the survival of organisms (Carreira *et al.*, 2004). **Figure 1** shows the Guanabara Bay map, and **Figure 2** shows abandoned vessels along the bay.

RESULTS AND DISCUSSION

The environmental risks concerning old vessels are numerous, mainly because, according to Law No. 12.815 of June 5, 2013, Decree No. 8.033 of June 27, 2013, and ANTAQ Resolutions, Art. 37, sole paragraph, vessels older than 30 years without proven documentary evidence of retrofit will not be accepted at the Port of Santos. Also, according to Marselou *et al.* (2019), the end of the life cycle of ships has an average operational activity of 30 years. In this case, ship recycling can be an opportunity to reuse materials, help the economy, and contribute to human and environmental health. In this context, the process of decommissioning ships offers alternatives such as complete or partial removal, the creation of an artificial reef, relocation, and recycling (Bull & Love, 2019). **Table 1** shows studies on water pollution from nautical activities, and **Figure 3** illustrates the approximate average operational activity of polluting ships from nautical activities.

According to Alencar (2021), accidents with vessels in Guanabara Bay are not uncommon. Some examples include the accidents occurred in November 2011, when the catamaran Gávea I, carrying 907 passengers, collided twice with a decommissioned pier in Praça XV, and 54 people were injured. In May 2015, the Vital Brasil ferry of old construction

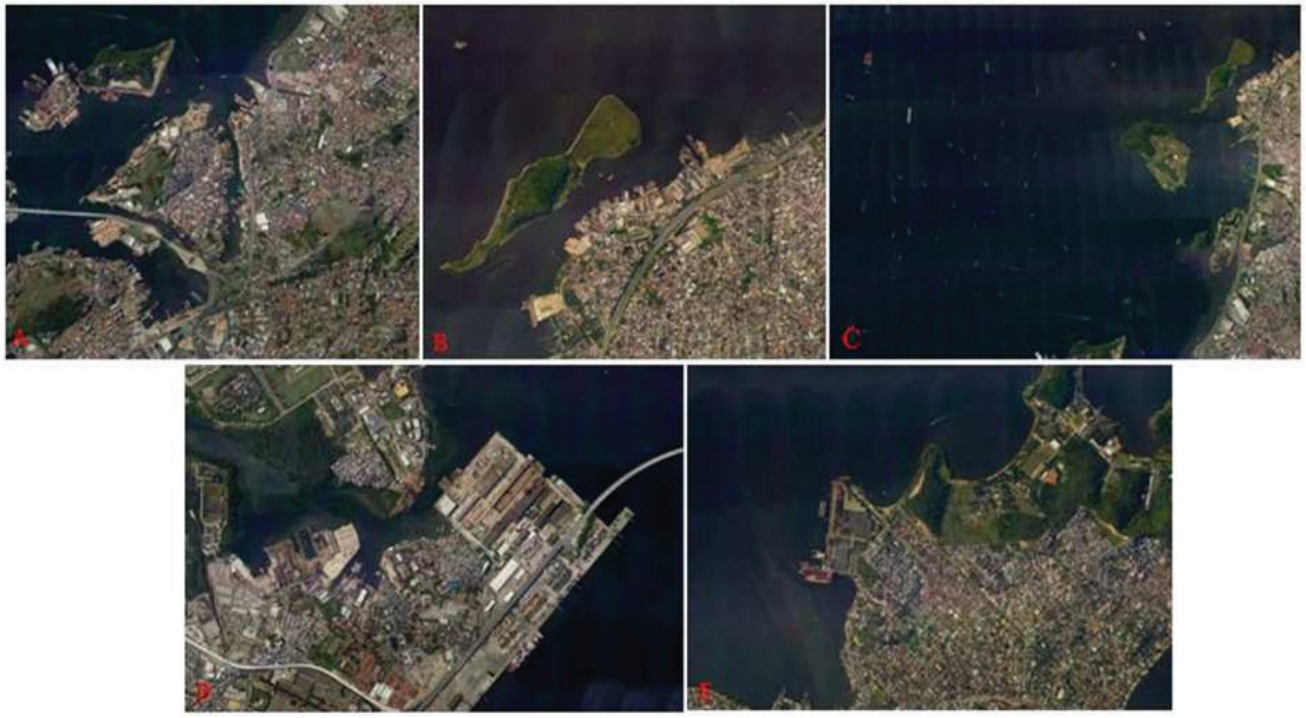

Figure 2. Image of abandoned vessels along Guanabara Bay: A = São Gonçalo coast; B = Niterói port; C = vessels inside the bay; D = Ilha do Governador.
Source: The authors

