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GLOVE: The Global Plastic Ingestion Initiative for a cleaner world

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ABSTRACT

Plastics are one of the most used materials in the world. Their indiscriminate use and inappropriate disposal have led to inevitable impacts, for instance ingestion, on the environment arousing the attention of the global community. In addition, plastic ingestion studies are often written in scientific jargon or hidden behind paywalls, which makes these studies inaccessible. GLOVE is an online and open-access dashboard database available at gloveinitiative.shinyapps.io/Glove/ to support scientists, decision-makers, and society with information collected from plastic ingestion studies. The platform was created in the R environment, with a web interface developed through Shiny. It already comprises 530 studies, including all biological groups, with 245,366 individual records of 1458 species found in marine, freshwater, and terrestrial environments. The main goal of the GLOVE dashboard database is to improve data accessibility by being a scientifically useful grounded tool for designing effective and innovative actions in the current scenario of upcoming global and local agreements and actions on plastic pollution.

1. Introduction

Currently, plastic pollution is recognized as a global crisis, and we are moving forward to a global agreement to combat this issue. The UNEP resolution named "End Plastic Pollution: Towards an internationally legally binding instrument" in the Fifth Session of the United Nations Environment Assembly (UNEA-5) reinforced the creation a plastic pollution international agreement by the end of 2024. The resolution addresses whole lifecycle of plastics, including their production, design, and final disposal (UNEP, 2022). The transition to a global agreement needs science-based information accessibility to support the efforts and involvement of all sectors, including scientists, governments, industries, third sector entities, and society.

In this context, an open-access platform is a powerful tool to aid the identification of knowledge gaps and provide guidance for ongoing and future measures. Also, this is relevant to obtain accurate conclusions reducing the number of redundant studies and rising and inspiring new research-based solutions. The availability of web-based platform data has a crucial role in the application of science-based management actions and public policies (e.g., Global Partnership on Marine Litter – www.gpmarinelitter.org, Global Biodiversity Information Facility (GBIF) – www.gbif.org, Freshwater Information Platform (FIP) – www.fr

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eshwaterplatform.eu, The IUCN Red List of Threatened Species – www.iucnredlist.org) since the number of publications and information have been increasing rapidly leading to a data overload. They ensure the most up-to-date grounded information to the universities, research centers, decision-makers, and other stakeholders who can develop the most suited environmental strategies. However, we do not have a global platform for ingested plastic debris involving whole Earth great ecosystems (marine, freshwater and terrestrial) to support future international agreements and local actions on animal and environmental health (Walker et al., 2021).

The magnitude of plastic pollution has created a scenario in which its effects are considered irreversible (MacLeod et al., 2021). One of the most deleterious effects is related to ingestion by wild animals that can cause harmful problems such as chronic and acute health problems (Bucci et al., 2020; Marn et al., 2020; Puskic et al., 2020; Santos et al., 2021). Up to now, >1400 species have ingested plastic ranging from small invertebrates (e.g., zooplankton) to large mammals (e.g., elephants). In addition to affecting individuals, plastic spreading through different food webs harms the biota at community levels (Santos et al., 2021) since the formation of heteroaggregates in the gut of prey can increase trophic transfer to predators. Thus, this could affect the energy and nutrients transfer to higher trophic levels (Egbeocha et al., 2018). Also, plastic ingestion is a route for entrance and biomagnification of toxic substances (e.g., phthalates, pesticides, heavy metals), which can cause a reduction in feeding activity, depletion of energy on offspring and mortality of exposed individuals (Carbery et al., 2018).

Lists of species that have ingested plastics have been widely published in different articles and reports over the last years (e.g., Gall and Thompson, 2015; Kühn and van Franeker, 2020; Santos et al., 2021). However, they are not updated as new lists are published, so these lists often become outdated due to the rapid pace of publication (Santos et al., 2021). In addition, they are frequently hidden behind paywalls, expensive journal subscriptions, and written into scientific jargon making the information inaccessible to decision-makers, scientists, local communities, and non-governmental organizations (NGOs), especially to organizations and people from low- and middle-income countries.

Therefore, we present GLOVE (the *Global Plastic Ingestion Initiative*), the first web-based and open-access dashboard database aimed to share science-based data to support participatory, collaborative, and transformative processes. Our goal is to provide information for scientists, general public, conservation managers, policymakers, and local communities who cannot easily access to plastic ingestion data. This information is needed to better decision-making on marine, freshwater, and terrestrial management which may contribute to determine the level or concentrations of plastic debris in their territories; identify and alert risk factors to local/endangered species as well as potential sources of plastic.

GLOVE dashboard database improves data availability, accessibility, and comparability that changes the way how we use data on plastic pollution. The platform wants to provide information and enable knowledge to support local and global actions for the environment and society. It permits monitoring plastic ingestion data by biological group or species according to a wide range of descriptors, such as polymeric composition, color, and shape of plastic debris. All the data can be downloaded free of charge in CSV format.

The GLOVE dashboard database mission includes:

[1] Reducing the complexity of the studies published by providing rapid responses for plastic ingestion about the biological groups and technical features of plastics;
[2] Providing an overview of methodologies and main results published on plastic ingestion studies;
[3] Monitoring past and present plastic ingestion studies seeking to identify changes, trends, and gaps;
[4] Promoting and supporting a communication that allows scientists, researchers, and other stakeholders to discuss protocols for plastic ingestion analysis.

This initiative supports our commitment to the 2021–2030 United Nations Decade of Ocean Science for Sustainable Development goals (IOC, 2020), which propose disseminating information on ocean-related issues to guarantee a clean, transparent, and accessible ocean for future generations. Also, the Decade on Ecosystem Restoration aims to prevent, halt, and reverse the degradation of ecosystems on every continent and in every ocean (ONU, 2019). To achieve these purposes, it is required a solid information base fed by long-term observations.

