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Where are Brazil's marine litter scientific data?

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The environmental sciences work with datasets every day. Recently, data sharing has become a more familiar activity for academic researchers. Records of marine litter are scarce and generally difficult to find worldwide, especially in databases. This work reviews and analyzes data repositories to identify the existence of datasets related to marine litter in Brazil. Only one global repository specializing in marine litter was found, and it is in the early stages of operation. Only two datasets about marine litter in Brazil were found in the generalist repository Figshare that do not follow all the FAIR principles (Findable, Accessible, Interoperable, and Reusable) for data sharing. A few initiatives are being developed aiming to collect and share marine litter data, but only one of them (Our Blue Hands) is already in place and uses a standardized, replicable method, and aims to share the data by design. Our work identified interoperability as the main point to be tackled within our context. In the UN Decade of Ocean Science for Sustainable Development (2021–2030), it is essential that repositories are created, improved, and encouraged to address the specific needs of marine litter data-sharing and researchers' behavioral shift to start sharing the data already collected. Data sharing not only allows for the integrated vision of the academic community but can also contribute to public policies, helping decision-makers and encouraging a more sustainable science regarding financial and natural resource use.

KEYWORDS

FAIR principles in open education, interoperability among databases, dataset, repositories in science and technology, sustainability, predictable ocean, GPML, cooperation (with civil society organizations)

Introduction

The environmental sciences work with data every day. Recently, data sharing has become a more familiar activity for academic researchers (Goben and Sandusky, 2020). Available data can support new research and can be used by decision-makers. Technological advances, including the internet and easy access to information, help advance science. Despite the technology available, more data are produced every year that needs to be organized and accessible. Data accessibility brings advantages to science and society and links different study areas (Barreto et al., 2019). It would be possible to carry out many studies with already existing data. An example is that in the

COVID-19 pandemic scenario, some reviews and reanalysis used previously available data. This shows that the available data is important to guide our next works more consciously (Saadat et al., 2020). During COVID-19, the universities were closed in Brazil and most parts of the world to contain the spread of the virus. Due to the global lockdown, researchers had no access to their laboratories, and fieldwork was canceled. Since scientists are "rated" by their number of publications, they had to find some way to keep publishing during this time. Some options were review articles and analysis using data that were previously collected and/or available in repositories.

However, it is not only in a pandemic scenario that data should be shared; if not shared, data remain unused. Hence, sustainable initiatives for resources and/or biological samples are used for data collection and processing, which can be optimized by sharing and reusing the data.

Marine litter is an important theme worldwide, presented in the Sustainable Development Goals (SDGs) target 14.1, "By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution" (United Nations, 2022). Among a wide range of pollutants, marine litter and nutrients were prioritized. Also, marine litter is listed as an Essential Ocean Variable (EOV) by the Global Ocean Observing System (GOOS), highlighting the relevance of marine litter impacts on marine conservation and the importance to collect and provide such data. In the scenario of the UN Decade of Ocean Science for Sustainable Development (2021–2030), marine litter datasets following FAIR principles can help to achieve a clean and predictable ocean.

Depending on research areas, data sharing can be in its early stages or better developed. In some study areas, it is possible to choose a suitable repository, organize the data, prepare the metadata, accessory documents, copyright, consent, and permissions, and deposit the dataset (EDCTP, 2022) more easily than in other fields. Data regarding marine litter could help better understand the current scenario and support decision-making. In this work, we bring a review of previously used and potential scientific marine litter data and databases focusing on Brazil.

Brazil is the fifth largest country in the world in terms of land area (8,547,403 km^2) (IBGE, 2021). The Brazilian economy has components based on coastal and marine activities, for example, oil and gas exploitation, harbor and industrial activities, fishing, leisure, and tourism. Also, almost 30% of the population lives in the coastal zone (IBGE, 2011). Besides being a large and developing country with diverse and complex environmental and socio-economic issues, Brazil is the fourth largest plastic waste producer in the world (Zamora et al., 2020). This can cause a loss of 5.7 billion Real (Brazilian currency) a year for not dealing with this problem (Zamora et al., 2020), and also increase marine litter pollution. In this context, the number of papers about marine litter in Brazil is increasing (Castro et al., 2018; da Silva Videla and de Araujo, 2021). However, there are few datasets available related to these publications for further development of possible solutions to marine litter problem based on data.

This work aims to review and analyze data repositories to identify the existence of datasets related to marine litter in Brazil, bringing a global point of view of marine litter data sharing. In addition, we aim to highlight the importance of FAIR principles and data sharing as key points for improving and encouraging sustainable science of natural resource use and conservation.

Data, databases, and related repositories

It is common sense that data is the primary building block for both information and knowledge (Zins, 2007b). Data, information, and knowledge are the major components of information science (Zins, 2007a). Although there are some divergences in the definitions of what really involves this area (e.g., the subtypes of knowledge), for the purpose of this work, we are going to consider data, information, and knowledge as parts of sequential order. Therefore, data will be the precursor of information, which will serve as the base for knowledge. Data for this work is any set of records from observation or measurement arranged comprehensively.

