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GEOSCIENCES

Citizen science as a tool for collaborative site-specific oil spill mapping: the case of Brazil

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Abstract: Many maritime disasters lead to oil pollution, which undermines ecosystem balance, human health, the prosperity of countries and coastal areas across borders, and people's livelihoods. This is a problem that affects the whole world. Governments must strive to ensure that operations in the marine environment are safe and avoid oil pollution by adopting methods that anticipate future scenarios to mitigate the effects of this pollution when it occurs. This study investigates a method of managing contaminated coastal areas, aiming to contribute to the management of the environmental crisis caused by disasters through the use of online collaborative mapping by volunteer collaborators. Volunteer collaborators have been sending georeferenced data and photographs of locations affected by pollution. This information is processed and printed on a cartographic basis created by the web-mapping platform, Google MyMaps©. Photos of 90 locations were plotted on the map, and the pictures demonstrate that the oil slicks that reached the Brazilian coast had very different shapes and consistency. This research can contribute as a participatory monitoring tool during and after oil spills, promoting the oriented preservation of marine ecosystems through citizen science.

Key words: oil pollution management, brazilian coast, data-driven process, citizen science.

INTRODUCTION

Since August 30, 2019 (official date), dense crude oil reached the beaches of Brazil's North and Northeast regions. Until March 19, 2021, 1,009 affected localities were counted, in 130 municipalities belonging to 11 coastal states (IBAMA 2020)[1]. According to the Brazilian Navy, from September 2019 to February 2020, almost 6,000 tons of crude oil (including sand and other materials) were collected[2]. The social losses of the spill were also significant, having affected at least 66.000 fishermen and shellfish gatherers (Brasil 2019), an underestimated number[3], since not all workers have a General Fisheries Registry (in Portuguese, "Registro Geral da Pesca", RGP), closed to new entries since 2013 (Mesquita & Quinamo 2020). In addition, people who participate in the fish processing chain were not counted (Souto 2020b). Food security has also been affected in many places, where there has been a ban on catching and marketing fish, because of contamination with polycyclic aromatic hydrocarbons (MAPA 2019). Negative effects had recorded related to the oil spill off the coasts of Northeast Brazil between

[1]List of coastal localities affected by the oil spill event in Brazil, identified since August, 30th, 2019. Available at: http://www.ibama.gov.br/phocadownload/emergenciasambientais/2020/manchasdeoleo/2020-03-19_LOCALIDADES_AFETADAS.pdf.

[2]Brazilian Navy. Fighting Oil. Available at: https://www.marinha.mil.br/combate-ao-oleo/sobre.

[3]According to Boletim Estatístico da Pesca e Aquicultura no Brasil 2008-2009, 833,205 fishermen were registered in the country in 2009 (MPA 2009).

2019 and 2020. Analyzes of seawater sampling points revealed the presence of heavy metals at levels above the concentration allowed by Brazilian legislation. In this area were found polycyclic aromatic hydrocarbons (naphthalene, phenanthrene, fluoranthene, fluorene, and acenaphthalene) in aquatic animals such as seawater, fish, and jellyfish (bivalves) (Soares et al. 2021).

Because more than 3,000 km of coastline were affected by the event, government monitoring was impossible in such a large area (Soares et al. 2020), that's why is essential to have a network of local information, provided by the inhabitants of the localities and other actors, in order to improve the data collection regarding the areas reached by crude oil and the evaluation of the damage caused by this type of pollution.

In addition to the large volume and area involved in the spill, the crude oil reached the Brazilian coast with different characteristics, as a result of weathering of the material released at sea. The registration of the spatial occurrence of these oil slicks with photos can assist in the future formulation of action protocols. For each type of oil slick, there is an appropriate control procedure response. Therefore, the map of the occurrence of oil slicks is an important information source to respond to similar events that may occur in the future on the Brazilian coast. With the discovery of the pre-salt layer and the continuation of oil reserve auctions, there is the likelihood of an increase in the frequency and intensity of oil pollution events, likely further highlighting the role of the collaborative online map. There are no precedents for the use of Citizen Science similar to that given by this research.

Nonetheless, citizen science has contributed to disaster risk reduction (DRR) by promoting the scientific knowledge progress, presenting a systematic global mapping of citizen science, communicating early warnings of danger that contribute to the assessment and management of impacts. It assists in the quality of decision-making around risk reduction (Hicks et al. 2019). Citizen science data presents a new source of parameters that can be used in sustainability reporting and monitoring. Citizen science requires a broad global ecosystem of data through partnerships to accelerate and leverage investments to improve its use and the intensity of the impact of the results (Fraisl et al. 2020).

The UN Sustainable Development Goals (SDGs) have presented an aspirational vision for achieving a sustainable global future (United Nations 2015). Accessible, reliable, acceptable, measurable, and robust data are essential to measuring progress towards goals and the SDGs (Dunning & Kalow 2016). In this sense, citizen science data appear as a new data source to be used to generate information and monitor sustainable development (Datashift 2017). Although citizen science is already contributing to the monitoring of sustainability, studies and knowledge about the real contributions of citizen science to the framework for measuring sustainability in coastal areas are still lacking. Citizen science requires building partnerships around data to strengthen environmental monitoring of coastal areas and prevent oil accidents, contributing to sustainable development and improving the quality and usability of information (Fraisl et al. 2020).

