Ocean and Coastal Management 243 (2023) 106771

Contents lists available at ScienceDirect

Ocean and Coastal Management

journal homepage: www.elsevier.com/locate/ocecoaman

Moving towards open data, public access, and information sharing to combat marine plastics pollution in the Philippines and the Southeast Asian region

Ricardo C. Alindayu II [a], Lance Oliver C. Licnachan [b], Ramgem L. Luzadas [a], Paul Samuel P. Ignacio [b], Deo Florence L. Onda [a,*]

[a] Microbial Oceanography Laboratory, The Marine Science Institute, University of the Philippines, Diliman, Quezon City, 1101, Philippines
[b] Department of Mathematics and Computer Science, University of the Philippines - Baguio, Gov. Pack Road, Baguio City, 2600, Philippines

ARTICLE INFO

Keywords:
Plastic pollution
National database
Marine debris
Monitoring
Open data

ABSTRACT

Despite the consistent tagging of countries in Southeast Asia as among the top polluters of plastics in the oceans and the increasing local literature documenting the presence and abundance of plastics in marine environments, there still lacks a comprehensive, open, and accessible repository for marine plastics pollution data in the region. As such, this study presents the development of the *PlastiCount Pilipinas* portal in line with the call for a common data repository by the Philippines' National Plan of Action for the Prevention, Reduction, and Management of Marine Litter and the ASEAN Regional Action Plan for Combating Marine Debris in the ASEAN Member States. A total of 14 existing databases were reviewed to identify key features for the online portal implemented to promote ease of access and diversified functionality. For the database, a total of 38 publications, 2 reports, 1 scientific poster, and 3 baselining studies were used to develop the initial ground-truthed baseline for marine plastic pollution, covering 23 provinces and 14 regions across the Philippines. The challenges presented by an observed variation across different methodologies and reporting styles emphasize the critical need to harmonize methods toward generating a more refined national baseline for marine litter. The initial baseline data and other resources such as manuals, information sheets, photographs, news, and publications are uploaded onto a public online portal for viewing and download (https://plasticount.ph/). Data and resource submissions from the public are also accepted and considered for inclusion in the database. The insights gained from developing the online portal and database for the Philippines can be used to inform the development of a regional database for Southeast Asia towards reducing marine litter.

1. Introduction

Marine plastics pollution (MPP) has been a persistent and prevalent threat with strong global and regional implications due to the interconnectivity of the oceans. Mismanaged plastics leak from land- and sea-based sources into the coastal and marine environment where retrieval becomes difficult, eventually causing environmental and health issues to humans, other organisms, and even ecosystems (Thushari and Senevirathna, 2020; Watt et al., 2021). As such, national governments and intergovernmental organizations have developed and implemented action plans and policies to curb the threat of MPP, especially with its increasing urgency brought about by the COVID-19 pandemic (Peng et al., 2021; Shams et al., 2021). Globally, the United Nations (UN) has adopted the Sustainable Development Goal (SDG) Target 14.1, to wit: *"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, 2015). To achieve this, the United Nations Environment Assembly (UNEA) of the United Nations Environment Programme (UNEP) highlighted the importance of regional cooperation towards proper science-based management of MPP on both the micro- and macro-levels (UNEP, 2019). These are also geared towards coming up with a legally-binding global plastics treaty negotiations, which are currently ongoing and are expected to be completed by 2024 (UNEP, 2022).

* Corresponding author. Room 201, Microbial Oceanography Laboratory, The Marine Science Institute, Velasquez Street, University of the Philippines, Diliman, 1101, Quezon City, Philippines.
E-mail address: dfonda@msi.upd.edu.ph (D.F.L. Onda).

https://doi.org/10.1016/j.ocecoaman.2023.106771
Received 10 April 2023; Received in revised form 28 June 2023; Accepted 24 July 2023
Available online 27 July 2023
0964-5691/

At the regional level, several action plans have been developed with a direct focus on a specific geographical area, given the unanimous recognition of the transboundary nature of the problem of MPP. Europe was among the first to implement a policy focused on the abatement of marine litter and microplastics through the enactment of the Marine Strategy Framework Directive or MSFD (Gago et al., 2016; Galgani et al., 2013). Asia soon followed suit with the Northwest Pacific Region, South Asian, and East Asian Seas having their own actionable plans for marine litter (da Costa et al., 2020; Hermawan and Astuti, 2021). Similarly, other regions around the world crafted their own action plans as well to manage the problem within their jurisdictions.