The use of data is important for different areas, including environmental sciences. The use of natural resources and the ecological footprint for data collection in the environmental sciences can be optimized if more studies are carried out with the same dataset. Oceanographic cruises that collect a large amount of data also have polluting potential, for example, due to the use of fossil fuel. Using data already collected can better justify the polluting activity and allow more people to use, discuss and compare data. In addition, data availability can support better understanding or even the integration of ideas, allowing the detection of temporal and spatial patterns, such as physical oceanography data that can indicate patterns of accumulation and disposal of marine litter (Van Sebille et al., 2020). Thus, places to store and share data are becoming more common in the scientific community. Data storage requires infrastructure and energy. To make this more sustainable, it is recommended to optimize existing data repositories and resources to improve interoperability and reusability (Tanhua et al., 2019).

In agreement with this, some government and funding agencies require that researchers make their data available to receive financial support (Michener, 2015; Brainard, 2021), which plays an important role in the open science and open data movement. In 2022, the Brazilian government launched the National Consortium for Open Science (ConCIenciA in Portuguese), an initiative that aims to encourage open data repositories for research data in the national territory and support their governance with international acceptance and visibility. An action of ConCIencia was the launching of

LattesData platform (https://lattesdata.cnpq.br/) from Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), a funding agency from Brazilian government. The repository was created to reunite, storage and share scientific data from funded CNPq researchers, in the future it can be open for every researcher. It highlights the role of universities in facilitating pathways to address environmental problems (Gardner et al., 2021) by providing FAIR (Findable, Accessible, Interoperable, and Reusable) data.

There are several repositories where scientists from different areas are able to share their data. Data repositories can be generalists or specialists. Generalists do not require specific formatting and/or topic of research, while specialists accept only data referring to a research area and/or certain formatting for the database (De Pooter et al., 2017). Most of the time, scientists do not know where to publish, which leads to unavailable and scattered data (Park and Wolfram, 2017). Nevertheless, the importance of sharing has been overcoming the difficulties, allowing the sharing culture to grow despite the adversities (Pendleton et al., 2019).

The open scientific data approach is proposed to help increase the speed of science, allow the comparison and cross information, increase the reproducibility of scientific work as well as mitigate data manipulation (Hampton et al., 2013; Pendleton et al., 2019). In addition, it is a strategy to optimize resources and produce a more sustainable scientific outcome, including transparency of public funds used in data acquisition.

The goal of Open Science is to make scientific research and its dissemination accessible to all levels of society. Also encompassed in the concept of Open Science are open access, open educational resources, open-source software, and citizen science, all of which are grounded in equity, diversity, and inclusion (European Commission, 2019).

In addition to online repositories, many countries have a Spatial Data Infrastructure (SDI) that includes technology, policy, standards, and human resources and encompasses activities, such as data acquisition, processing, distribution, use, maintenance, and preservation. In other words, an SDI goes far beyond an online repository. Some examples are the British Oceanographic Data Center (BODC), the Centro Argentino de Datos Oceanográficos, the Australian Ocean Data Network (AODN), the North American National Centers for Environmental Information (NCEI), and the Infrastructure for Spatial Information in Europe (INSPIRE). However, the SDI might not have data on marine litter; an exception is EMODnet, which is an EU SDI including marine litter data.

In Brazil, the National Spatial Data Infrastructure (NSDI) was launched in 2010, aiming at the integration between systems of different institutions. Its purpose is to catalog, integrate, and harmonize existing geospatial data in Brazilian government institutions. It has good documentation and defined standards for data and metadata (Gandra et al., 2018). However, in general and globally, there is still a lack of national and international collaboration for SDIs (Gandra et al., 2018); in addition, it is necessary to increase the scope to cover timely themes such as marine litter. An example is the vanguard work that is done in EMODnet, an SDI that covers most of the Essential Ocean Variables (EOVs) and keeps updated on new themes such as marine litter.

Sharing is not a problem

Despite the importance of sharing data, this is still a trend for most researchers all over the world that used to keep their data under personal control and now are dealing with the data sharing process (Reichman et al., 2011). Therefore, the first big challenge is the cultural change shift (Pendleton et al., 2019). Some of the factors that do not collaborate to this change are time and effort to find suitable repositories to upload the data, write appropriate metadata, and format the data in templates that do not always fit the type of data sampled (Park and Wolfram, 2017). Since it is still a new field, there is not much information on what to do in terms of standardized procedures and guidelines for the authors. In this regard, an example is a step-by-step guide developed by Soranno (2019) to facilitate this decision process. There are other examples such as the EMODnet ingestion portal (EMODnet, 2022a) and the EDCTP Knowledge Hub (EDCTP, 2022) guidelines.

Another factor contributing to the resistance to sharing data is data authorship/ownership (Costello, 2009; Reichman et al., 2011), which concerns about data misinterpretation and misuse (Campbell et al., 2002; Borgman, 2012). Both of these are related since many times authors start viewing this data as a product that was created by them and not only as a result/output of their work (Broom et al., 2009). There are laws about intellectual property and initiatives as the Creative Commons license, which guarantee the authors the credit for the data. However, the problem seems to be more related to the work put into collecting the data and the need to overprotect it rather than the actual ownership (Broom et al., 2009; Perrier et al., 2020). On the other hand, researchers understand that collected and processed data should be accessible to contribute to science and assure transparency, especially in the case of government funding bodies (Broom et al., 2009).

