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Oil spill + COVID-19: A disastrous year for Brazilian seagrass conservation

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HIGHLIGHTS

• Brazil suffered the most extensive oil spill ever recorded in the tropical oceans.
• Brazil has the second-highest number of deaths caused by COVID-19.
• Oil spill consequences have not yet been analyzed for Brazilian seagrass beds.
• Pandemic and large-scale environmental disasters increase impacts on seagrass.
• Combined impacts on seagrass conservation need to be analyzed.

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ABSTRACT

The COVID-19 pandemic has been the greatest global public health threat of the 21st century. Additionally, it has been challenging for the Brazilian shores that were recently (2019/2020) affected by the most extensive oil spill in the tropical oceans. Monitoring programs and studies about the economic, social and ecological consequences of the oil disaster were being carried out when the COVID-19 (coronavirus disease 2019) pandemic was declared, which has heavily affected Brazil. For Brazilian seagrasses conservation, this scenario is especially challenging. An estimated area of 325 km² seagrass meadows was affected by the 2019 oil spill. However, this area is undoubtedly underestimated since seagrasses have not yet been adequately mapped along the 9000 km-long Brazilian coast. In addition to scientific budget cuts, the flexibilization of public and environmental policies in recent years and absence of systematic field surveys due to COVID-19 has increased the underestimation of affected seagrass areas and ecosystem service losses due to the oil spill. Efforts to understand and solve the oil spill crisis were forced to stop (or slow down) due to COVID-19 and the economic crisis, leaving ecosystems and society without answers or conditions to identify the source(s) that was/were responsible for this spill, mitigate the damage to poor communities, promote adequate impact assessment or restoration plans, or properly monitor the environment. Our results highlight that pandemic and large-scale environmental disasters may have had a synergistic effect on the economy (e.g., artisanal fisheries and tourism), public health and ecology, mainly due to government inaction, social inequality and poorly studied tropical ecosystems. The results of this study also demonstrate the need to analyze the short- and long-term impacts of the combined effects (oil spill + COVID-19) on the recovery of the economy and coastal ecosystems.

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1. Introduction

By the end of August 2019, crude oil from a “mysterious” source (Escobar, 2019) started to appear and spread over more than 3000 km along the Brazilian coast. Almost immediately, several groups including NGOs, state universities, research institutes, local communities, and the general public/volunteers started manually collecting oil without appropriate techniques or coordination with the Federal Government (Brum et al., 2020; Soares et al., 2020a). Geochemical characteristics of the oil material indicate that it is a heavy oil compatible with Venezuelan sedimentary basin (Oliveira et al., 2020), with the oil that was found along the 3000 km coast likely from the same source (Lourenço et al., 2020). It is crude oil that was badly weathered at sea or a product manufactured with heavy oil produced in Venezuela (Oliveira et al., 2020). Although the origin of the oil is known, the source of the spill (company, ship or shipwreck) has still not been elucidated, leaving the disaster; which occurred a year ago, without any responsible party to account for the environmental and social costs and consequences.

This oil spill is considered the most extensive and severe environmental disaster ever recorded in Brazilian history, as well as in the South Atlantic Ocean basin and tropical oceans (Soares et al., 2020a, 2020b). This disaster affected over 55 marine protected areas and threatened ecosystems such as mangroves, seagrass meadows, coral reefs, estuaries, sandy beaches and rhodolith beds (Magris and Giarrizzo, 2020; Soares et al., 2020b; Nasri Sissini et al., 2020). In addition to ecological impacts, the oil spill severely affected traditional fishing communities, since fishermen were no longer allowed to consume or sell mollusks, crustaceans and fishes that make up their diet and economy (Araújo et al., 2020; Ramalho and Santos, 2020). Brazil has one of the most extensive and densely populated tropical coastlines in the world, with the most diverse tropical ecosystems in the South Atlantic (Copertino et al., 2016), including extensive seagrass meadows.