2. Methods

2.1. Data sources

The GLOVE platform aggregates a set of research studies on plastic ingestion available on Google Scholar (GS). To build the dataset, we searched the literature of GS using the following keywords terms: "debris ingestion" and "plastic ingestion" with the Boolean operator "or". Then, we filtered records of plastic ingestion involving marine (i.e., estuarine, coastal, and oceanic), freshwater, and terrestrial species published in peer-reviewed journals and books in English. When articles from other languages (e.g., Portuguese, Dutch, and Spanish) were retrieved in the search, they were included.

The scientific names were reviewed to eliminate possible synonyms and the scientific nomenclature (family, genus, and species) was aligned with the current specific taxonomic databases, FishBase – www.fishbase.se/search.php, AviBase – www.avibase.bsc-eoc.org/avibase.jsp, ASM Mammal Diversity Database – www.mammaldiversity.org/, The Reptile Database – www.reptile-database.org/, and the World Register of Marine Species: WoRMS – www.marinespecies.org/.

2.2. GLOVE and the Shiny app

The GLOVE platform is digitized in R as an object of the class data frame. R is one of the most widespread statistical, collaborative, and open-access software (www.r-project.org/). A web-based dashboard application was devised to permit: (1) the presentation of GLOVE and the participation of additional users and contributors; (2) spatial and temporal visualization of the information available in the GLOVE platform, and (3) the selection of user-defined subsets of data and related scientific publications.

The GLOVE web-based application was developed using Shiny (Chang, 2015), an R package designed to build interactive web apps directly from the R platform. Shiny allows the development of user-friendly interfaces linked directly to statistical functions and routines in the R environment, so that non-expert R users can easily obtain complex plots or tables without the need for coding. The principal goals of the Shiny application for GLOVE are to promote data sharing and support the user in the quantification of species' plastic ingestion.

2.3. Data descriptors

To be included in this platform, only papers, books, or chapters were required, and they should have satisfied the following prerequisites:

- Reporting specifically on plastic ingestion by wild animals;
- Published or posted online prior to December 2020;
- All languages were considered;

Papers were not included when:

- Presented data on external interactions, i.e., with the fish gills or skin;

- They are review and preprint papers, abstracts, and other types of gray literature;
- Reported on experimental trials on plastic ingestion.

As the GLOVE dashboard database is a recent tool, the studies included on the platform were published or posted online until December 2020 to start the structuring of the platform, data extraction, and data curation, as well the interpretation of data and writing of this manuscript throughout the years 2021 and 2022. Nevertheless, our trained research team will be working to update the platform continuously.

To include and organize the studies on GLOVE platform, two different researchers carried out the search on GS. Then, a dataset was available to a trained team of four researchers who so far are the only ones responsible for feeding the platform. They did a systematic review of this dataset that was debugged, and duplicates were eliminated before including on the platform. To determine the use of an article or a book, descriptions like wild or farm organisms, or experimental studies in the title, abstract, or methods were used as an exclusion criterion. So, each study was read individually to extract the information manually from methods and results. This information was organized in an excel sheet to submit to the GLOVE dashboard database.

The following categories were retrieved from each publication (Table 1). In addition, a full table with all descriptors used in the study can be found in the Supplementary material (Table S1).

Overall, these descriptors were grouped as described below and in the Fig. 1.

[1] Information on the biological group – Taxonomic details, integrated using the “taxize” package in the R environment (Chamberlain et al., 2017), and body size.

[2] Information on the sampling procedures – Methods and geographic information (location and time). When the geographic coordinates were not available or assessed in the study, the latitude (1) and longitude (1) were estimated (Table 1), and remarks were inserted on the OBS column.

[3] Information on the results – The characteristics and quantity of the plastic debris. When possible, plastic debris were classified according to GESAMP (2019): MiP - microplastics (<5 mm), MeP – mesoplastics (5–25 mm), or MaP - macroplastics (>25 mm–1 m) as well as shape and color categories. In addition, we calculated the total number of items identified per each study and/or the frequency of occurrence, when the number of individuals that ingested plastics and the total number of individuals analysed was provided by the authors. In these cases, remarks were inserted on the OBS column such as “Total items of plastic debris overestimated” if other types of litter were included (e.g., fisheries items). “Total items of plastic debris underestimated” was used when other categories of non-plastic litter were excluded (e.g., miscellaneous items). In addition, the frequency of occurrence (FO% PD – plastic debris) descriptor might be a little different from the original study due to data inclusion or exclusion of non-plastic litter. Then, remarks are also included in the OBS column. Finally, when any kind of data was not available or assessed in the studies, the descriptor was noted as “NA”.

3. Results and discussion

Here we outline the dashboard database visualization presenting the panels of GLOVE dashboard database and a brief introduction to the website. In addition, the main outcomes are described regarding all biological groups and features of plastics ingested.

3.1. Dashboard database visualization

GLOVE platform supports different modes of interactive use via the

Table 1

Table summarization listing all descriptors used in the GLOVE dashboard database. Here, you can check the structure and definitions used based on GESAMP (2019). The fully table are available in the Supplementary material (Table S1).

Categories	Description	Class	Units	Required
REFERENCE	Reference	Character	–	Yes
DOI/ISSN	DOI/ISSN of the publication. If not available/assessed = NA	Character	–	Yes
CODE CITATION	Code Citation of the references inserted on the base	Numeric	MPB00000	Yes
YEAR	Publication year	Numeric	–	Yes
ECOSYSTEM, HABITAT, COUNTRY	Place and/or area where samples were collected. If not available/assessed = NA	Character	–	No
BIOLOGICAL GROUP	Biological group of the organisms analysed	Character	–	Yes
MEAN SIZE	Mean size of organisms that ingested plastic or did not ingest plastic. If not available/assessed = NA	Numeric	μm, mm, cm, m	No
UIS	Individual size unit. If not available/ assessed = NA	Character	μm, mm, cm, m	No
ML	Measuring length of organisms that ingested plastic or did not ingest plastic. If not available/assessed = NA. It includes beak length, body length, carapace length, carapace width, cephalothorax length, curved carapace length, discs length, fork length, Full length, larval length, lower jaw fork length, lower jaw fork length, nearest centimeter, pedal disc diameter, shell diameter, and others	Character	–	No
SIZE VARIANCE	Size variance of organisms that ingested plastic or did not ingest plastic. If not available/assessed = NA	Numeric	MAD, SD, SE	No
VARIANCE UNIT	Individual size unit. If not available/ assessed = NA	Character	MAD, SD, SE	No
MAX AND MIN IND LENGTH	Minimum and maximum individual length of organisms that ingested plastic or did not ingest plastic. If not available/assessed = NA	Numeric	μm, mm, cm, m	No
	Starting and final month of sampling.	Character	–	No