Disaster risk monitoring and management

The disaster-oriented risk management approach is a systematic approach that aims to investigate, identify and monitor the risks of disasters associated with natural environmental impacts and anthropic impacts, seeking to reduce (or eliminate) these risks. Risk management must be incorporated into the management processes of public and private organizations, exercising an instructive and guiding role. Modern risk management requires a holistic and modular approach, considering external variables in its management process, such as meteorological variations, environmental services, green technological innovation, socio-political threats, among others (Twigg 2004, Orimoloye et al. 2020).

Disaster risk monitoring and management play crucial roles in coastal management and planning (Xianwu et al. 2020). It requires a participatory approach based on data collection and processing technologies relevant to management of anthropogenic and natural disasters. The development of analytical techniques for disaster risk management using geographic location tools can facilitate collaborative and proactive management, including different countries and nations facing common challenges (Zhang et al. 2020).

Many contributions on disaster risk management methods in coastal areas (Calil et al. 2017, Gallina et al. 2016) explore different environmental challenges and ecological disasters, followed by reported environmental impacts in developed countries (Mendelssohn et al. 2012) and developing countries (Surianto et al. 2019). Despite the great research efforts of environmental disasters continue to occur. Impacts of disasters and support management models still face great uncertainties (Orimoloye et al. 2021).

Oil pollution in coastal areas causes different types of environmental impact, at different levels, depending on the bathymetry, topographic profile, amount of pollutant discharged release its origin, hydrodynamics of the affected area, among other variables. The environmental impacts resulting from oil pollution have threatened the environmental balance of national and international coastal areas, becoming a permanent risk and challenging governments, specialists, and decision-makers (Karakoç & Ediger 2020).

Coastal areas are under pressure from different causes. However, one main problem is the deficit management of these regions. In coastal areas, several social and economic factors interact with environmental and ecological factors, determining the sustainability level of coastal ecosystems (Souto & Batalhão 2020). For example, the global maritime transport by 2050 is predicted to increase 1,209%, generating impacts beyond environmental pollution (Sardain et al. 2019).

Collaborative oil accident work has been developing through a social network visualization approach such as human sensor networks and information retrieval. They are like field sensors that observe a determined event and produce measurements of it. In these cases, the public has been very active in collaborating and discussing impacts and implications at different accident points. Several people who have witnessed firsthand the damage caused by the oil have reported their accounts from various geographic points. Photos, short texts, and videos posted from oiled beaches have been used in this type of study, as in the case of Deepwater Horizon, Gulf of Mexico, United States (Aulov & Halem 2012).

Collaborative approaches to autonomous oil spill detection, delimitation, and containment have been explored to avoid environmental anomalies, prevent further spills, and increase the spread of pollution and gravity (Woerner et al. 2017). In northeastern Brazil, a tool was recently developed by the INCT Tropical Marine Environments using a collaborative approach, strengthening a participatory monitoring network that emerged from society. This tool aims to systematize and share information to facilitate the integration of community actions with academia, considering environmental and social impacts (INCT AmbTropic 2021).

Governments should be encouraged to adopt anti-oil pollution risk management approaches to adopt preventive rather than palliative actions (Kostianoy et al. 2014). Disaster-oriented management must be achieved beforehand, considering the current scenarios and looking for future possibilities. It must be a long-term goal, with immediate actions and measures, developed through a continuous process of adaptative improvement. This improvement influences the resilience of the system (Martínez et al. 2017).

The resilience of coastal areas to oil pollution must be examined systematically, respecting each step of the government management process and each cycle of the ecosystem included in the marine environmental system. Resilient disaster risk management needs to achieve a participatory management framework, involving different stakeholders. The lack of this compromises its application, legitimacy, and effectiveness because the community's resilience is multidimensional and depends on the interaction with stakeholders (Almutairi et al. 2020). This can influence society's perception of disaster risk (Arias et al. 2017).

This paper integrates individual collaborations promoting the monitoring of coastal areas at low cost, as well as relationship networks between several collaborators that did not exist before. This can strengthen the connections between citizens and science, contributing together to coastal governments, increasing the involvement and engagement of stakeholders in Brazil's coastal areas. The continuous increasing of individual collaborations promotes the construction of databases that must be used for historical analysis and predictive analysis in future researches.

Citizen science

The field of citizen science studies has expanded rapidly in recent years, especially in the last two decades (Kullenberg & Kasperowski 2016; Bonney et al. 2016). The growth of this field of studies has aroused the interest of decision-makers, public policymakers, private and public organizations, scientists, and research funders (Bonney et al. 2016, Skarlatidou & Haklay 2021). This is a real opportunity for those who wish to explore citizen science to generate knowledge and increase public engagement and involvement with science. In this scenario, citizen science has evolved towards the debate around which policies, plans, programs, projects, and activities constitute true citizen science.

There is an interdisciplinary effort to create a consensual conceptual definition of citizen science, however, this has been a challenge as this is a topic situated at the intersection of various fields of science (Shirk et al. 2012, Tauginienė et al. 2020). Citizen science can be understood as and where public participation and knowledge production, or social context and epistemological aspects meet, assuming that this intersection can admit different forms (Irwin 2015). It also incorporates the role of citizens as stakeholders of research findings and conclusions, taking into account public and environmental factors (Irwin 1995, Hall et al. 2016). All of this strengthens "scientific citizenship", promoting a direct link with political actions and public management decisions, for example.