Seagrasses are ecosystem engineers in shallow-water coastal areas and have an important role as three-dimensional habitats that attract several animal and plant species (Orth et al., 2006). Moreover, they are not isolated ecosystems and are generally physically and ecologically connected to neighbouring tropical seascapes such as mangroves, estuaries, rhodolith beds, and coral reefs (Costa et al., 2020). Finally, seagrass meadows provide several ecosystem and cultural services, including reduced coastal erosion; suitable areas for nursery, settlement, forage, spawning and breeding for numerous associated marine species; increased water transparency; improvement of water quality; leisure; diving areas; storage of large amounts of blue carbon, and are also an important source of food and income for coastal populations (Ruiz-Frau et al., 2017; Nordlund et al., 2018a, 2018b).

On the other hand, seagrass meadows are being threatened all over the world, with alarming cover loss rates caused by both natural and anthropogenic sources (Waycott et al., 2009; Orth et al., 2006; Griffiths et al., 2020). In Brazilian meadows, this scenario is not different (Copertino et al., 2016), but has been especially challenging this past year (2019/2020). An estimated area of 325 km² of seagrass meadows was affected by the oil spill disaster (Magris and Giarrizzo, 2020). However, this number is undoubtedly underestimated since seagrass meadows have not yet been fully mapped along the 9000 km-long Brazilian coast (Copertino et al., 2016), and few researchers have been monitoring these ecosystems (Fig. 1). Besides scientific budget cuts in recent years, the absence of systematic field surveys due to COVID-19 increases the underestimation of seagrass meadow area affected by the oil spill and the degree and specific ecosystem services affected by such disaster.

Monitoring programs and studies about the economic and ecological consequences of the coastal ecosystems and populations, especially fishermen, were being put in place by a few state research agencies in late 2019 and early 2020. However, in March 2020, the Coronavirus disease (COVID-19) pandemic was declared (World Health Organization, 2020) and heavily affected Latin America after Europe and Asia. Since then, Brazil has the second-highest number of deaths and has become the third most affected country worldwide by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) (>4 million inhabitants infected, ~15% of global cases) due to the combined lack of organization by the Federal Government, substantial budget cuts in the public health system, social inequality, low number of tests (diagnosis of COVID-19 by RT-PCR), low sanitation coverage, high population density in coastal cities, low education level, high level of poverty, and the continental size of the country (Braun et al., 2020; Lancet, 2020; Marson, 2020).

The COVID-19 pandemic has substantially impacted local economies, social inequality and the environment (Lal et al., 2020; Ramalho and Santos, 2020). In this sense, understanding the immediate and long-term impacts of the pandemic and social interventions on the coastal environment is urgent (Tahir and Batool, 2020; Zambrano-Monserrate et al., 2020). Four underlying research lines were recently published: (1) COVID-19 and environmental degradation, (2) COVID-19 and air pollution, (3) COVID-19 and climate/meteorological factors and (4) COVID-19 and temperature (Shakil et al., 2020). One year after the first oil disaster and in light of the global pandemic, the relationship between large-scale environmental disasters (e.g., oil spill) and the conservation of ecologically and economically important coastal ecosystems (e.g., seagrass meadows) has not yet been analyzed in the literature (Shakil et al., 2020). Therefore, this present article briefly (1) discusses the consequences of the oil spill on Brazilian seagrass meadows that have been observed so far, (2) discusses the early state of studies and mobilization and the effects added by the COVID-19 pandemic, and (3) proposes some next steps.

2. Oil on the Brazilian seagrasses

By August 2020, the area affected by the oil spill extended from the Amazonian coast to Rio de Janeiro (Soares et al., 2020b). All six species of Brazilian seagrasses occur in this region (Halodule beaudettei Hartog,
Halodule emarginata Hartog, Halodule wrightii Asch., Halophila baillonii Asch., Halophila decipiens Ostenf. and Ruppia maritima L.) (Copertino et al., 2016; Magalhães and Barros, 2017) including unique and rare populations of H. beaudettei (one population) and H. baillonii (2 populations) (Fig. 1). In this context, the area affected by the oil spill overlaps (Magris and Giarrizzo, 2020; Soares et al., 2020a) with the distribution of the main eco-engineering seagrass species. Therefore, it has affected different types of vegetated ecosystems throughout the distribution area of these tropical benthic habitats. This region also has the most diverse, extensive, and exuberant Brazilian seagrass meadows (Magalhães et al., 2015; Barros et al., 2016; Copertino et al., 2016;) and two oceanic archipelagos (Fernando de Noronha and Abrolhos) with seagrass population registered (Copertino et al., 2016; Magalhães and Amaral, 2021). The oil reached Abrolhos (Escobar, 2019), but Fernando de Noronha meadows were not affected (Magalhães and Amaral, 2021).