Reviewing these regional policies and frameworks revealed the common need for the baselining of MPP in a wide range of compartments, sizes, and classifications. This is particularly evident with the increasing interest in baselining efforts through scientific studies (Simul Bhuyan et al., 2021) and citizen science initiatives (Ammendolia and Walker, 2022; Olen, 2022; Zettler et al., 2017). Proper baselining of marine litter can elucidate new insights such as on source-sink dynamics, transport mechanisms, and monitoring spatial and temporal changes in abundance and composition (Omeyer et al., 2022; Ryan et al., 2009; 2020). Such information requires science-driven solutions through technological and policy-based interventions (Löhr et al., 2017).

MPP baseline data are often reflected as plastic debris density data but are produced using different methods and reporting styles. Although efforts to generate baselines have been increasing as evidenced by the existence of several repositories (Cowger et al., 2020; Hartmann et al., 2019; Molina Jack et al., 2019; Monteiro et al., 2022; Walker et al., 2021) and the continuous clamor for methods harmonization to allow for data comparison (Galarpe et al., 2021; Omeyer et al., 2022), sharing platforms and accessibility of data sets remain a challenge, especially for less developed countries (Haarr et al., 2022). In addition, several international platforms that have been developed seem to be fine-tuned to the needs of more developed regions such as Europe's *EMODNet Chemistry* and *Marine LitterWatch* (Golumbeanu et al., 2017; Molina Jack et al., 2019). They also suffer from gaps in geographical coverage and data granularity needed by developing countries to come up with effective and localized interventions (Ramos et al., 2022). For Southeast Asia (SEA), these gaps may be attributed to marine litter being a nascent research field as seen in the Philippines (Abreo, 2018; Galarpe et al., 2021), Thailand (Bissen and Chawchai, 2020), Indonesia (Vriend et al., 2021), Malaysia (Tan et al., 2022), and Vietnam (Walker et al., 2021). Other challenges faced by the region include the lack of publicly available data (Haarr et al., 2022) and specialized equipment needed for data collection (Omeyer et al., 2022).

The establishment of a data repository for MPP in SEA is timely and relevant given that countries in the region have been consistently tagged as among the hotspots for this issue (Jambeck et al., 2015; Law et al., 2020; Meijer et al., 2021). In fact, the Association of Southeast Asian Nations (ASEAN) Regional Action Plan includes provisions for the development of both national and regional baselines through the harmonization of quantification methods and the establishment of an MPP database (Hermawan and Astuti, 2021; Walker et al., 2021). Although attempts have been made to create such databases within the region (i.e. Vietnam, Indonesia, and Thailand), these are yet to be operationalized for public access (Hermawan and Astuti, 2021; Walker et al., 2021). ICC, 2020, the Coordinating Body on the Seas of East Asia (COBSEA) launched a database for MPP studies in SEA but the presentation and analyses presented were limited to trends, number of publications, and thematic review (Lyons et al., 2020). Efforts to integrate and develop an interactive visualization for these data are also in the pipeline but yet to be launched (Lyons, pers. comm.). Nonetheless, these efforts emphasize the importance of establishing a common, freely accessible repository for ground-truthed MPP data in the region.