The term citizen science has been used to describe different forms of participation in the production of scientific knowledge. Therefore, overlaps with other terms that have been used to describe participatory action research and digital volunteerism, including Community Science, Civic Science, Popular Science, Participatory Mapping, Participatory Science, Voluntary Geographic Information, Community Remote Sensing, Citizen Observatories, Crisis Mapping, and Citizen Generated Data, among others (Haklay et al. 2021). The wide range of scientific and monitoring activities in which we can see public participation is so broad. There are also several cultural and organizational contexts and a wide variety of disciplines that have sought to contribute to the development of citizen science.

After that, we seek to encompass the different perceptions and points of view of collaborators and affiliated communities and identify the common characteristics they expect from a citizen science activity. People's contributions are from practitioners interested in specific subjects that foster open science. This target group from different geographic locations and multidisciplinary acts contributes to the latent discussion about which actions and activities should be included in the field of analysis or not.

This study aims to offer a methodological approach for mapping contaminated coastal areas that contributes to the management of the environmental crisis caused by disasters, using an online participatory mapping by volunteer collaborators. The methodology in question had not been used until the mapping was realized by the first author in 2019[4]. The following section presents the methods. The next one demonstrates the results, and the last one points out the discussion.

MATERIALS AND METHODS

To develop an environmental management method, the collaborative map approach was used, based on photos shared by participants in the field. This study used this methodological resource as a visual tool to complement the knowledge of geographic information (Sumadio et al. 2020). Thus, collaborative maps increase the amount of information and its potential interaction with other georeferenced findings (Spanish Ministry for Ecological Transition 2015). In addition, collaborative maps are not restricted to expert users. The various local stakeholders and people who live in the surrounding community can collaborate with the assessment and management process (Fogli 2013). This type of approach can attract more knowledge to coastal area maps to develop the understanding skills of local stakeholders.

The collaboration of local stakeholders in our research made it possible to identify, demonstrate and investigate the range of views of what can constitute citizen science. It indicated specifications related to the context of each one, bringing together a set of characteristics that reflect the diversity of information about citizen science, as explored by Haklay et al. (2020).

In view of the gravity of the oil pollution event that occurred on the Brazilian coast in the years 2019-2020, collaborative mapping of affected localities began on October 28, 2019, using an online map, made available with the platform *Google MyMaps©* (Figure 1)[5], as suggested by Neis et al. (2010). In this initial step, invitations were sent to fishing community leaders and dissemination was carried out via social networks (Facebook and Instagram) and via Whatsapp, in order to reach other coastal actors (tourists, managers, etc). The platform is still open to receive photographs of the

[4]After launching her own collaborative map, the first author of this paper received contacts from the following NGOs, requesting sharing of their methodological proposal: Greenpeace, WWF and Climate Observatory (all offices in Brazil). From this mapping, other similar initiatives were carried out, such as the interactive map of the INCT Tropical Marine Environments, released in April, 2021 (INCT AmbTropic 2021).

[5]http://mapapetroleo.ivides.org.