(continued on next page)

Table 1 (*continued*)

Categories	Description	Class	Units	Required
STARTING AND FINAL MONTH	If not available/ assessed = NA			
STARTING AND FINAL YEAR	Starting and final year of sampling. If not available/ assessed = NA	Character	–	No
SAMPLING FREQUENCY	Sampling frequency. If not available/ assessed = NA. It can present a combination of one, two or more periods. So, it includes daily, weekly, biweekly, monthly, annually, occasionally, and seasonally	Character	–	No
SAMPLING METHOD	Sampling method refers to the way the plastic debris were sampled. It can present a combination of one, two, or more ways. It includes the visualization of bolus and/or feces, lavage, necropsy, dissection, body, radiography, regurgitation, direct observation of feeding, and others	Character	–	Yes
ORGAN CONTENT	Type of organ analysed. If not available/assessed = NA. Abbreviations: GIT = gastrointestinal tract; Proventriculus = gizzard for birds; Proventriculus/ Gizzard + Ventriculus = stomach for birds. Gut might be Stomach + Intestine for fish. Tissue = all body of invertebrates. Data from bolus, faces and others not included in this column.	Numeric	–	No
NUMBER OF SAMPLING UNITS	Total amount of sampling unit studied related to bolus, feces, organs, and others	Numeric	–	Yes
NUMBER OF ORGANISMS	Total amount of organisms analysed. If not available/ assessed = NA	Numeric	–	No
TOTAL MiP, MeP, AND MaP	Total amount of MiP (microplastics < 5 mm), MeP (mesoplastics 5 mm–25 mm), and MaP (macroplastics > 25 mm–1 m) found in the sampling units. If not available/ assessed = NA. Size classification according to GESAMP (2019)			
TOTAL PD	Total amount of plastic debris. If not available/assessed = NA. The TOTAL PD might be different from original data published due to inclusion or exclusion of other marine litter types (e.g., metal, wood). When it occurs, remarks like "Total items of plastic debris overestimated" or "Total items of plastic debris underestimated" is described on OBS column	Numeric	–	No
FO% PD	The FO% plastic debris (PD) can be different from original due to data inclusion or exclusion of other types of marine litter (e.g., metal, wood). This column includes FO% of all organisms analysed or organisms that ingested plastic debris according to the study. Remarks in the OBS column like "FO% plastic debris overestimated" and FO% plastic debris underestimated". FO% = Ni/N × 100. FO% = frequency of occurrence of plastic debris. Ni = number of sampling units that contained plastic debris. N = total number of sampling units examined. If not available/assessed = NA.	Numeric	–	No
NF% PD	NF% plastic debris. Numeric frequency NF% = Na / N × 100. NF% = numeric frequency of plastic debris. Na = number of plastic debris. N = total number of items. If not available/ assessed = NA	Numeric	–	No
FW% PD	FW% plastic debris. FW% = Wa / W × 100. FW% = frequency of weight of plastic debris. Wa = weight of plastic debris. W = total	Numeric	–	No

(*continued on next page*)

Table 1 (*continued*)

Categories	Description	Class	Units	Required
	weight of items. If not available/assessed = NA			
DEAD	If the animal was found dead or was not survive during the rescue/research. If not available/assessed = NA	Character	–	No
TOTAL FRAGMENTS, PELLETS, AND OTHERS.	Total amount of fragments and others. Some definitions: Fragments; Fibers (including filament, strand, and thread); Pellets (including resin bead and mermaid's tears); Beads (microbeads); Foam (including EPS and PUR); Film (including sheet); and Paint chips. If not available/assessed = NA. Definitions according to GESAMP (2019)	Numeric	–	No
TOTAL OTHER SHAPES	Total amount of other shapes (e.g., straws, packing, fishing nets). If not available/assessed = NA	Numeric	–	No
SHAPE UNIT	Unit used by the authors (i.e., total number, percentage, %FO). If not available/assessed = NA	Numeric	–	No
AVERAGE SIZE PD	Average size of plastic debris. If not available/assessed = NA	Numeric	–	No
MIN AND MAX SIZE PD	Minimum and maximum size of plastic debris. If not available/assessed = NA	Numeric	μm, mm, cm, m	No
SIZE VARIANCE PD AND VARIANCE TYPE	Size variance and variance type of plastic debris. If not available/assessed = NA	Numeric	–	No
SIZE UNIT	Size unit of plastic debris (i.e., μm, cm, mm). If not available/assessed = NA	Character	–	No
AREA PD	Total area of plastic debris. If not available/assessed = NA	Numeric	μm^2, mm^2, cm^2, m^2	No
AREA UNIT	Area unit of plastic debris (i.e., μm^2, cm^2, mm^2, m^2). If not available/assessed = NA	Character	–	No
MASS PD	Total mass of plastic debris in grams. If not available/assessed = NA	Numeric	g	No
VOLUME PD	Total volume of plastic debris in ml	Numeric	ml	No
		Numeric	–	No

Table 1 (*continued*)