In the Philippines, as a response to this challenge, the national government through the Department of Environment and Natural Resources (DENR) enacted the National Plan of Action for the Prevention, Reduction, and Management of Marine Litter (NPOA-ML) in 2021. This document details the country's strategy to reduce marine litter of all types, including plastics, with the main goal of "Zero waste to Philippine waters by 2040" and a vision of "a Philippines free of marine litter through shared responsibility, accountability, and participatory governance" (Bueta, 2022; DENR, 2021). The NPoA-ML outlines the plan towards achieving the main goal and vision into ten main strategies that support activities on environmental management, industrial innovation, communication, finance, and policy.

Strategy 1 of the NPOA-ML focuses on "[establishing] science- and evidence-based baseline information on marine litter". This strategy recognizes that the establishment of the national baseline for marine litter is crucial to constructing and implementing effective, long-term, and appropriate mitigation and intervention strategies. However, the first version of the NPOA-ML bases itself on widely cited international studies (i.e., Jambeck et al., 2015; Law et al., 2020) that recognize the Philippines as one of the top ten plastic polluters to the marine environment. Hence, due to the lack of locally-produced hard data, the document emphasizes its non-commitment to the presented information without any form of validation.

Given the country's consistent categorization as one of the top polluters of marine litter based on statistical models, as well as the dependence of the country to the marine environment, the development of a national repository is necessary to accommodate the rapidly accumulating data generated by different baselining studies. Here, we present *PlastiCount Pilipinas*, the first open, national database, and website for MPP research and resources in the Philippines. This initiative collates and organizes available information as initial seed data from secondary sources (peer-reviewed publications and unpublished baselining studies) to establish a national database and public web portal for data visualization, resource sharing, and data collation from public contributions. The portal caters to user needs and follows best international practices for repository development. For this, we detail practical and technical insights gained through the development of the database and portal to provide a solid framework towards developing national harmonized data collection protocols and integration systems for both the Philippines and possibly the entire Southeast Asian region.

2. Methods

2.1. Website scoping

Existing publicly accessible websites, which host a marine litter database, were retrieved from search engines (Google, Google Scholar, Scopus) and other literature (peer-reviewed articles, press releases, news articles) using keywords such as "marine", "litter", "debris", "ingestion", "microplastics, "macro-plastics" and "data", and other combinations. Particular emphasis was placed in searching for websites or similar platforms existing in ASEAN member nations. The list provided by Walker et al. (2021) was also used to initialize the compilation process. Websites that focus on marine litter with functional links and easily accessible data were also reviewed. On the other hand, conceptual databases (i.e., with framework but no actual website) or mirrors of other websites were omitted from the list to avoid duplication. Additionally, websites solely focusing on river or land pollution were omitted to focus on marine litter. The website search was conducted from August 2022 to April 2023 using English keywords as an initial reference point, from which links to non-English databases were located and included in the list.

Each website was assessed for its basic functionalities such as geographical scope, focus (micro/macro-plastics), compartments, methods, data reporting styles, and acceptance of public contributions through any submission mode (e.g., form, email). The insights obtained from this review informed the development of the functionalities of the *PlastiCount Pilipinas* portal.

2.2. Data and resource collation for initial baseline

The *PlastiCount Pilipinas* portal was designed to not only include a database for MPP but also other relevant resources such as publications, information sheets, photographs, and videos useful for advocacy, education, and policy work. For the database, a systematic review of peer-reviewed articles, conference papers, technical reports, poster presentations, and other written work was conducted on Scopus, Google, and Google Scholar to create an initial collection of ground-truthed baseline data coming from curated sources. The keywords used for the literature search include “plastic pollution”, “plastic waste”, “marine debris”, “marine litter”, “ingestion”, “microplastics”, “macro-plastics” and “Philippines”. Other possible keyword iterations were used to ensure that the majority of Philippine-based studies were considered for review. Manuscript titles, abstracts, and content were scanned for any of these keywords. While English keywords were used, the systematic review was open to reports in other Philippine languages (e.g., Tagalog, Bisaya). Lastly, only those published on or before February 2023 were included.