The impact of oil on seagrasses varies according to the oil type, degree and time of exposure and affected species, which can result in mortality and reduce their tolerance to other stressors (Zieman and Zieman, 1989). The variety of oil scenarios and responses leads to a lack of consensus about the degree and overall impacts on the seagrass communities, indicating a situation that is more scenario-dependent than species-dependent (Fonseca et al., 2017). The hydrophobic nature of oil molecules allows them to bind to membrane cells of aquatic plants, which rapidly reaches the thylakoid (where the photosynthetic apparatus is located) and accumulates, causing membrane oxidation and damaging photosynthesis and respiration (Marwood et al., 1999). Thus, disperse oil can reduce shoot and flower densities, plant growth, and area loss (Thorhaug and Marcus, 1987; Marshall, 1990; Dean et al., 1998; Kenworthy et al., 2015). Mutagenic and carcinogenic substances can be incorporated into plant tissues and can decrease tolerance to other stressors and transfer these substances to primary and secondary consumers (Zieman and Zieman, 1989).

In addition to its effects on vegetation, oil spills can have a profound and selective influence on the various animals and plants inhabiting seagrass meadows (den Hartog and Jacobs, 1980), which is the present case along the Brazilian coastline. Thus, Lourenço et al. (2020) detected that light hydrocarbons were still present in the oil from the mysterious Brazilian spill. Chemical characterization of this oil (Lourenço et al., 2020; Oliveira et al., 2020) showed that light hydrocarbons were still present, increasing the probability of negative effects and ecotoxicological risks to organisms in seagrass beds upon release in the water column. Therefore, the associated fauna and flora may be killed, poisoned, smothered, fouled, and asphyxiated, reducing their commercial demand and value (Zieman and Zieman, 1989; Taylor and Rasheed, 2011) (Fig. 2a, b, c, d).

Brazilian seagrasses shelter and attract diverse invertebrate and fish fauna with high ecological and economic importance (Pereira et al., 2010; Barros et al., 2016; Costa et al., 2020), including threatened species as the manatee (Trichechus manatus Linnaeus, 1758) and the green sea turtle (Chelonia mydas Linnaeus, 1758). Since it requires habitats with seagrass, manatee sightings drastically diminished at the Federal Protected Area (APA do Delta do Parnaíba) a few weeks after the accident, according to the NGO Comissão Ilha Ativa, which recorded crude oil on seagrass leaves (Portal do Dia, 2019). After the Deepwater Horizon oil spill, a model was proposed as an attempt to estimate the number of manatees in areas potentially affected by oil (Martin et al., 2014), but the impact of the oil on these animals has still not been studied sufficiently. However, official reports have declared that sea turtles seem to be the most affected fauna, representing 66% of the 159 oiled marine animals registered (IBAMA, 2020) (Fig. 2c).