Categories	Description	Class	Units	Required
TOTAL COLOR (BLUE, WHITE AND ETC.).	Total amount of color items. If not available/assessed = NA. It includes blue, white, transparent, gray, black, yellow, brown, orange, colored, and other colors. "Colored" is multicolor items or are a classification used by the authors. "Other colors" refer to silver, tan, red-brown and other unusual colors sorted by the authors. Definitions according to GESAMP (2019)			
COLOR UNIT	Color unit of plastic debris used by the authors (i.e., total number, percentage, %FO). If not available/assessed = NA	Character	–	No
POLYMER (1) to (12)	Type of polymer identified in the samples. If not available/assessed = NA	Character	–	No
POLYMER (1) to (12) ITEMS	Total amount of polymer identified in the samples. If not available/assessed = NA	Numeric	–	No
OTHER POLYMER	Type of polymer not completely identified in the samples. If not available/assessed = NA	Character	–	No
OTHER POLYMER ITEMS	Total amount of polymer in the samples. If not available/assessed = NA	Numeric	–	No
POLYMER UNIT	Polymer unit of plastic debris used by the authors (i.e., total number, percentage, %FO). If not available/assessed = NA	Character	Percentage, number	No
QA/QC PROTOCOL	Yes/No to QA/QC (quality assurance/quality control) protocols applied during the sampling and/or analysing. If not available/assessed = NA	Character	–	No
EXTRACTION METHOD	Extraction method of plastic debris from the sampling units. It can present a combination of one, two or more ways. If not available/assessed = NA. It includes digestion, filtration, density separation, and visual selection	Character	–	No

(*continued on next page*)

Table 1 (*continued*)

Categories	Description	Class	Units	Required
POLYMERIC ANALYSIS	Method used for polymer analysis. If not available/ assessed = NA. It includes ATR-FTIR, HT-SEC, Melting test, Raman spectroscopy, Micro-FTIR, Bright- and dark-field spectroscopy, density gradient, and others	Character	–	No
OBS	Observation – a remark about the columns LAT and LONG (remark - Geographic coordinate estimated when lat/ long unavailable), FO% PD (remark - FO% plastic debris overestimated or FO % plastic debris underestimated when data were calculated adding/ excluding other categories of non-plastic debris), and TOTAL PD (remark - Total items of plastic debris overestimated or Total items of plastic debris underestimated when data were calculated adding/ excluding other categories of non-plastic debris). If not available/assessed = NA	Character	–	No
SPECIES, KINGDOM, PHYLUM, CLASS, SUBCLASS, ORDER, FAMILY, SUBGAMILY, GENUS	Taxonomy rank of the organisms studied. If not available/assessed = NA. To species category if not identified, it was added sp. Or spp. According to the authors	Character	–	No
LAT AND LONG	Latitude and longitude of sampling point. The geographic coordinate was estimated based on the location of the study area when not available. Remarks in the OBS column (Geographic coordinate estimated)	Numeric	Decimal degrees	Yes
ENGLISH COMMON NAME	English common name of the organisms studied. If not available/ assessed = NA	Character	–	No
TOTAL P	Total amount of plastics debris identified	Numeric	–	No

website through maps, plots, and tables on the main interface (Fig. 2). For instance, to search a species on this platform:

- Open https://gloveinitiative.shinyapps.io/Glove/ in a web browser

Then, the web interface is presented and organized in two subpanels as you can see in Fig. 2a. The left subpanel represents the main component of the interface and hosts a dynamic bar showing the principal statistics of the dashboard database and its subsets defined according to the user's inputs through the selection menu (in the right subpanel). The left subpanel also hosts a series of windows displaying: I. **Overview**: a short looped video that presents the GLOVE geo database (Fig. 2a); II. **Map**: a dynamic, fully zoom-capable map showing the distribution of all the items of plastic debris ingested by the species or sample(s) corresponding to the user query (Fig. 2b); III. **Summary plot**: three plots summarizing the colors and percentage composition of the polymers and shapes of plastic ingested in the subsets selected by the user (Fig. 2c); IV. **References**: the list of references (scientific studies) corresponding to the user's selection. A direct link to each paper is provided in the final column of this table (Fig. 2d); V. **About:** used for mentioning the people who lead the project and helped in the creation of the GLOVE; VI. **Helps and Feedback**: email contact for additional help or to submit feedback or bug reports; VII. **License & Terms of use**: a statement that Glove is free software, and everyone can redistribute it and/or modify it under the terms of the GNU General Public License as published by the Free Software Foundation.

The interactive menu on the right side allows the user to select different subsets of the GLOVE platform records (Fig. 2a) based on four features: I. **Period** – the time range in years of the desired publications and related data can be defined using a slider bar; II. **Biology** – four picker input boxes allow the user to select the **Biological Group**, **Class**, **Species name**, and **Common name**; III. **Geography** – two picker input boxes allow the user to select the **Habitat/Ecosystem** and **Country**, and IV. **Plastics** – three picker input boxes allow the user to select the **Shape**, **Color**, and **Polymer** of the ingested plastics. Every time the user interacts with one of the widgets in this menu, the Shiny application automatically queries the GLOVE dashboard database and updates all the maps, plots, and tables in the main interface. Finally, the user can also download the complete table of the GLOVE database for the selected query through the **Download** button located in the bottom right of the menu.

4. Overview of the GLOVE data

GLOVE platform resulted from peer-reviewed papers and books published or made available online from the 1980s to the end of 2020. Almost 90 % (467) of the studies inserted in the platform were published in the past ten years, indicating an increasing number of studies during this period (Fig. 3). The data encompasses all five oceans and seven continents (Fig. 4). We examined 530 studies covering all biological groups, including 245,366 individuals representing 1458 species from marine (M) (88.6 %), freshwater (F) (7.9 %), and terrestrial (T) (2.5 %) environments or a combination (C) of them (1 %). Most of the species were fish - 62.8 % (from M – 82.7 %, F – 16.4 %, and C – 0.9 %) and birds - 23.7 % (from M – 89.6 %, F – 1.7 %, T – 0.9 %, and C – 1.7 %), followed by invertebrates, 9.3 % (from M – 89.7 %, F – 9 %, and C – 1.3 %), mammals, 3.7 % (from M – 92.7 %, F – 1.8 %, and F – 5.5 %), and reptiles - 0.5 % (from M – 100 %).