Despite some governmental and funding agencies moving toward implementing data sharing, there is still lack of specific incentives for researchers to share the data (Costello, 2009; Reichman et al., 2011), such as clear rules, training, and planned financial support. Additionally, there is resistance from some spheres of the scientific community to make data available in an organized and open manner (Perrier et al., 2020). So, there is an urgent need to change this culture and work together in a less-competitive way making cooperation the mainstream science model (Figure 1).

In an attempt to mitigate some of the problems related to data sharing, various societal sectors worldwide—academia,

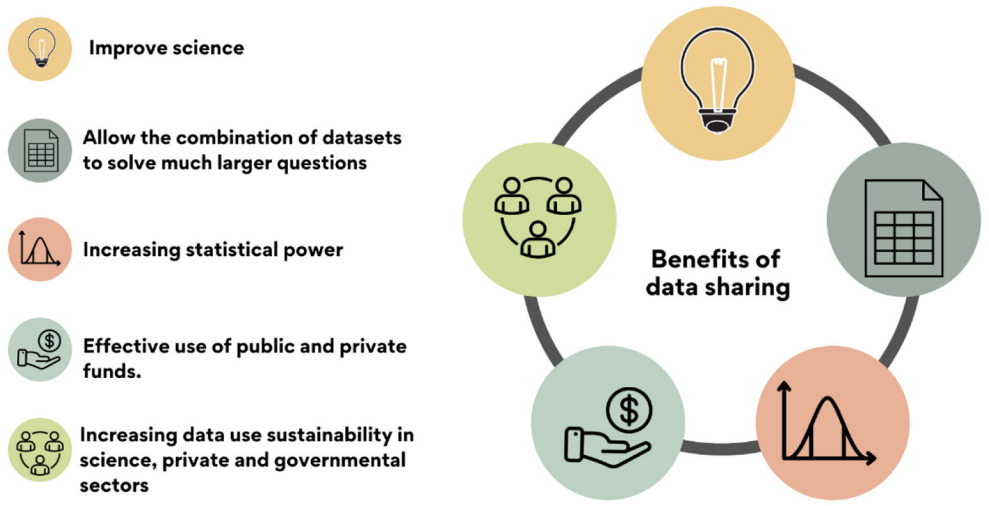

FIGURE 1
Benefits of data sharing under FAIR principle, based on Perrier et al. (2020).

industry, funding agencies, and publishers—have agreed to use the FAIR principle (Findable, Accessible, Interoperable, and Reusable). In this context, data must be Findable, having a unique identifier for the data file and the data content. Accessibility: the sampling/data collection protocol and datasets are open and free. Interoperable: data representation is done with language that follows the FAIR principle, and different repositories can access and provide datasets. Reusable: the data are made available with detailed metadata that allows more than one use/study (Wilkinson et al., 2016; Tanhua et al., 2019).

The FAIR principle allows data to be easily used by other researchers, decision-makers, and machines (Wilkinson et al., 2016). The FAIR principle help to mitigate the problems raised related to data integrity, quality, and adequate amount of details that allow the reuse of the data (Perrier et al., 2020). Quality check and control performed by humans and/or machines is an important practice to keep repositories reliable.

The publication of articles with supplementary material containing the data used does not characterize a data repository since it does not meet the FAIR principles, has no specific identifier for the dataset (e.g., DOI) (not Findable), and rarely presents metadata or standardization (not Accessible and Reusable). Also, journal publishers do not have a repository structure to store and make available datasets submitted as Supplementary material. There are papers being published with Supplementary material that could also be datasets to be placed in repositories.

Metadata are data that provides basic information about the main dataset, such as the time zone of collection, details about equipment, method used, etc. Some publishers and journals encourage data sharing in repositories, such as Data in Brief and Mendeley Data, that have started the process of publishing data papers and/or dataset. In this case, the data present a detailed metadata in agreement with the FAIR principle. However, the publication process is costly.

Methodology

This review analyzed open data repositories to identify the presence of datasets related to marine litter in Brazil. Google's Dataset search (https://datasetsearch.research.google.com/) was used on the first search to find datasets and their host repositories. Google's Dataset is a platform that compiles all datasets available online being a powerful tool for global searches. The main goal is to organize the information that exists in the world and make it accessible and useful.

In Google's Dataset website, a search was performed using the terms: "marine litter," "marine debris," "lixo marinho," "lixo no mar," "Brasil," "Brazil," "plástico," "plastic," "microplástico," "microplastic." The searches were conducted until April 2022, with no restrictions on the start date. The datasets found in the searches were assessed and checked for the rules of FAIR principles (Wilkinson et al., 2016; Tanhua et al., 2019).

Although, Google's Dataset search is not considered a repository since it is a search tool that redirects users to the repositories. It was not possible to find data papers through Google's Dataset search, indicating that this type of publication is in an intermediate area between data publication and a scientific article. Second, an active search was conducted to

TABLE 1 A summary of data repositories and potential of data related to marine litter in Brazil.