![Fig. 2.](image-url) a and b) Seagrass meadows inspection after oil spill with the register of dead fauna at Suape, Pernambuco State (Photo: Raul Aragão); c) sea turtle (Caretta caretta), after being covered in oil, collected in Maragogi, Alagoas State, by the Biota Conservation Institute (Record of the Biota Conservation Institute); d) massive mortality of the cockle Tivela mactroides at Alagoas state (Record of the Biota Conservation Institute); e) seagrass debris impregnated with oil at Porto da Lama, Piauí state (Photo: Liliana Souza); f) popular mobilization for cleaning oil residues in Pernambuco State (Photo: Internet).
Since seagrasses are distributed in shallow waters and intertidal areas in the Tropical Southwestern Atlantic (Northeast region of Brazil), meadows have been affected both directly and indirectly by the oil spill. In the eastern portion of the northeastern coast, crude oil was registered between seagrass leaves in many locations at Carneiros Beach, Pernambuco state. At this location, seagrasses not only suffered from the oil but from the cleaning process by the local population, who tore seagrass leaves as they collected oil by hand. On this beach, small oil stains were observed in the sediments until January 2020. The initial monitoring activities also registered an indirect impact of the oil, which remained in the meadows and percolated underground, in Suape Bay, Pernambuco. Unfortunately, as a result of the COVID-19 quarantine, this monitoring was suspended. At a manatee sanctuary in Japaratinga, Alagoas state, small amounts of oil reached the beach almost daily for at least four months, reaching the seagrass meadow at low tides. In this area, massive mortality of the cockle Tivela mactroides (Born, 1778) was reported, affecting artisanal fisheries of this bivalve (Fig. 2d).

After the broad publication of images and alerts from the regions that were first affected, non-governmental organizations and civil society along the northern sector of the Brazilian coast were on alert, which lead to most oil being rapidly collected at sea or along the beaches (Soares et al., 2020b). Some oil spots were recorded on sandy beaches in Maranhão (September 22, 2019) to the far west of Rio Grande do Norte (October 24, 2019). On the northern coast of Rio Grande do Norte, the Brazilian Navy certified that the oil was not found around river mouths, where extensive seagrass meadows are present. Only a small amount of oil (2 kg) with seagrass stems and leaves (Fig. 2e) was collected around the Timonha-Ubatatuba estuarine complex in Ceará, although there are other reports of oil on leaves from the drift line along Piauí coast (Comissão Ilha Ativa, 2020), where the most diverse seagrass meadows and one of the most critical marine animal herds occur in Brazil. However, the impacts of these contaminants on the estuarine and marine food chains and trophic biomagnification have not yet been assessed at a microscopic level. Moreover, recent studies showed contamination of zooplankton that are the base of the marine food web (Soares et al., 2020b).

Seagrass meadows have also been observed in deeper areas, near initially affected areas as the east coast of Ceará, and also in areas with oil recurrences in January 2020, as Ilarema and Icapuí, which we could not access after the disaster. Researchers from the Instituto de Ciências do Mar (Universidade Federal do Ceará) have hypothesized that the permanence of oil buried in sediments justifies the recurrences (due to an interaction of tides, waves, upwelling, and wind speed), which was also observed in other areas along the Brazilian coast in the beginning and in June 2020.

Despite the oil collection, several researchers noticed the permanence of oil in several ecosystems along the Northeast coast in early 2020, including touristic points as Salvador (Bahia), where the oil on rocky surfaces continued emitting the characteristic smell (Cerqueira, 2020). This occurs because the oil is impregnated in intertidal sandstone reefs (Magris and Giarrizzo, 2020) and could not be removed by the mechanical action or abrasive products used by volunteers or local authorities. Other approaches, such as bioremediation by microorganisms, need to be developed.

The permanence of oil in tropical coastal ecosystems, even in small spots, can be harmful to ecosystem engineering species (as corals, mangroves and seagrasses) (Beyer et al., 2016) and can compromise ecological dynamics of benthic communities in rocky shores and sandy beaches (De la Huz et al., 2005; Stevens et al., 2012; Soo et al., 2014). The Deepwater Horizon accident affected an area of 2100 km, and a decade later, concerns about long-term impacts are still an issue and, some groups, like seagrasses, are considered understudied, and monitoring and research are indicated for years to come (Beyer et al., 2016).

In addition to ecological impacts, the persistence of oil can affect commercial species and economic activities such as small-scale and subsistence fisheries in local and traditional communities (Araújo et al., 2020; Soares et al., 2020b). Many fishing communities along the Brazilian coast have been strongly affected by the combined effects of the oil spill and the COVID-19 pandemic. The oil spill temporarily decreased (or eliminated in some areas) catches of fishes, crustaceans, and mollusks, and also drastically reduced fish consumption and sales (Araújo et al., 2020). Soon after the 2019 oil spill, COVID-19 caused synergistic negative effects on artisanal fisheries, compromising food security, income, and the public health conditions of these poor people (Braun et al., 2020) who are already not included in most public policies (Ramalho and Santos, 2020).