Five personnel conducted the search from June 2022 to February 2023, with validation of entries conducted periodically to identify any possible duplications in references. Once compiled, each paper was scanned for any quantitative data that may be used for initial baselining (e.g., plastic debris density and classification). Primary work with clear micro- or macro-plastic counts were further considered, while those with no relevant information or incomplete data were still included in the compiled reference tab of the portal. Additionally, data from ongoing baselining studies were also contributed by other researchers through personal correspondence. In particular, three baselining studies with national scopes, namely PlasMics (DOST-NRCP, 2021), *PlastiCount Pilipinas* (DOST-PCIEERD, 2022), and REINVEST WPS (DOST-PCAARRD, 2022), also provided primary data for inclusion into the portal. The full titles of these baselining studies may be found in the reference section. Lastly, other metadata such as author affiliations and funding sources were recorded in the database.

The data derived from the publications and ongoing studies were filtered and converted into recommended units provided by UN SDG 14.1 to allow for comparison among varying baselining methods. The converted data was classified according to its scope (micro- or macro-plastics), then subsequently classified according to count range, morphology, shape, polymer type, color, and product, as applicable (Table 1).

Table 1
Data categories for the initial database.

Data Category	Focus	Definition	Visualization
Count range	Macro Micro	according to the average count of micro- and/or macro-plastics for a given set of coordinates and total sample area	Bubble map
Morphology	Micro	according to the observable structure of microplastics under the microscope, similar to shape but has a more definitive characterization (e.g. filament, fragment, film, pellet, foam)	Pie graph
Shape	Micro	according to observable physical characteristics of microplastics under the microscope that resemble common shapes. Some are in their common observable or natural shape (e.g. ovoid, rounded) or in their decomposed or fractured or unnatural shape (e.g. degraded, irregular)	Pie graph
Polymer Type	Macro Micro	according to the chemical composition of the plastic (e.g. PP, PE, PET)	Pie graph
Color	Micro	according to the observable color of the microplastics with or without the use of a microscope (e.g. blue, green, white)	Pie graph
Product	Macro	according to the intended use or general function of the plastics as industrial or commercial products (e.g. bottles, utensils, rope)	Pie graph

2.3. Database and website development

During the review of existing websites, functionalities identified to be relevant to the overarching goal of hosting open access data facilitated the development of the system architecture of the *PlastiCount Pilipinas* portal. The website itself was developed using CodeIgniter PHP Framework for the base. For the marine litter database, a relational database management system was set up using MySQL with data derived from the peer-reviewed publications and baselining studies. Once set up, JavaScript libraries were used to generate spatial visualization of count data (OpenLayers) and graphical visualization (Plotly) of plastics classification according to morphology, shape, polymer type, color, and product type which users can freely download from the web portal. Links to publications and news articles were listed on the web portal to serve as pointers, leading users to the original hosting platform in due consideration of intellectual property.

3. Results

3.1. List of MPP websites

A total of 14 websites that focus on plastic pollution in the marine environment are summarized in Table 2. The access links to each database are made available in the supplementary data section in Table S1.

3.2. List of references for MPP baseline in the Philippines

In total, 62 references ranging from peer-reviewed journal articles, scientific posters, baselining reports, and student theses were identified to be relevant to MPP in the Philippines (Fig. 1). Given the portal’s scope of marine, estuarine, and riverine environments, a total of eight references (Table S2) were omitted because of their distinct focus on lake ecosystems and food industries. The remaining 54 references were reviewed for any quantitative data that may be incorporated into the baseline, with special attention to plastic counts, classifications, and location information. A total of 13 references (Table S2) were omitted given these filtering criteria since they either lack quantitative information, use models instead of empirical data, review papers in the field, or describe singular isolated events where sessile species are preferred for monitoring programs (GESAMP, 2019), leaving 41 references for further data retrieval and unit conversion. Three baselining projects contributed their data, resulting in a final total of 44 references (Table 3) to generate the initial baseline for the *PlastiCount Pilipinas* portal.

3.3. Database schema for MPP baseline

The retrieval of data from the publications and ongoing studies informed the development of the relations between objects in the MySQL format. A relational database management system was developed given the direct relationship of plastic quantification data to other information such as references and sampling stations (Fig. 2).