Coverage	Type	Repository	Marine litter data for Brazil	Notes
National	Specialist	BNDO	None	Distribution of data through an e-mail request. Difficult to search for available data. Incomplete metadata. Brazilian Navy is responsible for keeping the repository.
	Specialist	GOOS	None	Each project associated has its own website and criteria for uploading and downloading the data. Difficult to search for available data.
International	Specialist	OBIS	None	Depends on the cooperation of institutions to feed the database. Specialist repository. Darwin Core format
	Generalist	Figshare	2	No data audit/curation Incomplete metadata Provide metrics (view, downloads and citations)
	Generalist	PANGAEA	None	With data audit/curation
	Generalist	KNB	None	With data audit/curation
	Specialist	GPML	None	Gathers data from partners

identify other repositories. In each repository, there was a search using the same keywords used in Google's Dataset. Active searches have a controlled level of uncertainty. However, by overlapping different search methods, it is possible to keep it to an acceptable minimum.

Regional repositories, e.g., focused on the EU Member States, Artic region, Indonesia, or other region outside the analyzed area, were not considered in the analysis because they were not related to the main goal of the study. However, Brazilian and global repositories that did not present marine litter's data in Brazil accounted for a better understanding of the possibilities of future data hubs focusing on marine litter in the region.

Results and discussion

Marine Litter is a pressing environmental problem in the 21st century; many scientific papers are published in Brazil annually involving macro and/or microlitter, especially in coastal zones (Castro et al., 2018; da Silva Videla and de Araujo, 2021). The complex nature of litter data and the lack of standardization regarding the use of the already existing guidelines (e.g., GESAMP, UNEP, and NOAA) for collection and nomenclatures are often detrimental in the process of making litter databases available, as well as entailing management and conservation challenges (Hartmann et al., 2019). Marine litter encompasses a wide range of materials from various sources, including Abandoned Lost or otherwise Discarded Fishing Gear (ALDFG), sanitary materials, and construction waste; there are a lot of litter typologies, glass objects, anthropic wood, plastic fragments, microplastics. Different types of litter have different measurable parameters, e.g., size, weight, color, malleability, material, brand, possible source, among others.

Marine litter data

Seven data repositories related to environmental science with the potential to present a Brazilian marine litter dataset were identified (Table 1). Two repositories had national coverage: Banco Nacional de Dados Oceanográficos in Portuguese (BNDO) and the Brazilian node of Global Ocean Observing System (GOOS). Five repositories had international coverage: Ocean Biogeographic Information System (OBIS), which is integrated with the Brazilian Biodiversity Information System (SiBBr), Figshare, Pangaea, KNB, and Global Partnership for Marine Litter (GPML).

One specialist repository for marine litter was found: the Global Partnership on Marine Litter (GPML) Data Hub. However, in 2022, the platform is in its early stages of operation and there are no clear guidelines on how the data curation and/or auditing process will work. GPML works as a hub that puts together data from different data partners, such as Florida State University, University of Leeds, Alliance to End Plastic Waste, GRID Arendal, and EMODNet Chemistry. The platform also proposes to be a place to deposit best practices and experiences to tackle marine litter worldwide. There is no dataset from Brazil available in GPML yet.

Regarding national repositories, one possible database for marine litter data could be the National Oceanographic Database (BNDO) (https://www.marinha.mil.br/chm/dados-

do-bndo/acesso-dados-e-produtos), which is managed by the Brazilian Navy. The aim of the institution is to promote and coordinate the participation of Brazil in the activities of the Intergovernmental Oceanographic Commission of UNESCO (IOC - UNESCO) related to Ocean Services and Ocean Mapping. However, the data are focused on physical and geological oceanography, and for some access data, it is necessary to contact by e-mail to request access, which in many cases can delay the research and/or decision-making process. Also, besides its difficult user interface and incomplete metadata, it does not meet the accessibility and reusability of the FAIR principles and has no data on marine litter listed in its available variables.

The Global Ocean Observing System (GOOS) is led by the Intergovernmental Oceanographic Commission (IOC) of UNESCO and co-sponsored by the World Meteorological Organization (WMO), the United Nations Environment Programme (UNEP), and the International Science Council (ISC). The Brazilian node (https://www.marinha.mil.br/secirm/psrm/goos) is led by the Brazilian Navy and is focused on physical oceanographic measurements from 10 projects, such as Prediction and Research Moored Array in the Tropical Atlantic (PIRATA). A weak point is that each project associated with the Brazilian GOOS node has its own website and criteria for uploading and downloading the data, making it difficult to search for available data, especially regarding format files and time series. It also does not present marine litter data listed in its available variables.

Regarding international coverage repositories, the Ocean Biogeographic Information System (OBIS) is a specialist repository focusing on marine biodiversity. The repository compiles data from various national nodes. One of these nodes and also Brazil's first initiative for sharing environmental data is the Brazilian Biodiversity Information System (SiBBr—Sistema de Informação Sobre a Biodiversidade Brasileira in Portuguese), an online platform that integrates data on biodiversity and ecosystems from various sources in Brazil and abroad. The platform is easy to use and has a user-friendly interface. Strengths include data curation and the use of the Darwin Core (DwC) format to write and publish data. It is one of the platforms with better adherence to the FAIR principle. Additionally, OBIS has packages in R that make it easy to import data for exploratory and statistical analysis; the data is accessible and interoperable. The dependence on partner institutions to feed the platform can be a weakness. However, the scientific community is very active and presents acceptance of the idea of data sharing, and the platform is kept updated. It has no data for marine litter, not even related to interactions with the fauna globally. It happens because OBIS accepts data in Darwin Core (DwC) format, which is not applicable to marine litter data.