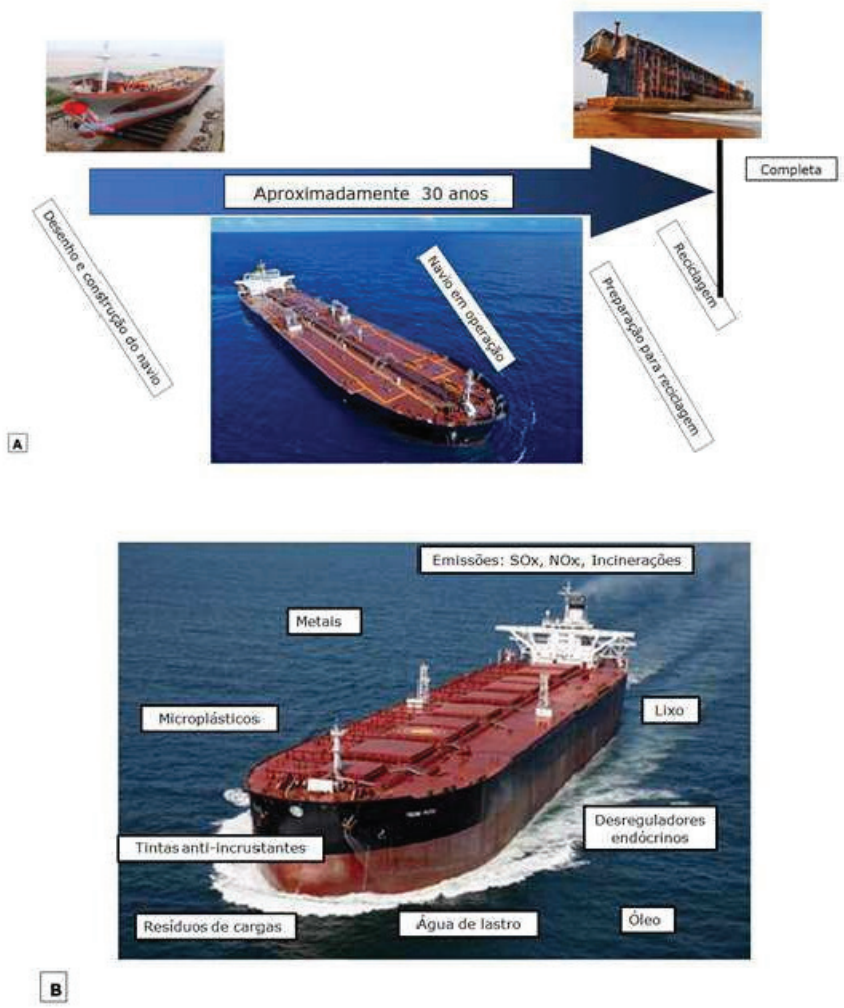

Figure 3. Approximate average operational activity of ships (A). Pollution associated with nautical activities.
Source: The authors

(1962) collided with a floating pier when arriving at the Cocotá platform in Ilha do Governador, where 700 people were stranded for more than two hours waiting for help. In July of this same year (2015), the ferry Boa Viagem collided with a wall at Praça XV station with 900 people on board, leaving 15 passengers injured (Alencar, 2021).