To initialize the database, published references and baselining studies are added to the *Reference* table (highlighted in orange). A unique reference code is assigned to each item in the table to serve as the primary key (PK). Other supporting information relating to the reference is added to the table such as the title, year published, author(s), publication type, and URL/DOI.

The sampling stations derived from the references are recorded in the *Station* table (highlighted in yellow). A one-to-many relationship

Table 2
List of publicly available marine litter web repositories.

Web Repository	Scope	Focus	Compartment	Data Gathering	Data Reporting	Public Contribution
Australian Marine Debris Database	Australia	Macro	Coast	Coastal clean-up	Map	Yes
Beach Litter (OSPAR)	Europe	Macro	Beach	Coastal clean-up	Map	Yes
Coastal Observation and Seabird Survey Team (COASST)	West Coast of the United States	Macro	Biota (entanglement)	Survey	Table	Yes
Deep-Sea Debris Database Japan Agency for Marine-Earth Science and Technology (JAMSTEC)	Japan, Philippines, Hawaii and other Pacific nations	Macro	Underwater	Survey	Table Photos	No
EMODNet Chemistry	Global sea regions	Macro Micro	Beach Seafloor Water Surface	Survey	Table	Yes
Global Plastic Ingestion Initiative (GLOVE)	Global	Macro	Biota (ingestion)	Secondary references	Map	No
Litter Intelligence	New Zealand	Macro	Beach Freshwater Stormwater	Coastal clean-up	Table	Yes
Litterbase, Alfred-Wegener-Institute	Global	Micro Macro	Beach Surface water Pelagic zone Seafloor	Secondary references	Map	Yes
Marine Debris Tracker, NOAA	Global	Macro	Beach	Coastal clean-up	Map	Yes
MarineDebris.ID	Indonesia	Macro	Beach	Coastal clean-up	Map	Yes
Marine Litter Database, AKTH	Mediterranean Sea (Cyprus, Israel, Lebanon)	Macro	Beach	Coastal clean-up	Map Table	Yes
Marine Litter Watch, European Environment Agency (EEA)	Europe	Macro	Beach	Coastal clean-up	Map Graph	Yes
Ocean Conservancy Trash Information and Data for Education and Solutions (TIDES)	Global	Macro	Beach	Coastal clean-up	Map Table	Yes
Rydde	Norway	Macro	Beach	Coastal clean-up	Map Graph	Yes

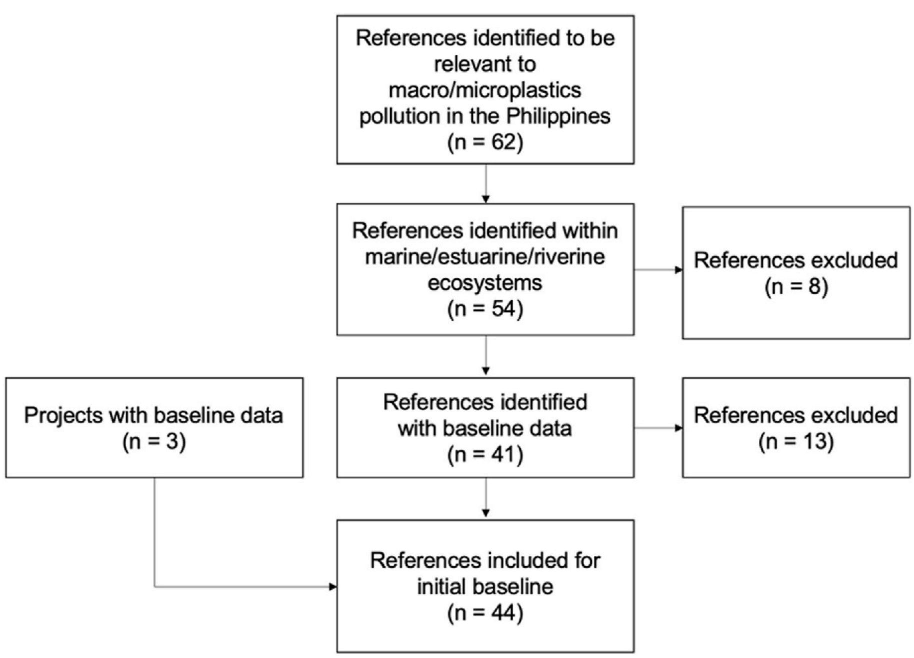

Fig. 1. Results of the systematic review for the database.