Figshare is a generalist repository (https://figshare.com/). The biggest weakness is the lack of auditing and curation of the published datasets, which makes searching difficult. It also allows datasets in several data formats; hence, it does not meet the FAIR principle. However, Figshare was the only database that had Brazilian marine litter data. Only two datasets were found in Brazil, one regarding microplastic (Zanetti and Leonel, 2019) and one on macro litter (Ramos et al., 2020). Both datasets have complete metadata, data identification keys, and meet the FAIR principles. Also, both datasets are relatively recent, highlighting that Brazil is only starting the process of sharing marine litter data. In Brazil, there is one case of marine litter dataset publication in a repository (Ramos et al., 2020) and its related article (de Ramos et al., 2021). For the other dataset (Zanetti and Leonel, 2019) located during our search, there is no published paper associated yet. It shows that data publication can happen in different phases of paper publication (pre, during, or post); licenses and temporary data embargoes help scientists decide when they will make data available. However, the growing number of publications on the topic (Castro et al., 2018; da Silva Videla and de Araujo, 2021) suggests that Brazilian researchers have a fair amount of data kept under personal control while it could be published, giving a better picture of the marine litter situation and even helping decision-makers address this problem. PANGAEA is an open access data hosting system aiming to archive, publish, and distribute georeferenced data from environmental surveys; it is a generalist repository. The data goes through an auditing process, which ensures integrity and authenticity, as well as high usability. Also, PANGAEA is hosted by the Alfred Wegener Institute, Helmholtz Center for Polar and Marine Research (AWI) and the Center for Marine Environmental Sciences, University of Bremen (MARUM). The repository does not present marine litter datasets for Brazil despite presenting these data for other locations, thus emerging as a viable option regarding marine litter data sharing for Brazilian researchers. In addition, the repository meets all FAIR principle.

Knowledge Network for Biocomplexity (KNB) is an international repository aiming to facilitate ecological and environmental research. It is similar to PANGAEA; it also has data auditing and curation and adheres to the FAIR principle. The platform is focused on data management, and the metadata pass through a quality check, following the guidelines proposed by Borer et al. (2009). It has no datasets of marine litter for Brazil, but it does have marine litter data for other places. Again, being a possible option for datasets on the topic.

The BNDO and SiBBr (OBIS) databases are examples that Brazil has specific databases. In the case of BNDO, it still could improve some features, but it shows potential to share data in other areas (e.g., physical and geological oceanography). On the matter of marine litter, there is no specialist database in the world or in Brazil to host a marine litter dataset.

Direct observations, remote sensing, and numerical modeling can be integrated to compose a specialized marine litter repository and a global Integrated Marine Debris Observing System (IMDOS), as proposed by Maximenko et al. (2019). Data regarding marine litter can have different sources and formats; it will be important

TABLE 2 FAIR principle according to repositories with marine litter data fitness for the Brazilian context.

	Figshare	PANGAEA	KNB
Findable	Datasets are not easy to find. It is necessary to know dataset details or its DOI.	The interface is user-friendly, and it is easy subset regions, time ranges, or themes to find datasets. It is possible to search using DOI.	
Accessible	Metadata is not mandatory. Metadata is not always explaining all the necessary things to understand the dataset. There is no curation process	All data and metadata are quality checked. There is a tutorial in how to prepare data and metadata. Experienced data curators are available to help with each dataset submission.	There are guidelines for submissions. It uses MetaDig program to evaluate metadata quality (https://github.com/NCEAS/metadig-engine).
Interoperable	Datasets from different sources or publishers.	Data processed for machine readability. Some web portals connected (e.g., OBIS, Google Dataset Search)	Some connected portals [The State of Alaska's Salmon and People (SASAP)].
Reusable	Since metadata sometimes is poor, it can impair data reusability. It is free without a review process.	Data is verified to be readable for machines, which allows efficient and reliable data re-usage. Quality data and metadata allows people to reuse the data. Python (pangaeapy) and R (pangaear) packages It is free.	Quality data and metadata allows people to reuse the data. R package (rdataone) There are available tools to help manage data such as Metacat (https://knb.ecoinformatics.org/knb/docs/). It is free.

and facilitate the researcher or decision-maker usage if they can see, subset, and download the data in a unique portal that is integrated with other data repositories enhancing the interoperability.

However, GPML is being developed and will soon make great progress for the scientific community. A database specific for this topic have to take into consideration all the characteristics and peculiarities of litter data, highlighting the quality of the data and increasing the chance of reuse, facilitating a sustainable scientific approach to minimize financial resources use and allow best management decisions. Despite not having a local database focused on marine litter, Brazilian researchers need to start sharing data on the topic in favor of the benefits this can cause. In this case, generalist databases can be the temporary solution, at least while the GPML is not fully operational to deposit data directly.

Three generalist repositories (Figshare, PANGAEA, and KNB) present the potential to receive marine litter data. Only Figshare presents it for Brazil, although it is important to pay attention to the FAIR principle on these repositories (Table 2). The FAIR principle was analyzed following Tanhua et al. (2019) approach.