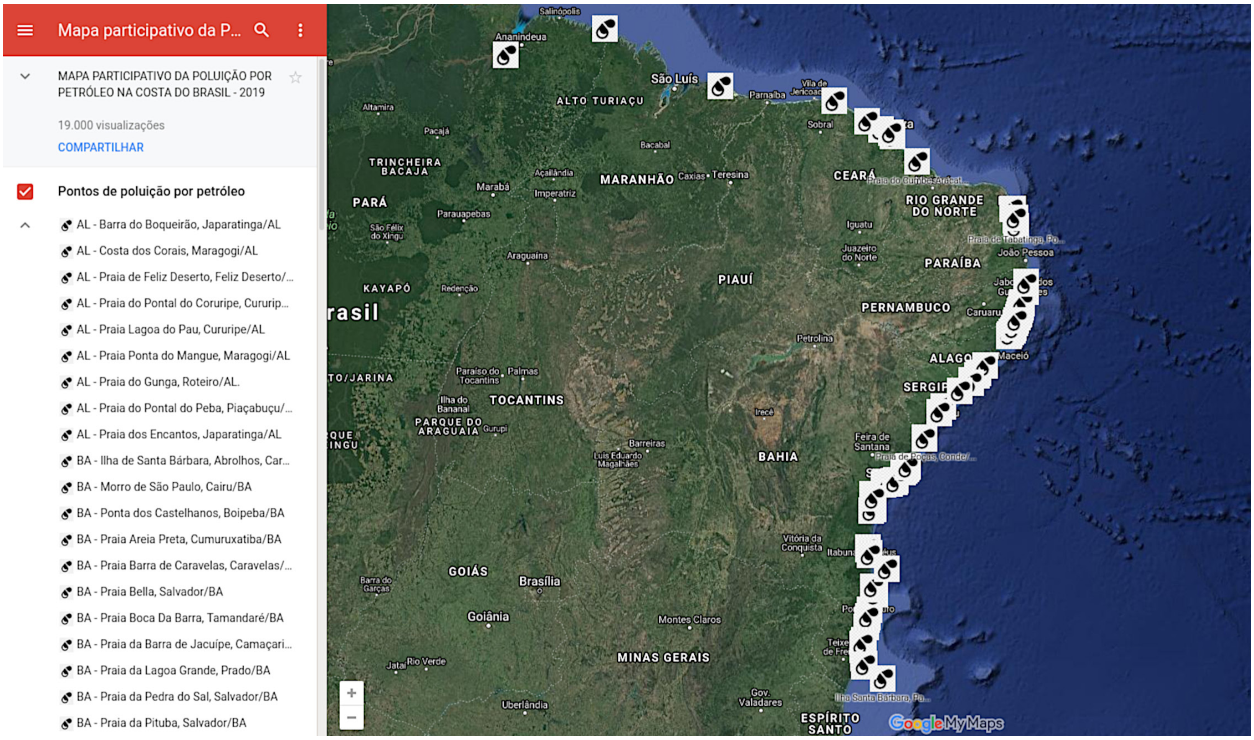

Figure 1. Participatory map of oil pollution – Brazil – 2019 - 2020. Available at: http://mapapetroleo.ivides.org.

contributors, but the addition of new photos has greatly diminished from November 2019.

Photographic records sent by volunteers who were in the affected locations (by Whatsapp© and by email mappart.petroleo2019@gmail.com) were plotted on the map. To publicize the initiative, a web page was created[6] that presented the project and the guidelines for sending georeferenced photographic records through the indicated communication channels (Figure 2). It was not the case of a "pre-selected audience", since the disclosure was not directed to specific people or groups. The contacts for sending the photographs were (and still are) available on the project's website (http://mapaparticipativo.ivides.org).

As the georeferenced photographic records (containing geographic location, latitude, and longitude) were requested and for this purpose, the use of the SW Maps program was recommended and a short step-by-step guide was made available to the volunteers at the project's website: http://www.ivides.org/index/index.php/mapa-participativo-petroleo.

The photographic records were verified by the team that coordinates the mapping and stored in a Google Drive© virtual directory, classified into folders indicating the corresponding states and municipalities. This classification facilitates the subsequent consultation of photos. For each affected locality, the following data are recorded:

- Name - Name of the locality;
- Description - Description of the locality with the photo credits;
- Location – The name of locality, municipality, and coastal state;
- LATLONG - geographic coordinates of the occurrence - latitude, and longitude;

[6]No mobile application was developed for this initiative, due to the urgency of the situation. The map was made available online just over a month after the official start of the event (August 30, 2021) - available at: http://mapapetroleo.ivides.org.

Figure 2. Capture of the project's web page with instructions to the public participation.

- Date - Date of the photo;
- Name of the volunteer – name of the person who took the photo; and
- E-mail of the volunteer – e-mail of the person who took the photo.

In addition to the photos sent by volunteers, other photos from online media vehicles or technical reports from environmental government agencies were plotted on the map, and credits were recorded.

The collaborative map records can be exported in a Keyhole Markup Language file (.kml), a data format based on the Extensible Markup Language (.xml), which makes it possible to store and display geographic data on 2-D maps or 3-D models. The web addresses of the photos are also stored in this data table.

Thus, users can easily download the .kml file directly from the collaborative map and use it in other geovisualization/geoprocessing platforms (Zichar 2012).

The records obtained from the collaborative mapping showed that the oil slicks that reached the Brazilian north and northeast coast in 2019 and 2020 had different characteristics, according to the time of exposure of the marine environment to the oily material. Thus, photographic records of the following types of oil slicks were obtained: *i*) Fresh oil (FR) - unweathered, liquid oil; *ii*) Mousse (MS) - emulsified oil occurring over broad areas; *iii)* Tar balls (TB) - discrete accumulations of oil <10 cm in diameter; *iv*) Patties (PT) - discrete accumulations of oil >10 cm in diameter; *v*) Tars (TC) - highly weathered oil of tarry, nearly solid consistency; *vi*) Surface Oil Residue (SR) - non-cohesive, heavily oiled surface sediments, characterized as soft, incipient asphalt pavements; and *vii*) Asphalt Paviment (AP) - cohesive, heavily oiled surface sediments - according to the typology established by the 4th edition of the *Shoreline Assessment Manual*, published by the *U.S. National Oceanic and Atmospheric Administration* (NOAA 2013, p. 47) (Figure 3).

Initially, it was thought to classify and quantify the oil slicks, registered on sent photographic records, according to the types of stains and the parameters contained in NOAA (2013) or Owens & Sergy (2020), but some photographic records did not show well the appearance or the size of the oily residues, and

Figure 3. Examples of oil slicks found in the littoral of the Northe and Northeastern Regions of Brazil: (a) Sítio do Conde's Beach, Conde/ Bahia (Redemar); (b) Tabatinga's Beach, Natal/ Rio Grande do Norte (PCCB/UERN); (c) Namorados' Island, Itaporanga da Ajuda/ Sergipe (Marcos Rodrigues); (d) Guarajuba's Beach, Camaçari/ Bahia (Pablo Sena); (e) North Beach, Ilhéus/ Bahia (ICMBio); (f) Paiva's Beach, Cabo de Santo Agostinho/ Pernambuco (Municipal Government of Jaboatão dos Guararapes).

this step of the methodology was discarded during the development of the research.