The studies (total number of records) identified were conducted primarily in Europe (23.3 %), and Asia (19 %), followed by South America (14.2 %), North America (13.3 %), Oceania (13.5 %), Africa (2.7 %), Antarctica (0.3 %), and Central America (0.3 %) (Fig. 4). A number of studies were predominantly in wealthier countries, where more scientific infrastructure is available to support research activities on plastic pollution. In this context, low- and middle-income countries are more vulnerable as a result of limited infrastructure which threatens

Fig. 1. Diagram showing how the descriptors are divided into three categories in the GLOVE dashboard database. The information on biological group provides taxonomic information, and body size. The information on sampling procedures describes the methods used and provides geographic data where the samples were collected. The information on the results provides quantitative data on plastic ingestion, including the total number of items of MiP (microplastics), MeP (mesoplastics), MaP (macroplastics); the Frequency of Occurrence of the Plastic Debris (FO% PD); the Numeric Frequency of the Plastic Debris (NF% PD), and the Frequency of the Weight of the Plastic Debris (FW% PD); the characteristics of the plastic debris; the shapes of plastic, colors, and the polymer identified in the samples.

the health of both the environment and their human population, especially in regions where fishery resources, for example, are an indispensable food resource for local communities (e.g., populations in the Amazon region, Brazil – Giarrizzo et al., 2019). Human consumption of animals that have ingested plastic offers the potential to co-transfer hazardous substances (Cox et al., 2019).

The platform includes the report of 164,866 items of plastic debris ingested by varied species. The frequency of occurrence (FO%) of plastic ingestion in all biological groups indicated that fibers were most frequently observed (71 %), followed by fragments (58.2 %), and film and sheet (26.5 %). Other shapes represented <20 % (Fig. 5). Regarding biological groups, fibers are the main shape found in all groups, except for Birds (Fragments – 63 %), and commonly reported to invertebrates (95 %) (Fig. 5). Other shapes like plastic pellets were reported in Birds (39.4 %) and Reptiles (26.7 %) in great proportions, while paint chips (3.3 %) were just reported in Reptiles (Fig. 5).

Generally, fibers are the predominant shapes identified in several organic and inorganic samples. They are becoming a global aquatic pollutant being found in the atmosphere, bottom sediments, and invertebrates (Mishra et al., 2020). The ingestion of fibers and other shapes of plastic debris can be affected by the color and odor of plastics since they may determine the detectability of an item or the preference of a given species (Santos et al., 2021; Xiong et al., 2019) or due to plastic availability resulting in expected increases in ingestion. On the GLOVE platform, we detected a trend regarding colors in which the predominant ones were blue (61 %), black (58.1 %), and light colors (transparent – 44.3 % and white – 40.3 %) in all biological groups (Fig. 6). A color preference, in this case, is a relevant and accessible drive that may provide interesting insights into plastic ingestion. So, future research should provide more systematic insights into possible patterns of plastic ingestion related to the taxon or geographic area (based on local availability), which may better clarify the role of plastic color in the detection and ingestion of items by organisms with distinct foraging strategies and water column position.

The understanding of the potential drivers of plastic ingestion is crucial to evaluating the risks faced by species (Santos et al., 2021). The

Fig. 2. Screenshots of GLOVE dashboard database where a) the main interface is organized into two subpanels (left and right subpanels). The left one represents the main component of the interface and hosts a dynamic bar showing the principal statistics of the database and its subsets defined according to the user's inputs through the selection menu (in the right subpanel). In addition, the user can see a short looped video of georeferenced points extracted from the studies inserted on GLOVE; b) a global map showing georeferenced points extracted from the studies inserted on GLOVE. The different colors represent the biological groups; c) a summary plot regarding colors, polymers, and main shapes of ingested plastic in all biological groups, and d) References used to compile the dataset. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

ecological traits of the species and the characteristics of plastic, such as color, shape, and odor have been identified as the primary factors (Pfaller et al., 2020; Roman et al., 2019; Santos et al., 2016; Savoca et al., 2016, 2017, 2021), and a unifying framework was recently proposed for the comprehensive assessment of plastic ingestion risk (Santos et al., 2021). The combination of different factors defines the probability of plastic ingestion (from low to high) in an organism. As reported by Santos et al. (2021), the drivers behind plastic ingestion are: (i) the resemblance of the plastic to prey (color, shape, size, and odor), (ii) the nutritional state of the organism (its risk of starvation), (iii) food selectivity (on the continuum of a generalist to a specialist), and (iv) the abundance of plastic in the environment.

More importantly, to understandably study plastic pollution, it is necessary to standardize procedural methods for future studies on plastic ingestion. This poses a major gap in plastic pollution research in all methodological steps, including extraction from biological tissues and polymer identification.

In the studies added to the platform, several methods were used and applied in accordance with the animal's size. Visual methods (i.e., naked eye or microscope) were commonly used in larger animals (e.g., birds and mammals) while chemical-based extraction or other detail-oriented methods were used in smaller animals, such as small invertebrates and fish. These distinct methods imply plastic debris identification differences regarding their size. It means that visual methods, for instance, are not suitable to identify small particles, especially items smaller than 1 mm (Hidalgo-Ruz et al., 2012), and therefore, the total loads of plastic identified in larger animals might be underestimated since smaller items might have been lost. This could result in biased trends in and amongst all biological groups. Thus, the combination of different methods, i.e., chemical digestion, flotation, and polymer techniques may improve the