Analyzing the FAIR principle regarding the generalist repositories Figshare, PANGAEA, and KNB, it is possible to observe that Figshare is the repository that worst fits in FAIR principle, especially related to data and metadata quality checks. The two datasets found for marine litter in Brazil are placed on Figshare. Despite having some weaknesses related to the FAIR principles, from a scientific point of view, this characteristic can allow that not well-standardized data to be published.

An important initiative from PAGAEA and KNB is using open-source programming languages (Python and R) to spread data usability, which can save resources from research institutions and environmental agencies and expand the analysis. In addition, connections between different data portals optimize resources since the maintenance costs can be distributed. Interoperability and reusability are factors related to sustainability since it is possible to optimize resources (natural and/or financial) and analyze data with greater consistency, allowing more developed environmental monitoring that results in practical actions in society. Marine litter data in emerging economies should be a key topic to be addressed by repositories due to its importance in local, regional, and international spheres. GPML is a starting repository that should be integrated into other repositories, such as Figshare, PANGAEA, and KNB, to optimize computational efforts and encourage interoperability.

The increasing number of research papers on marine litter topic suggests that the data is being collected. The reason why it is not being shared remains unclear but can possibly rely on the same fears/problems most of the researchers that do not publish data, have. However, the benefits of sharing should overcome insecurities and fears.

Marine litter data sharing around the world

A successful legislative framework involving the standardization of marine litter data and the construction

of data baselines was the European initiative within the Marine Strategy Framework Directive (MSFD) that created the first world's beach litter database. This consultation included 22 European countries, and 3,063 surveys were conducted on 389 beaches between 2012 and 2016. In addition, data from non-European countries that have coastlines facing Europe were also included (European Commission, 2013; Addamo et al., 2018).

The biggest challenges encountered by Addamo et al. (2018) in building the European baseline were related to the compilation of data with different formats, quality, and protocols used for litter sampling. Europe is the most advanced territory regarding marine litter sharing data; there are more than 15,000 dataset results for marine litter search on data.europa website (search done on December 2021).

The European Environment Agency has developed a Marine LitterWatch mobile app to collect information on marine litter. It is a citizen science initiative that aims to help fill data gaps in beach litter monitoring. All data is available on an online platform, and it is possible to visualize and download all data easily. Despite being an European platform, there is a record of Copacabana beach in Brazil. It is possible to observe that it was a top-down initiative but included citizen science approach. Different stakeholders should work together to achieve the best data sharing and availability.

Also, in Europe, European Marine Observation and Data Network (EMODnet) in the chemistry hub developed the first pan European Marine Litter Database (MLDB). It expresses a collective effort involving specially the EU-Technical Group on Marine Litter and EMODnet Chemistry structure; they developed guidelines focused on harmonizing marine litter data, vocabulary, and quality controls (EMODnet, 2022b,c). Hanke et al. (2019) devolved an analysis of a pan-European 2012–2016 beach litter dataset, including data availability, spatial and temporal data coverage, data treatment, and results (Hanke at al., 2019). This report is important to understand gaps and priorities. In the near future, with repositories about marine litter worldwide, it will be possible to have a global picture following Hanke et al. (2019) data treatment and analysis.

EMODnet marine litter data hub contains data on beach and sea floor litter from a variety of sources, including existing International and Regional Sea Conventions, and data submitted by the EU Member States, EMODnet partners, and external research or monitoring projects. Most datasets have come from existing monitoring projects that have published their data in project-specific databases (e.g., OSPAR, ICES DATRAS, even in the PAGAEA repository). These databases may hold more and differently formatted information, so direct comparison with these sources is not always possible, although it is possible to download harmonized datasets where data are formatted following Guidelines regarding vocabulary and values accepted in EMODnet marine litter data hub (EMODnet, 2022b,c). Also, the interoperability between repositories appears to be working well and FAIR principles were considered and are being applied to marine litter in Europe in the context of EMODnet chemistry, improving released data sets quality (Partescano et al., 2021).

A global initiative is the G20 Implementation Framework for Actions on Marine Plastic Litter (MOEJ, 2019). It aims to put in place the Action Plan on Marine Litter, based on each country's national policies, approaches, and circumstances. Brazil presented advances related to the National Plan to Combat Marine Litter (MMA, 2019). For efficient information sharing and updating, as well as for outreach to wider international communities, a network was created; the idea was the same as that proposed by IMDOS stakeholders (Maximenko et al., 2019).

Data usability

The importance of shared data spreads to different areas of society through academic, educational, and management purposes. Data from satellites, autonomous underwater vehicles, and other platforms are coming together and producing emerging data streams from social media, smartphones, and low-cost distributed sensors to create a "data tsunami" (Jucan and Jucan, 2014). More data have been collected about the oceans in 2018 alone than in the entire 20th century. Citizen science is becoming a major player in this change and how we make data available. It is necessary that data from automatic systems and citizen science pass through a quality check process that verify its usability, metadata quality, and reliability. There are some frameworks being developed to access the quality control of oceanographic data; an example is an open-source package on Python called CoTeDe, which aims to provide an adaptive and automatic quality check that combines different quality control standards according to the equipment (CBT, Argo, and CTD) and the researchers' own needs (Castelao, 2020). In addition, data quality check procedures on ocean wave data, which include automatic and manual check procedures, are well described by Doong et al. (2007).