In addition to the online collaborative map, two other maps were prepared (Figures 4 and 5), with third-party data (IBAMA 2020, Soares et al. 2020), for visualization of the geospatial distribution of Brazilian Nature Conservation Units (NCU) and other locations affected by the disaster. So, the results found by the collaborative mapping were compared to the occurrence of oil stains on the coast of Brazil, as published by IBAMA in 2020 (classified and shown in Figure 4), and discussed in the following section of results.

Data from Soares et al. (2020), about the Brazilian NCU affected by the disaster, were classified and plotted on an interactive map (Figure 5) to assess the extent of damage in protected areas and to alert to the seriousness of the associated ecological damage since localities with high importance for the feeding and breeding of many coastal and marine species were affected. In this sense, the effects on mangroves and coralline formations are highlighted.

RESULTS

Our analysis demonstrated that the inclusion of citizen science is relevant in a collaborative approach to disaster management, as well as the levels of confidence of respondents in deciding whether a given image reflects their reality or not. The project was registered and plotted in the collaborative map photos of a total of 90 localities in the following coastal states: Pará, Maranhão, Ceará, Rio Grande do Norte, Pernambuco, Alagoas, Sergipe, and Bahia, with the highest concentrations in Bahia.

Despite being 90 locations, out of a total of just over 1000 oiled points, as identified by IBAMA (2020), the points obtained from the mapping with the photographs extend throughout

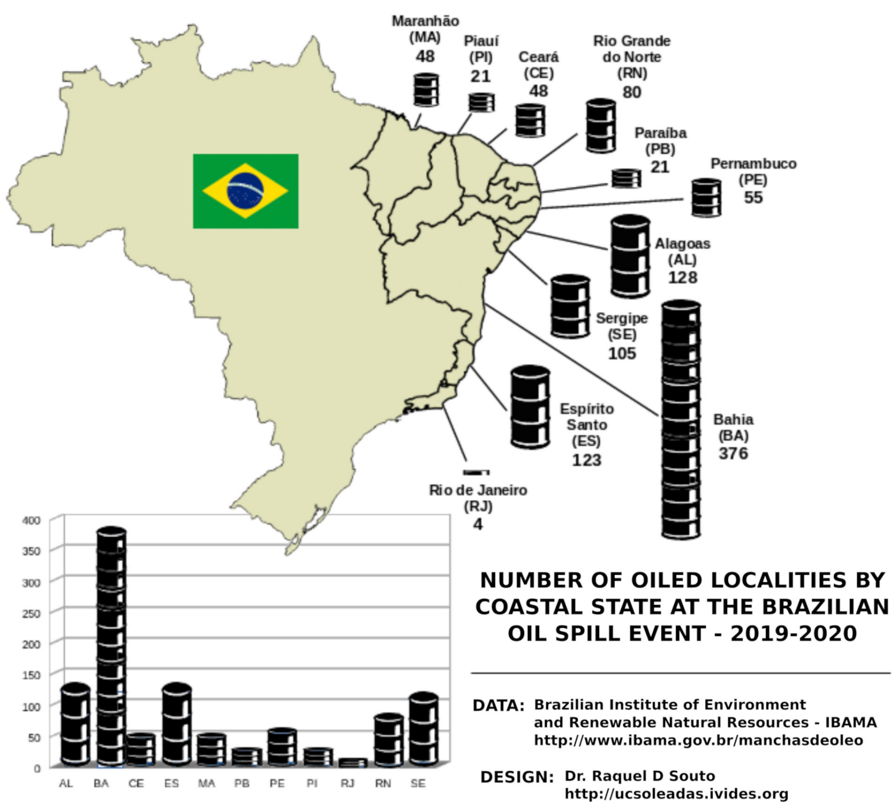

Figure 4. **Percentual distribution of the retired oil in each Brazillian coastal state, according to the official data. Translated from Souto (2020a, p. 54).**

the Brazilian coast, providing a sampling of the situation. Especially, with regard to the appearance of the oil slicks that arrived on the Brazilian coast. The spots presented different aspects, the result of different physicochemical weathering states of the substance, during the drift in the sea until reaching the coast. The use of these photographs, toghether with those provided by IBAMA (2020), can help in future assessments of dispersion (and, perhaps, the geographic location of the source of the spill).

The higher incidence of oil on the coastal zone of Bahia State could be confirmed by the data published by IBAMA (2020), from which the map of Figure 4 was drawn up, showing the distribution of the amount of oil collected between September 2019 and February 2020, when the Brazilian Navy closed coastal cleaning operations.

The photos sent mainly refer to the locations where NGOs and research groups work, which were helping to remove the oil slicks in the locations and supporting the resident population, which was heavily affected by the disaster. Many of these NGOs act also in Nature Conservation Units (NCU), which were heavily affected by the disaster (Soares et al. 2020).

The vast majority of photographs were received by Whatsapp©, with very little use of e-mail by volunteers. Most of the photographs were submitted by volunteers from fishing colonies or leaders of NGOs that were present in the oil-affected localities[7]. This and other appointments revealed limitations for this type

[7]Although ICMBio and IBAMA's photos were requested, unfortunately, they were not made available by these institutions to the first author. Photographic records from these institutions could greatly contribute to the collaborative map collection of this research.