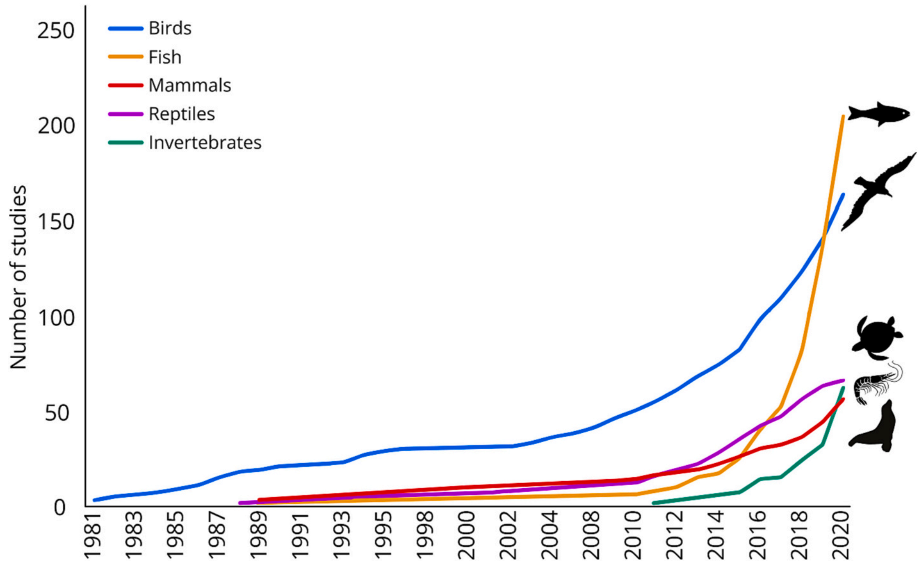

Fig. 3. Timeline of the publication of the reports of the ingestion of plastic debris by the species of the different biological groups. These include all the known records of plastic ingestion in marine, freshwater, and terrestrial wildlife. Data showed for birds, fish, mammals, reptiles, and invertebrates.

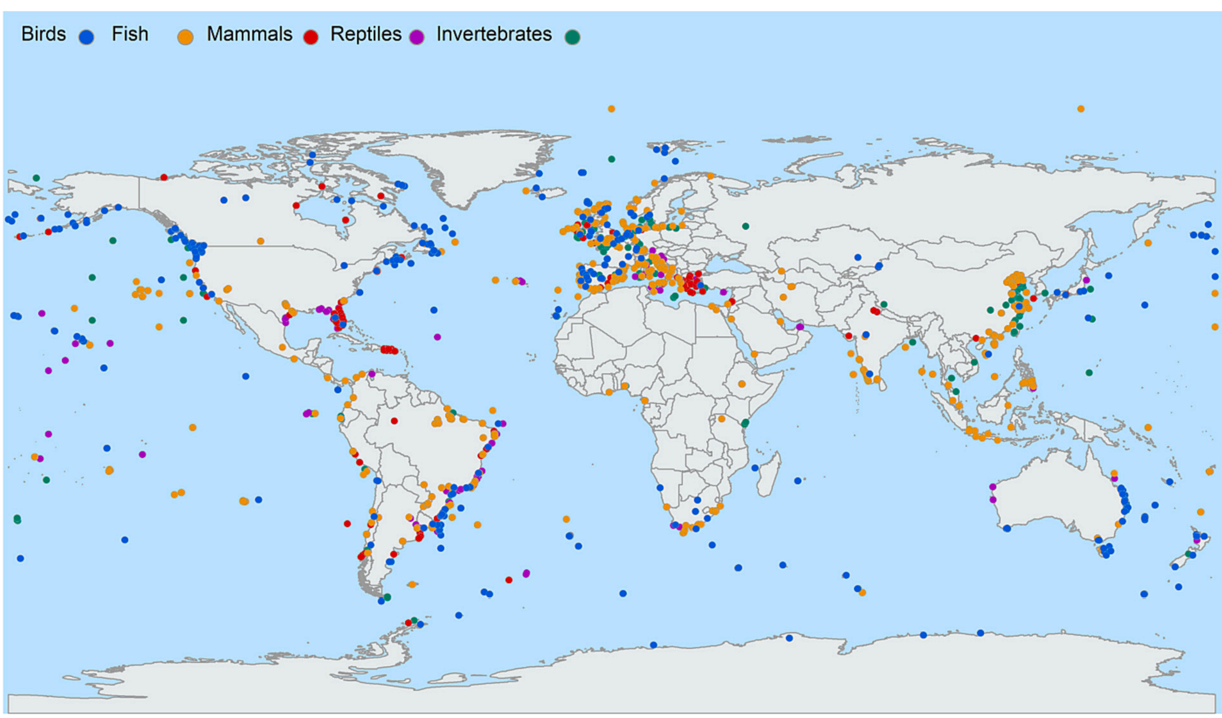

Fig. 4. Global distribution of the plastic ingestion records ($n = 6155$) by marine, freshwater, and terrestrial wildlife. Data are showed for birds, fish, mammals, reptiles, and invertebrates.

extraction and identification of small-sized items.

Considering the polymer composition, it was similar in and amongst biological groups, especially to Polyethylene (PE), Polyamide (PA), and Polypropylene (PP) (Fig. 7). Overall, these polymers are the most produced on a large scale as follow: 118 million tonnes of high- and low-density PE, 68 million tonnes of PP, and 59 million tonnes of PA, including other polymer fibers (Geyer et al., 2017). To identify these and other polymers, spectroscopic methods (28.1 % - $N = 530$) (i.e., ATR-FTIR, Micro-Raman, and NIR-FTIR) were used more frequently than gas chromatography-mass spectroscopy (0.2 %) or fluorescent microscopy (0.2 %) in the identification of ingested polymers. This might be pertinent and applicable to determine potential toxic substances intrinsically contained in plastic polymers during their production e. g. plasticizers, flame retardants, pigments, and antimicrobial agent as triclosan, many of them well-known endocrine disrupters, and carcinogenic (Lithner et al., 2011). Despite this, only around a third of the studies added to the GLOVE platform applied some method of polymeric analysis (Fig. 7).