3. Official responses and mobilization

The federal government’s response to the oil spill was very late, slow, and uncoordinated (Brum et al., 2020; Soares et al., 2020a, 2020b), making local governments, universities and NGOs responsible for initial mobilization and research (Fig. 2f). By the second wave of oil (in October 2019), the first public call for research assistance on the disaster was launched. Of the 11 affected states, only Pernambuco (in November 2019) and Alagoas (in October 2019) received emergency research assistance from their local governments. Alagoas allocated about US$ 38,236.90 to combat the oil spill on the coast. The Pernambuco State Agency of Research Support (FACEPE - Fundação de Amparo à Ciência e Tecnologia do Estado de Pernambuco), designated around US$ 500,000 to 10 research projects, with seagrass ecosystems included in two out ten of the selected proposals, but the funds are not available yet (September 2020). These projects include seagrass and associated fauna monitoring, and laboratory experiments that describe changes in photosynthetic efficiency, leaf and rhizome growth, and in the foraging rate of plants under oil stress.

By December 2019, a federal grant was initially designated to previously established long term projects like The National Institutes of Science and Technology Program (INCTs, in Portuguese) and The Long-Term Ecological Research Program (PELD, in Portuguese). Specific research grants were recently (July 2020) published with the support of the Brazilian Monitoring and Evaluation Group – GAA (2019), formed by the Brazilian Navy, Brazilian National Agency of Petroleum, Natural Gas and Biofuels – ANP and Brazilian Institute of Environment and Renewable Natural Resources – IBAMA.

Even without financial support, field activities started in January 2020, especially in Pernambuco State, to select monitoring areas, focusing on sites with data from before the disaster. Nonetheless, as the COVID-19 pandemic was declared, research field activities were suspended, and no money has been allocated to research projects (updated in September 2020). Such suspension is probably the worst effect of the quarantine on these studies since field activities were interrupted before management tools and strategies could be tested or implemented. Most universities and research centres were closed and remained so, with no reopening dates, leaving most samples that were collected before March 2020 unprocessed/analyzed.

During the Brazilian COVID-19 quarantine that started on March 16, 2020, a new wave of oil arrived on the shores of at least six states (Brazilian Navy, 2020) after a week of strong winds, high waves and spring tides. Oil samples analyzed from this event proved to be from the same source as the 2019 disaster (Brazilian Navy, 2020). As verified by our field team, this new arrival confirms that the oil is still out there, buried in intertidal estuarine, and seafloor sediments or trapped in coral reefs, and is still negatively affecting coastal and marine systems. However, since the pandemic was declared, researchers have been unable to maintain studies, and all financial support was reallocated to combat COVID-19.

4. Next steps

It is still early to assess the real impacts of this massive oil spill on the seagrass meadows on the Brazilian coast, especially in light of the
unknown origin of the oil, amount of oil spilt, unexpected recurrences, and the necessary COVID-19 quarantine, but effective actions are urgent. Although the visual effects of the disaster have almost disappeared, monitoring the affected areas is highly recommended, and mitigation and restoration are essential. In this way, ecosystem services provided by seagrass meadows should drive studies and efforts, since seagrasses act as blue carbon storage and nursery grounds for commercial species, and since much of the biodiversity associated with seagrass meadows may have been lost. Furthermore, since all six seagrass species are in the affected area (Fig. 1), species-dependent effects should also be addressed.