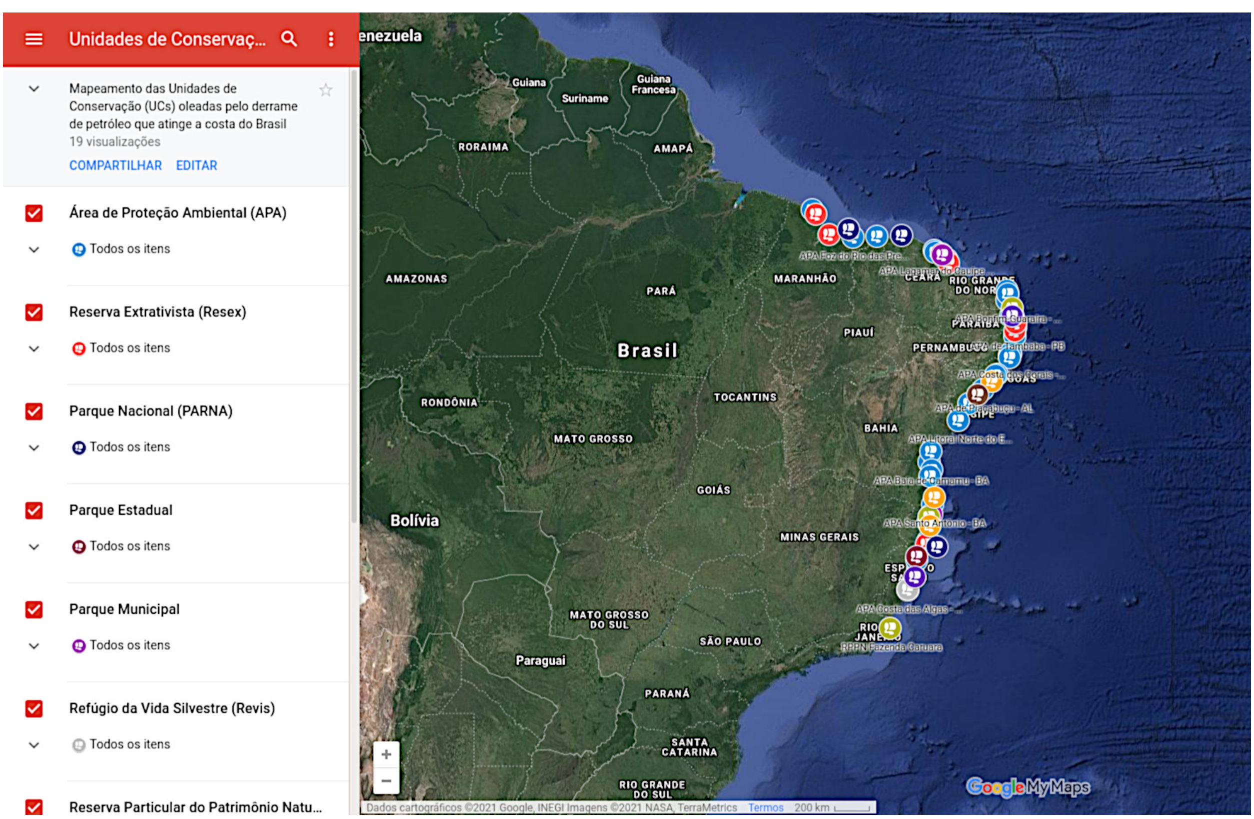

Figure 5. Online interactive map with the Nature Conservation Units affected by the Brazilian oil spill. Available at: http://ucsoleadas.ivides.org.

of mapping, which are discussed in the next section.

DISCUSSION

Given the magnitude and complexity (multidimensional and systemic event) of this event, participation is a crucial element of the survey. Participation leads to an increase in the population's awareness of their problems at the local level, also contributing visibility to social demands (Souto 2020c). The record of localities affected by the 2019-2020 Brazilian oil spill event also form a collection that can be consulted in assessments of this and future oil pollution disasters in Brazilian coastal and marine regions.

To increase confidence in the data contributed by the volunteers, the photos must be georeferenced or be recognized by a trusted source, such as government institutions or research centers. This can be a limiting factor for collaboration of individuals who are less familiar with technological devices, especially older people or others living in places farther from large urban centers.