5. The future

Many improvements are planned for the GLOVE dashboard and its database in the near future. We hope the platform could be connected to other databases (e.g., FishBase - https://www.fishbase.se, SeaLifeBase -

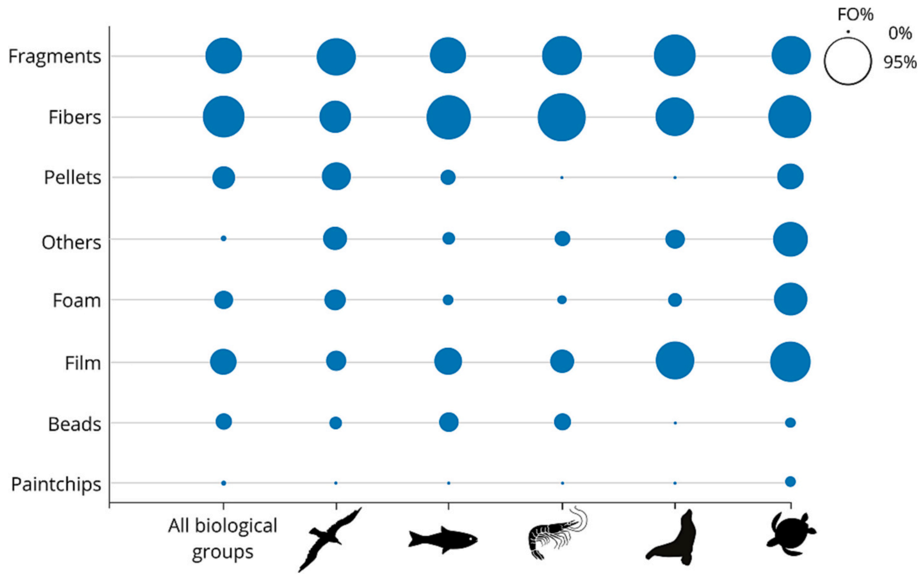

Fig. 5. Prevalence of plastic shapes ingested by wildlife. The frequency occurrence (FO%) was calculated from all known records of plastic ingestion in marine, freshwater, and terrestrial wildlife retrieved from the revised publications. Data are showed for all biological groups, birds, fish, invertebrates, mammals, and reptiles.

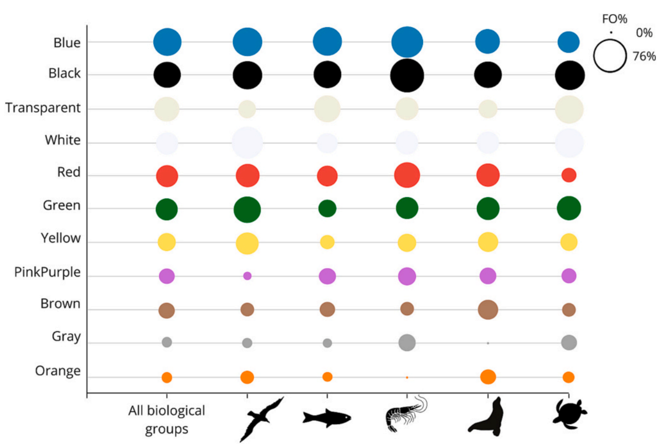

Fig. 6. Prevalence of plastic shapes ingested by wildlife. The frequency occurrence (FO%) was calculated from all known records of plastic ingestion by marine, freshwater, and terrestrial wildlife retrieved from revised publications. Data are showed for all biological groups, birds, fish, invertebrates, mammals, and reptiles. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

https://www.sealifebase.ca/, and the NCEI Marine Microplastics - https://www.ncei.noaa.gov/products/microplastics) to improve the quality and integration of data, as well as being a communication channel to facilitate an inclusive network around the standardization of methods.

Currently, the platform is fed just by our trained team, but we are planning to develop new ways to submit studies where researchers can send their results to be included and consequently feed the GLOVE dashboard database. This solution can also speed up new data entry and simultaneously support more collaborations and integration amongst the scientific community. For now, it is intended that the database be updated monthly to keep the platform up to date.

6. Conclusions

The lack of access to plastic ingestion data is problematic for many scientists, conservation managers, decision-makers, the general public, and local communities since they need good information to aid in the development of strategies, decisions, or processes to protect their habitats, ecosystem, and species. Nowadays, data from articles or reports are ordinarily not available and are written in technical terms becoming a barrier for those who need information as a basis for conservation. In addition, the exponential number of publications can generate a loss of information due to the lack of a reference source to find these studies. Thus, the GLOVE dashboard database facilitates efficient workflow by providing open-access information on plastic ingestion and sharing information from published data on articles and books about plastic ingestion by a range of diverse species from several environments of the world. Also, it provides an ample range of possibilities of using and applications to be a support tool for science, industry, conservation, education, management, culture, and environmental assessment as follows: to identify geographic, species, and thematic gaps; to synthesize information in species or biological groups; and to develop best practices and methods in plastic ingestion. To decision-makers – to identify species and gaps locally; and to find technical guidance to support initiatives through published studies.

The benefits of GLOVE platform are directed to environmental and social issues since, for instance, monitoring programs could be created to analyse species used for human consumption and/or those species of economic relevance and conservations programs for endemic species and animals listed on the IUCN Red List of Threatened Species. Thus, environmental projects on preventing and mitigating plastic pollution incidence and effects on biota could be better design, mainly those for specific taxa or geographic region. Regarding third-sector entities, they can produce strategic awareness campaigns and alliances in the conduction of social and environmental projects.

Our product is freely accessible allowing users to select data according to biology (e.g., biological group and species, environments), spatial (e.g., country), and plastics (e.g., polymer and shape) information. The user can make comparatives analysis amongst biological groups, species, geographic location, and plastic features. After being selected, the user can download the data free of charge in CSV format without registration thus facilitating the access to information. GLOVE dashboard database must be cited whenever any data is downloaded and used in studies, reports, and any media, as well as the references used on the platform.