The oil spill and the pandemic of COVID-19 were not only environmental and health issues, but have also highlighted the need for public policies regarding labour, social security and social assistance, as well as for the protection of coastal ecosystems (Silva et al., 2020), whose quality and ecosystem services are essential for thousands of families along the coast of Northeastern Brazil. Our discussion highlights that pandemic and large-scale environmental disasters may have caused a negative combination of economic (e.g., artisanal fisheries and tourism), public health, and ecological impacts, mainly due to government inaction, prolonged social isolation, social inequality and poorly studied tropical ecosystems. Moreover, efforts to understand and solve the oil spill crisis were forced to slow down or stop, leaving both ecosystems and society without answers and conditions to identify the primary source of this spill, mitigate the damage, promote adequate impact assessment, determine pollution effects, implement restoration plans or properly monitor the environments. These results also highlight the need to analyze the short- and long-term impacts of these combined effects (oil spill + COVID-19) and recover the economy, public policies, and coastal ecosystems.

The affected seagrass meadows and traditional local human communities on the Brazilian coast should receive attention in the forthcoming years due to the short, medium, and long-term impacts of this large oil spill (Brum et al., 2020; Shakil et al., 2020; Soares et al., 2020a) and COVID-19, which has severely affected their main sources of food and income were, especially after the quarantine. Monitoring programs, adequate scientific budgets and proper response measures must be implemented to minimize the cultural, spiritual, ecological, economic, and social effects of the spill and COVID-19 in affected states, localities and poorly studied vegetated ecosystems (Araújo et al., 2020; Soares et al., 2020b).

To elucidate the real magnitude of these impacts and to contribute to the restoration of the affected seagrass beds, we emphasize the utmost need for policies and research focused on the following key issues: (1) assessments of the severity of impacts on seagrass beds and connected coral reefs, sandy beaches and mangroves using approaches based on comparisons of past and present data (including satellite imagery); (2) experimental oil exposure studies on seagrass and fauna must be conducted with the specific kind of mysterious oil that reached the Brazilian coast, in different quantities, to understand the impacts at the ecosystem level; (3) identification of oil toxicity and its residues on marine organisms and in food webs using proxies such as stable isotope ratios, plant photosynthetic rates and DNA damage; (4) development of novel analytical techniques for chemical detecting of oil-derived compounds at low concentrations in water to predict the approach of oil before it arrives in the coast, allowing early actions to prevent oil from reaching environments such as seagrass; (5) the effects of a prolonged COVID-19 quarantine on the health of seagrass meadows and fishing activities, especially on artisanal fishermen, indigenous people, and quilombolas (African-slave descendants). The development of community-based restoration efforts (Soares et al., 2020b; Nasri Sissini et al., 2020) and sustainable economic activities are particularly important to help recover seagrass beds and communities doubly affected by the largest oil spill ever recorded in Brazilian history and the COVID-19 pandemic that has heavily impacted social inequality and poor communities.

5. Conclusions

The synergistic impacts of a massive oil spill that happened on the Brazilian coast in 2019, with oil recurrence in 2020, and the COVID-19 pandemic in socio, cultural, economic and ecological reflections have been disastrous. As the quarantine was imposed, budgets for ecosystem restoration actions, e.g. seagrass beds, were cut and ecological monitoring activities were stopped and are still restricted in September 2020. The Brazilian Federal government’s response to both disasters was slow, late and unorganized, potentiating the negative consequences of both. For future policies and research about the oil spill, we urge that the main focuses should be the chronic and acute toxicity of the oil to plant, animal and human communities, loss of ecosystem services, and the effects of prolonged COVID-19 quarantine on seagrasses and traditional communities which use them as their source of income or food. As a long-term strategy, the data generated by the next years’ research should be incorporated in a National Governmental action plan for oil spill rescue in different levels and ecosystems.

Credit authorship contribution statement

Karine Matos Magalhães: Conceptualization, Writing - original draft, Methodology, Writing - review & editing, Visualization. Krishna Vilanova de Souza Barros: Writing - original draft, Methodology, Writing - review & editing, Visualization. Maria Cecília Santana de Lima: Writing - review & editing, Visualization, Methodology. Cristina de Almeida Rocha-Barreira: Writing - review & editing, Methodology. José Souto Rosa Filho: Writing - review & editing, Methodology. Marcelo de Oliveira Soares: Writing - review & editing, Methodology.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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