Recently, on November 14, 2022, the bulk carrier São Luís, adrift in Guanabara Bay, collided with the Rio-Niterói bridge, officially called President Costa e Silva. The bridge connects the cities of Rio de Janeiro and Niterói, separated by Guanabara Bay. The bridge was inaugurated on March 4, 1974, and is 13 km long, of which 9 km are over the bay. In this collision, fortunately, there were no injuries, but it generated much apprehension and a massive 3-hour traffic jam until the structures were verified for impact. This collision brought out the need for discussion about the exposure to risks associated with the circulation of vessels in the bay, especially regarding abandoned and drifting ships, which need imperative solutions regarding the continuous pollution by different contaminants and the dangers of accidents (Alencar, 2021). Besides the risks of collisions, ship container accidents are equally severe and complex due to the quantity of cargo (Hlali & Hammami, 2019), especially since container pollution does not receive due attention because of deficiencies in management regulations (Wan *et al.*, 2022).

In Brazil, coastal areas are under intense environmental degradation, especially by anthropogenic pressure in their surroundings (Sanches Filho *et al.*, 2021; Silva *et al.*, 2021; Dias *et al.*, 2017; Fonseca *et al.*, 2011). In this case, industrialization near coastal areas is a huge source of contamination (Adyasari *et al.*, 2019). Guanabara Bay is the subject of different studies that expose the pollution levels from various industries, including shipping (Silva *et al.*, 2021). Among the research on pollution in Guanabara Bay are studies on

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Table 1. Environmental impacts from ship pollution

Pollutants	Studies
Metals	Morcillo *et al* (2016); Yılmaz *et al* (2017); Jitar *et al*. (2015); Khadanga *et al*. (2022); Liu *et al*. (2015); Ytreberg *et al* (2022); Lim *et al* (2022).
Endocrine Disruptors	He *et al* (2022); Salgueiro-González *et al* (2019); Beyer *et al* (2022); Mikac *et al* (2022); Lv *et al* (2021); Brinkmeyer (2016); Altug *et al*. (2012); Burkholder *et al* (2007); Wu *et al* (2017); Yin *et al*. (2021).
Paint	Almeida *et al*. (2007); Briant *et al*. (2022); Mohan *et al*. (2022); Karlsson *et al*. (2010); Ytreberg *et al*. (2021); Gaylarde *et al*. (2021).
Microplastics	Feng *et al*. (2022); Li *et al*. (2021); Cauwenberghe *et al*. (2015); Wang *et al* (2021); Yang *et al*. (2021); Yang *et al*. (2021); Naik *et al*. (2021); Shiu *et al*. (2021).
Emissions	Ytreberg *et al*. (2021); Wang *et al*. (2022); Bayazit & Kaptan, (2022); Yang *et al*. (2022); Gan *et al*. (2022); Toscano *et al*. (2022); Sun *et al*. (2023); Aakko-Saksa *et al*. (2023); Deng *et al*. (2022).
Waste	Connan *et al*. (2021); Kotrikla *et al*. (2021); Zhang *et al*. (2021); Joshi *et al*. (2023); Andrades *et al*. (2016); Duan *et al*. (2020); Horsman, (1982); Duan *et al*. (2021); Lee *et al*. (2013).
Ballast water	Ye *et al*. (2022); Yang *et al*. (2022); Elidolu *et al*. (2023); Salleh *et al*. (2021); Kurniawan *et al*. (2022); Lv *et al*. (2022); Lakshmi *et al*. (2021); Qiong *et al*. (2020); Drake *et al*. (2007).
Oil	Xing & Zhu (2022); Kamal and Kutay, (2021); Eronat *et al*. (2019); Prabowo and Bae (2019); Liu *et al*. (2016); Uçak (2022).
Cargo residues	Wan *et al*. (2022); Simcock, A. (2018), Broeze, (2017); Demil and Lecocq (2006); Frey and DeVogelaere, (2014); Ellis, (2011); Hinz *et al*. (2020).

trace metals in sediments. This complex environmental matrix is considered to be an enormous reservoir for a huge variety of substances. Therefore, they are excellent pollution indicators, especially from anthropic activities (Birch *et al*., 2020).