Overall, this initiative aims to strengthen approaches to tackle and

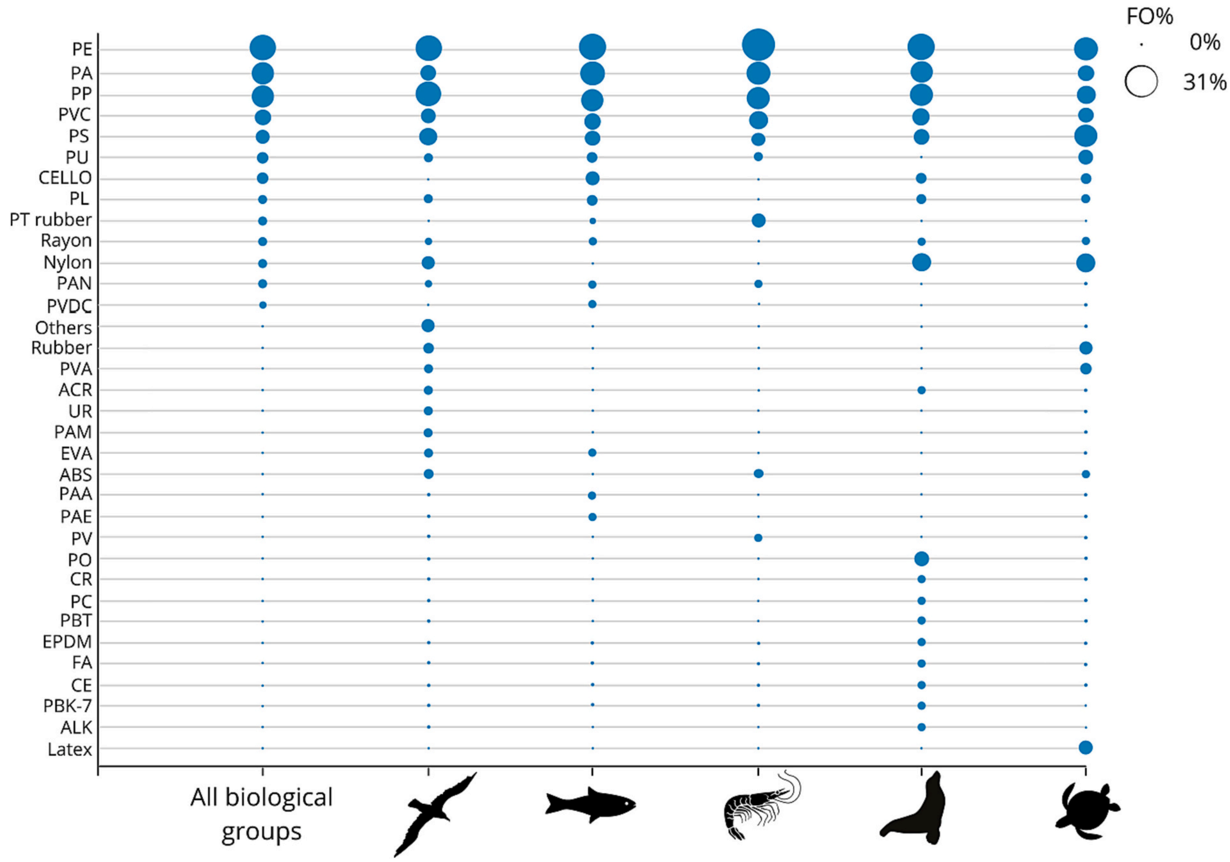

Fig. 7. Prevalence of plastic of different polymers. The frequency occurrence (FO%) was calculated from all the known records of plastic ingestion in marine, freshwater, and terrestrial wildlife retrieved from the publications identified in the literature search. Polymer abbreviation: Polyethylene – PE, Polyamide – PA, Polypropylene – PP, Polyvinyl chloride – PVC, Polystyrene – PS, Polyurethane – PU, Cellophane – CELLO, Polyester – PL, Polyterpene rubber – PT rubber, Polyacrylonitrile – PAN, Polyvinylidene chloride – PVDC, Polyvinyl acetate – PVA, Acrylic – ACR, Urethane – UR, Polyacrylamide – PAM, Ethylene vinyl acetate – EVA, Acrylonitrile butadiene styrene – ABS, Polyarylamide – PAA, Poly(aryl ether) – PAE, Polyvinyl – PV, Polyolefin – PO, Polychloroprene – CR, Polycarbonate – PC, Polybutylene terephthalate – PBT, Poly(ethylene propylene diene) – EPDM, Formaldehyde – FA, Cellulose – CE, Carbon black – PBK-7, Alkyd resin – ALK. Data are showed for all biological groups, birds, fish, invertebrates, mammals, and reptiles.

prevent plastic pollution, in line with Sustainable Development Goal (SDG) 14 *Life below water* as per its target 14.1 *Reduce Marine Pollution*: By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution. Moreover, SDGs 6 *Clean Water and Sanitation*, 11 *Sustainable Cities and Communities*, and 12 *Responsible Consumption and Production* are relevant to marine litter prevention. They are connected to the Ocean Decade (IOC, 2020) and the Decade on Ecosystem Restoration (ONU, 2019). Both Decades are focused to promote the transformation of thinking, attitudes, and policies for the implementation of all SDGs. Amongst their outcomes, they purpose to restore degraded areas, including the ocean, to improve habitat for wildlife (Claudet et al., 2020).

Moreover, the latest resolution approved by UNEP to create a global plastic pollution agreement by 2024 certifies the urgency of dealing with this problem at a global level (UNEP, 2022). We need global agreements to combat plastic pollution that give possibilities to governments and society, mainly from developing countries, to work under their conditions (e.g., lack of data on waste generation or few resources for waste management). We emphasize the urgency of these blue new deals (Armstrong, 2022) and science diplomacy to prevent and protect our societies and biodiversity from collapsing over the next few years (Polejack, 2021). The GLOVE dashboard database and its team are committed to enhancing the visibility and understanding of the data on plastic ingestion by wildlife to the benefit of all the sectors interested in solving the plastic pollution crisis.

Finally, we expect that this platform could influence the current research directions motivating new ways of plastic pollution research because, as we can see, the challenges are global on the Earth. Then, we need to face them through global networks using innovative tools and supporting data transparency and accessibility.

Supplementary data to this article can be found online at https://doi.org/10.1016/j.marpolbul.2022.114244.

CRediT authorship contribution statement

TG conceived the principal and led all stages of the research project. RM, TP, LM and M compiled the data. TR and AS checked the data quality. TR and EN constructed the Shiny App. RM and RA led the writing of the manuscript, and all the other authors contributed to the writing and approved the final version.

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.

Data availability

The data used in this study are available at https://gloveinitiative.shinyapps.io/Glove/

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