Regarding citizen science data, there are also some ways of accessing data quality. Successful projects have characteristics such as volunteer training and testing, expert validation, replication across volunteers, and statistical modeling of systematic error (Kosmala et al., 2016). Wiggins et al. (2011) created a framework of mechanisms (e.g., rating participant performance, expert review, paper data sheets submitted in addition to online entry, and data mining). These mechanisms can be used in citizen science projects before, during, and/or after their execution for ensuring data quality. They mapped two sources of errors (protocols and participants).

Data and metadata quality, data curation, and check are important to obtain meaningful information, and for the accomplishment of the FAIR principle, otherwise there is the risk to extrapolate data and information not well linked to the real

situation, especially when it was measured by automatic systems and citizen science without a data quality check process.

However, ocean data management has not kept pace with the growth of data production, which limits the ability to use both new and old data in marine science (Serrat, 2008; Pendleton et al., 2020). A substantial time and geographical data series may help to identify and understand anomalies and their frequency, strength, and duration. In a climate-changing scenario, it can be helpful to develop management strategies in cases of oil spills, floods, coastal erosion, among others. It is important to inform and engage stakeholders about the importance of ocean observing systems to society, decision-making, academia, and secure financial support to improve data infrastructure (Sales et al., 2020; Teixeira, 2022).

Marine litter is a theme to explore the potentialities of the free and open-source software (FOSS); R and Python are programming languages that have packages available to PANGAEA, KNB, and OBIS. A study in Brazil developed an open-source geospatial framework for beach litter monitoring using R and QGIS (Schattschneider et al., 2020); initiatives in this context can grow, improve, and/or can be easily used if there are marine litter data available to perform tests, thus improving sampling methods or base some management decisions. The available marine litter data in repositories can enhance the usability of open-source tools and framework analysis, such as proposed by Schattschneider et al. (2020).

There are some initiatives about marine litter in Brazil with potential regarding data sharing. An example is the Blue Flag program, which suggests a marine litter monitoring program on accredited beaches. With the monitoring program, beaches with Blue Flag in Brazil should have data in their annual reports, but it is not publicly available. Tombo beach in São Paulo, Brazil has Blue Flag certification for 12 years in a row in 2022, which means that probably there are many of marine litter data about this beach, although it is not yet possible to find/access it.

The challenges of working with data on marine litter are great; however, ocean management is often hampered by a lack of available and clear data on human activity and how it affects the ocean. To solve this type of problem, a "National Plan to combat marine litter" (PNCLM) (Plano Nacional de Combate ao Lixo no Mar in Portuguese) was launched in 2019 (MMA, 2019). The PNCLM encourages the development of a virtual platform to organize and share National marine litter data aiming for continuous improvement of prevention actions of pollution and environmental recovery (MMA, 2019). A virtual dashboard (https://app.powerbi.com/view?r=eyJrIjoiNDY2OTU3NmMtOGVmZS00NDEwLTlhNzItYjI2Y2FjNTYxOWE5IiwidCI6IjM5NTdhMzY3LTZkMzgtNGMxZi1hNGJhLTMzZThmM2M1NTBlNyJ9) with clean-up actions data is already being developed and is available online. However, there are some concerns about the type of data. Most of the information on the dashboard is from NGOs and may lack data curation, metadata, common vocabulary, and unit measure. Another problem is that sometimes litter was not classified, and when they are, the categories used can be overlapping. For example, two categories are "Plastic" and "Fishing materials"; however, most of the fishing materials are made of some sort of plastic. Data sharing should follow guidelines (e.g., UNEP, GESAMP, and EMODnet vocabulary) with adequate vocabulary and hierarchy for layers of terms. In addition, the data cannot be downloaded to perform other analyses. Although it is an interesting initiative to begin data sharing, it still needs improvement. Initiatives regarding the scientific community can also be developed to fulfill the actions established by the PNCLM. In addition, a sub-national scale (Federation states) is developing and launching its own plans to combat marine litter; this can spread and scatter actions and data regarding marine litter in Brazil.

In this context, it is important to have data curation and well-detailed metadata. To agree with the FAIR principle. In the future, it could be possible to integrate different platforms with different kinds of data that can improve environmental analysis. For example, marine litter data can be influenced by meteo-oceanographic factors, such as wind, tide, currents, among others, and an integrated platform with data can allow a much deeper understanding. This integration is one of the aims of the Spatial Data Infrastructure (SDI). Marine litter data available following the FAIR principle can also contribute to model inland waste management initiatives, mainly those ones that use a mathematical model to optimize management actions (Barma et al., 2022).

Another initiative in Brazil involving citizen science is "Our Blue Hands" (https://www.ourbluehands.com.br/), which was implemented for the first time in Brazil on Itamambuca beach and now is spreading to more cities in Brazil through volunteers and a citizen-science approach. The focus of this initiative is microplastic pollution with the aim of data sharing in a developing partnership with the OBIS repository. The strengths of this initiative is that the methodology applied is standardized, following the Monitoring Strategy for microplastic in the European Union in the context of the Marine Strategy Framework Directive (Hanke, 2013). This allows data comparison worldwide, especially in Europe. Also, Our Blue Hands aims to share the data following FAIR principles by design.