According to Baptista Neto *et al*. (2005), in Guanabara and Sepetiba Bays, located in the state of Rio de Janeiro, Guanabara Bay presented high levels of Zn, Pb, Cu, and Cr, possibly due to pollution from the rivers that flow into its waters, such as industrial, naval, latex, and ship paint waste, among others. In Sepetiba Bay, the traces of metals analyzed present a diffuse pattern (Ferreira *et al.*, 2013; Ferreira *et al.*, 2020). Moreover, according to da Silva *et al*. (2014), in two tributaries of the Guanabara Bay, the rivers Guaxindiba and Caceribu, Mn may pose contamination risks, especially to aquatic biota (Baptista Neto *et al*., 2006; Baptista Neto *et al*., 2013; Fonseca *et al*., 2013; Melo *et al*., 2015). Trace metals have been detected in Perna mussels from the Brazilian coast (Ferreira *et al*., 2013), and in organisms such as Dules Auriga, the bioavailability of metals has been observed (Hauser-Davis *et al*., 2019; Hauser-Davis *et al*., 2021).

As far as the oil industry is concerned, its impact on the environment is related to cumulative and synergistic effects. As an energy matrix, oil is a significant polluter (Landquist *et al*., 2013; Taylor *et al*., 2014; da Silva, 2022). Its effects can be long-term as it is a fossil fuel composed mainly of polycyclic aromatic hydrocarbons and, thus, organic pollutants that accumulate along food chains (Silva *et al*., 2021). As clarified by Euzebio *et al*. (2019), the exposure of individuals to oil spills can cause physical, psychological, genotoxic, and endocrine effects. Another risk associated with PAHs is their ability to be highly toxic, even when detected in small amounts in the environment (Ifegwu *et al*., 2015; Resende *et al*., 2016; da Silva, 2022).

Endocrine disruptors detected in the waters and sediments of Guanabara Bay signal serious risks to biota and human health (Viganò *et al*., 2008; Nascimento *et al*., 2018; Cunha *et al*., 2020; Santos *et al*., 2022). In Maracanã River and Canal do Mangue, tributaries of the bay, the presence of endocrine disruptors corroborates potential risks to animals, humans, and the environment by carriage (Nascimento *et al*., 2022). Similarly, the results obtained in mangroves and lagoons surrounding the bay indicate risks and a greater need for monitoring (Pinto *et al*., 2019).

The issue surrounding marine debris, especially plastic, is that it is a highly persistent pollutant (Galgani *et al*., 2010; Hale *et al*., 2020). According to Agamuthu *et al*. (2019), over 100 million macroplastic particles are present in the seas, with 51 trillion microplastic particles (<5 mm) floating on the ocean surface. In addition, ingestion of MPs contaminates marine animals, including microorganisms (Carvalho and Baptista Neto *et al*., 2016; Baptista Neto *et al*., 2020).

Furthermore, as Gaylarde *et al*. (2021) clarify, paint particles are a significant part of microplastic pollution in oceans, with serious ecological effects. These fragments come from paints used on different boat types and, by carriage, introduce other contaminants, such as trace metals and biocides (Gaylarde *et al*., 2021).

Studies in the metropolitan region of Rio de Janeiro reflect the presence of pollutants. Tonnes of solid waste from different polluting sources continuously flow into the Bay (Baptista Neto et al., 2011; Duarte and de Miranda, 2021). This quantity of garbage results from urban densification in the 17 municipalities surrounding its hydrographic region (Bernardino & Franz, 2016; Pinto *et al*., 2022; Elk *et al*., 2022). Thus, this work may contribute to the discussion of studies that address the different risks and reinforce the urgency of systematic actions, monitoring, and mitigation for the quality of life in Guanabara Bay.

CONCLUSION

Accidents in Guanabara Bay with abandoned and drifting vessels may have severe implications concerning accidents, human casualties, and significant environmental losses. Pollution can occur widely, from the water column on the surface and bottom to sediments, beaches, lagoons, and even mangroves. The impacts of bioaccumulation and persistence can also reflect economic and social losses, besides directly affecting the quality of life of the population living in their surroundings.

The degradation of the bay is associated with the activities performed, such as cleaning and maintaining ships and oil platforms, ballast water, oils, paints, garbage, metals, and other chemical compounds released into its waters over the years. In this case, adequate and integrated planning through specific legislation and dialogues with different social actors, such as politicians, academics, fishermen, and the population, is essential. Actions that contemplate the preservation and mitigation of the ecological quality of this significant ecosystem must emerge from this broad dialogue.

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