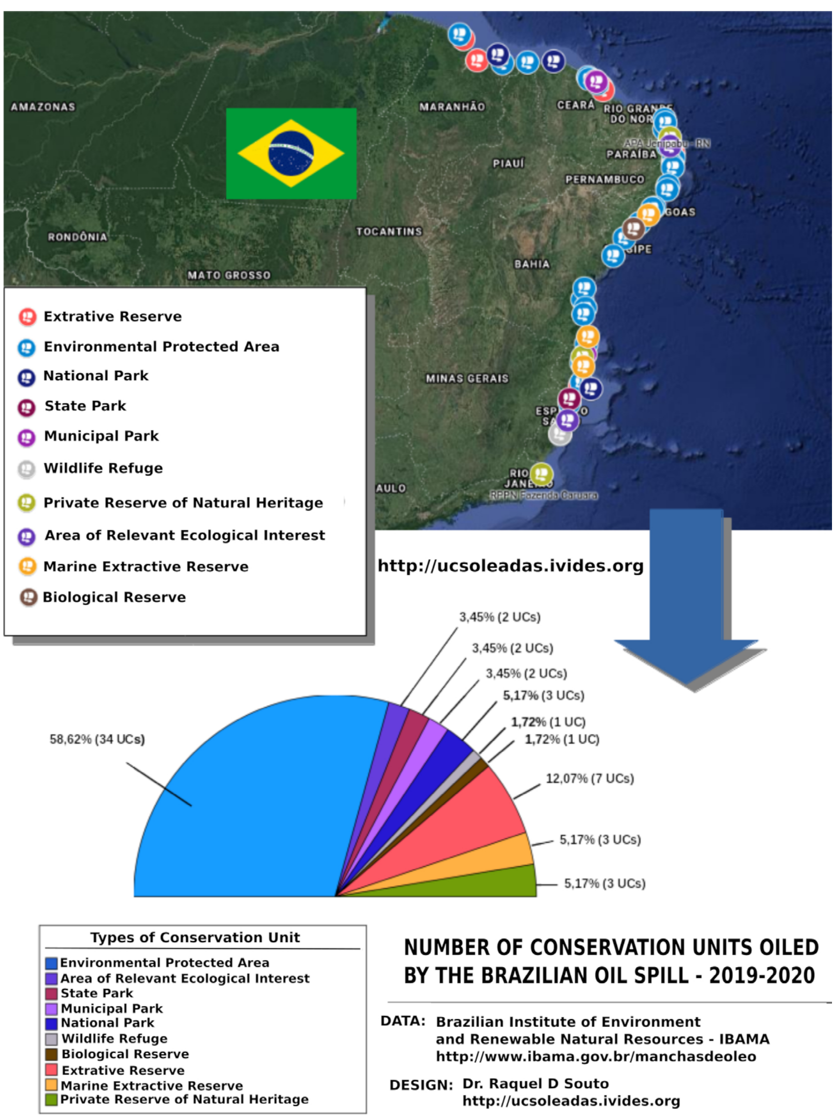

Figure 6. Nature Conservation Units affected by the Brazilian oil spill, classified by its type. Translated from Souto (2020a, p. 55).

What gives the scientific character, what differentiates this research from a mere set of photos shared between friends, concerns: (i) the adoption of a theoretical framework for the development of research – in the present research, the principles of participatory mapping are adopted and the characteristics of its methods are observed (Souto et al. 2021); (ii) minimum validation of data - inclusion of photos with geographic location (*geotagging*) and for this purpose, a manual was made available for using SWMaps, to capture the geographic coordinates, at the time of capturing the photo; and also, verification of the date of generation of the photographs (metadata of the file); (iii) this research is part of a larger research, which is part of the author's postdoctoral development period with the PPGG-UFRJ, and is also an initiative supported by the laboratories GeoCart-UFRJ and Lageot-UFF.

The chosen language for storing data, the Keyhole Markup Language (KML), is useful due to its compatibility with other geoviewers. However, Google MyMaps© uses Geographic Coordinate System (latitude-longitude) and the World Geodetic System (WGS-84). Therefore, the use of other types of geospatial data formats, coordinate systems, or geodetic reference systems will require data export and transformations into a geographic information system (GIS). The option to use Google MyMaps©, in the case of the present research, is due to its fastest learning curve, having launched the platform in less time than a week. Alternatively, OpenStreetMap© could be used, but this application is less intuitive for the lay public and requires more learning time.

Other initiatives with mapping of oilcloth photos can be mentioned, however, it is important to emphasize that they do not constitute Citizen Science experiences, whose assumption is the participation of lay people[8]. There is often a confusion between interactive (or dynamic) map - the one with which the user can interact; and collaborative (or participatory) map - one whose data and information were contributed by different people. For a more in-depth discussion, see Souto et al. (2021).

In general, the availability of photos of affected localities can assist in prevent on and mitigate on of damages caused by oil spills in Brazil. Each decomposition phase of the oily material demands different mitigation techniques - manual removal; machine-assisted manual recovery; manual recovery in rocky areas; manual oil recovery in mangroves; mechanical recovery and collection of tars at sea (IBAMA 2020).

The participation of traditional communities (fishermen, shellfish gatherers, *quilombolas*, *caiçaras*), together with the assistance of civil society organizations, was fundamental in facing the disaster (Soares et al. 2020, Souto 2020a, b, c). The communities themselves developed alternatives to prevent the arrival of oil on the coast, capturing sea tars with nets, protecting the estuary entrances with nets or placing containment barriers or buoys (Figure 7).

The availability of an online platform to register oiled localities also contributed to greater data and information exchange between the participants, in addition to the photos received by the project. Greater connection between these groups emerged, showing that

[8] https://www.inctambtropicii.org/mapadooleo https://sites.ufpe.br/ceerma/2021/04/27/lancamento-do-mapa-colaborativo-do-oleo/ https://www.ibpad.com.br/blog/comunicacao-digital/monitoleamento-com-mapa-interativo-cidadaos-podem-apontar-manchas-de-oleo-pelo-nordeste/ https://blog.img.com.br/ciencia-pesquisa-educacao/storymap-manchas-de-oleo-no-nordeste/ https://storymaps.arcgis.com/stories/a5bb1d12fef647fb89fb7a1d64aac0fd

Figure 7. **Containment of oily material by coastal communities: (a) Barriers in Aracati/CE; (b) e (c) Containment buoys in Caravelas/BA; (d) Containment nets to protect the Catu River (Cairu/BA). Source: Souto (2020b, p. 220).**

participation is an indispensable motor in monitoring and evaluation and contributing to its improvement, through the contribution of a large volume of qualitative data on a local scale. A conventional survey of this type of data (and in the extent of the disaster) is complex and costly, and it is often necessary to take several teams to the field. Citizen science can assist the effort.