The data-sharing culture is only in its infancy. There are other initiatives focused on other environmental areas in Brazil aiming for data sharing and its public availability (Table 3), but they lack some aspects of the FAIR principle, mainly the interoperability and accessibility. In some cases, there is a bureaucratic process to access data, or it is possible to only see processed data in a dashboard (e.g., PNCLM and NOAA), nearer to NGO's (e.g., Ocean Conservancy) model to make information available.

Since data are the building blocks for information and knowledge, the scientific community is responsible for the collection and quality of this data. It is important to highlight

TABLE 3 Some initiatives to share environmental/marine data in Brazil.

Name	Summary	Year	Website
National Bank of Biological Samples of Albatrosses and Petrels—BAAP	It maintains biological samples of albatrosses and petrels from bycatch in commercial fisheries. A collaborative network.	2013	https://baap.org.br/
Open Access Atlantic and Eastern Pacific Reef Fish Database	A dataset of 2,200 species of reef fish from the Atlantic Ocean and the east side of the Pacific. Easy download in.csv format.	2021	https://zenodo.org/record/4455016#.YnOnrdrMLIW
Oceanographic buoy data from PELD ILOC (Long-Term Monitoring of the Brazilian Oceanic Islands)	The buoys provide near real-time surface (1 m) and bottom (23 m) water temperature data, wind direction and intensity and wave height at 6-h intervals. Download is only possible for temperature data.	2022	https://aqualink.org/sites/1186

that some initiatives are starting in Brazil, bringing scientists together to discuss the marine litter issue. Brazilian Marine Litter Science Patch is an initiative that is being created in a collaborative and transversal way to integrate research projects and researchers on this topic. Another is "Polimera: a scientific network about marine litter" (https://polimera.org/). This initiative was created by universities in south Brazil. Despite being in their initial stages, they can bring a new paradigm to marine litter studies. Collaborative work among researchers is extremely important for the growth of the scientific community and enables standardized data, quality work, integrated views, findings, and the training of more researchers on the topic.

Future perspectives

Despite the various possible uses, the importance of sharing data and the great number of publications about marine litter in Brazil, there are still very little data published in databases. Some initiatives have already started, but there is still a long path ahead. More funding for environmental science, associated with incentives from funding agencies, should encourage scientists to share their data.

Brazil has numerous institutions and researchers that collect, analyze, and publish data on marine litter derived from specific projects in the form of scientific papers, thesis, dissertations, and reports. However, there are only a few frameworks to facilitate and encourage the availability and harmonization of these data. Ways need to be found to collect ocean data with quality and share following the FAIR principle; if data will be shared, resources can be optimized, and possible environmental impacts can be minimized since it will not be necessary to replicate sampling processes. Also, studies and decision-making will be based on more extended time series, improving science quality, which can support better management decisions in the context of SDG (Sustainable Development Goals) and beyond. The benefits are not only related to marine litter but also the information is the base of successful management actions regarding society and the environment.

In the management sphere, there are still gaps related to curbing marine litter. It is difficult to establish management strategies to combat marine litter if there is no accessible and standardized data baseline. It is urgent to seize the scenario of the UN Decade of Ocean Science for Sustainable Development (2021–2030) to build new relationships and alliances with stakeholders inside and outside academia. Especially regarding the objective of a predictable ocean in the Ocean Decade where society has the capacity to understand current and future ocean conditions. All societal sectors should enter the era of innovation, data sharing, and scientific co-creation. In this context, initiatives such as Our Blue Hands and clean-up actions may bring society closer to academia. Public spheres should encourage and support this initiative so it can be improved.

Soon, repositories such as GPML (entering in operational phase) and OBIS (through a partnership with Our Blue Hands) are some options to share marine litter data. Since OBIS follows the FAIR principle, it gives more credibility to datasets published in their repository. However, at present, the only option for marine litter datasets is generalist repositories, such as Figshare, PANGAEA, and KNB; since GPML is not fully operational, OBIS only accepts datasets on Ocean Biodiversity and uses Darwin Core (DwC) format. Partnership with new platforms, such as Global Ghost Gear Initiative (GGGI) data portal (https://globalghostgearportal.net/login.php), should be encouraged to gather together efforts and computational infrastructure.

The FAIR principles remain unknown and need promotion and compliance in the scientific community. In this context, sharing data should be encouraged, and not participating will lead to isolation in or outside academia. Scientists should also be encouraged to use available data worldwide in their field to give these data new analysis interpretations, and even more integrative uses, thus highlighting the international cooperation approach. Organization for sampling and protocols are well developed in marine sciences and even in marine litter sampling (Cheshire et al., 2009; GESAMP, 2019). So, it is necessary to use this expertise to incorporate data management and publication in the sampling protocols process.

Finally, FAIR data sharing can also be a question of environmental justice. Developed territories with resources to maintain data centers and their infrastructure should be made available worldwide to encourage data sharing and its use by worldwide researchers. Also, different places may benefit from shared data interpretation when considering similar environmental settings to elaborate their own management strategies, thus saving resources and speeding up ocean conservation and restoration actions.

Author contributions

BR contributed to the conception and design of the review and wrote the first draft of the manuscript. TL and MC contributed with new insights and wrote sections of the manuscript. All authors contributed to manuscript revision, read, and approved the submitted version.

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Conflict of interest

MC is a Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) fellow.
The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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