In the theoretical framework of the Sustainable Development Goal 14 (SDG-14), *Life in the water* (UN 2015, ECLAC 2018), Target 14.a (*Scientific knowledgement and technology transfer)* has a positive synergy with the Target 14.1 (*Marine Pollution)*, since the transfer of technology is important for fighting marine pollution of any kind. The Target 14.1 also relates to *Food security* (SDG-2), *Health and well-being* (SDG-3), *Water* (SDG-6), *Economic growth and employment* (SDG-8), *Industrialization and infrastructure* (SDG-9), *Cities* (SDG-11), *Sustainable consumption and production* (SDG-12), *Climate change* (SDG-13), *Terrestrial ecosystems* (SDG-15), and *Peaceful and including societies* (SDG-16) (Le Blanc et al. 2017, Souto & Batalhão 2020). With these preliminary relationships between the dimensions and themes of sustainable development, we note that marine pollution also affects terrestrial environments and dimensions, constituting a multisectoral problem that can be solved with increased coordination between different levels of public administration and various actors in coastal and marine regions (GESAMP 1996, IOC 2006, Ehler & Douvere 2007, 2009, CIRM 1990, Brasil 2004).

Hot topics of research on crisis management related to environmental impact, application of environmental or green technologies, and types of governance, including meta-governance and micro-governance. About studies of these topics they add experiences about the management of coastal areas. Participatory practices are initiatives that should also be explored.

The maintenance of a collaborative mapping with photos of the oiled localities will assist the subsequent analysis of scientists and technicians from government environmental agencies and other organizations. This map can also be used in analysis with the *Environmental Sensitivity Maps for Oil Spills, SAO Charts* (MMA 2014)[9]. In this sense, the following question is relevant: did the SAO Charts accurately predict the location of the areas that are most sensitive (from an ecological point of view) and susceptible (from the point of view of coastal dynamics) to episodes of the oil spill?

Because the environment is a public good, according to the Constitution of the Federative Republic of Brazil (Supreme Federal Court 2019), and the coastal zone is specifically a biome of great economic, social and environmental importance; the provision of a collaborative map provides the Brazilian population with access to information related to the disaster and involves civil society around the problem, highlighting the importance of participation in the conservation of this zone.

However, some limitations of the methodology were found in the development of collaborative mapping. The main one was the difficulty of using the programs and equipment by volunteers, for geolocation and recording of photographs. The same difficulty was encountered by researchers who developed other collaborative mappings, as reported in Freitas & Farias (2019), Sullivan-Wiley et al. (2019) and Silva Filho et al. (2015). Some limitations refer to the use of the My Maps online mapping platform: a) it limits the use of other types of geospatial reference systems; b) there is no automatic mechanism for validating the location of photographic records, which had to be carried out by the mapping team; c) some potential volunteers were wary of submitting photographs, which revealed a distrust of the mapping activity and the possible future use of personal information; d) the mapping received very little (or no) adhesion from government institutions, that are important actors at the moment of the control of this type of crisis, so intense and that reached an immense area of the Brazilian coast.

Regarding the validation of collaborative data - a topic of recurring interest in the scope of research using participatory or collaborative methods, the research by Brovelli & Zamboni (2018) is relevant, who measured the spatial accuracy of mapping buildings in OpenStreetMap. However, the present research focuses on the applicability of collaborative mapping as a tool for gathering local information in the event of an emergency situation. Ullrich et al. (2012) argues that validity is not property particular of a method, however, belongs to the data, findings, or conclusions reached by using a method, considering a context particular for a particular purpose. So, considering the initial purpose of the present research, it has reached its finality, it has demonstrated that online collaborative platforms can assist in the acquisition of data on a local scale, in an environmental emergency situation.

CONCLUSIONS

Until the release of the collaborative map discussed in this paper, there was no similar initiative in Brazil (and, perhaps, in the world), but we point out some researches using citizen science and participatory (or collaborative) mapping in the prevention or management of environmental (or socio-environmental) crises: Almeida & Ventorini (2014), Freitas & Farias (2019), Sullivan-Wiley et al. (2019) and Silva Filho et al. (2015).

[9]SAO Charts were prepared under the coordination of the Ministry of the Environment, Natural Resources and the Legal Amazonia of Brazil, with the objective of assessing the susceptibility of vulnerability coastal areas to the oil pollution events (MMA 2014).

The present research aimed to show the usefulness of online collaborative mapping, in obtaining local data, in events of environmental crisis, such as the oil disaster that hit just over half of the entire coast of Brazil, in the years of 2019 and 2020. Despite the limitations of the methods used (as discussed in this text), the photographs obtained allowed us to observe that the material that reached the Brazilian coast had different aspects, showing that they resulted from different periods of exposure to the physical-chemical weathering of the oil, during its drift in the sea, until reaching the coast. So, this article is expected to contribute to the improvement of monitoring and evaluation instruments aimed at disaster risk reduction, so that the country is better prepared for future oil pollution episodes.

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