describes the link from the *Reference* to the *Station* table given that there may be more than one sampling station in a single reference. A unique station code is assigned to each location, serving as the PK for this table. A singular pair of coordinates with two different study foci (i.e., microplastics in sediments and macro-plastics survey) are considered two distinct stations and therefore, would have separate station codes. Derived stations, which are averages of other sampling stations, are also recorded accordingly in this table to clearly identify possible inaccuracies depending on the extent of the original sampling stations. The *Stations* table relates back to the *Reference* table by using the reference code as the foreign key (FK).

The *By Count* table (highlighted in green) records plastic density data from sampling stations. Each entry in *By Count* is referenced by the station code and focus from *Station*. Not all records in the *Station* table

Table 3
List of references used for the initial baseline (MA – Macro-plastics, MW – Microplastics in Water, MS – Microplastics in Sediments, MB – Microplastics in Biota).

Reference	Province(s) Covered	Primary Body of Water	MA	MW	MS	MB
Abiñon et al. (2020)	Cebu	Camotes Sea, Cebu Strait, Olango Island				✓
Abreo et al. (2020)	Davao Oriental	Pujada Bay	✓			
Abreo and Kobayashi (2021)	Davao del Sur	Davao Gulf	✓			
Abreo et al. (2023)	Davao Oriental	Mayo Bay	✓			
Acot et al. (2022)	South Cotabato, Sarangani	Sarangani Bay	✓			
Avila et al. (2021)	Leyte	Mangonbangon River, Tigbao River, Burayan Creek		✓		
Bilugan et al. (2021)	Cavite	Bacoor Bay				✓
Bingham (2019)	Cebu	Visayan Sea	✓			
Bonifacio et al. (2022)	Lanao del Norte, Misamis Occidental, Zamboanga del Sur	Panguil Bay			✓	✓
Braña et al. (2021)	Capiz	Sibuyan Sea				✓
Bucol et al. (2020)	Negros Oriental	Bohol Sea, Tañon Strait			✓	✓
Cabansag et al. (2021)	Leyte, Eastern Samar	Cancabato Bay, Leyte Gulf, Lawaan River				✓
Castro et al. (2021)	Metro Manila	Manila Bay			✓	
Colacion et al. (2020)	Iloilo	Guimaras Strait			✓	
de Castro (2021)	Palawan	Green Island Bay		✓		
Deocaris et al. (2019)	Metro Manila	Pasig River		✓		
Espiritu et al. (2019)	Batangas	Bombong Estuary, Tayabas Bay		✓	✓	✓
Espiritu et al. (2023)	Metro Manila	Pasig River, Marikina River				✓
Esquinas et al. (2020)	Misamis Oriental	Macajalar Bay	✓		✓	
Gaboy et al. (2022)	Lanao del Norte	Iligan Bay	✓			
Gomez and Onda (2023)	Cavite, Metro Manila	Manila Bay	✓			
Inocente and Bacosa (2022)	Surigao del Sur	Lianga Bay	✓			
Insigne et al. (2022)	Cavite	Bacoor Bay				✓
Jambre (2021)	Zamboanga del Norte	Pulauan River, Liboran River				✓
Kalnasa et al. (2019)	Misamis Oriental	Macajalar Bay	✓		✓	
Malto and Mendoza (2022)	Sorsogon	Sorsogon Bay		✓		✓
Navarro et al. (2022)	Agusan del Norte	Butuan Bay			✓	
Obanan et al. (2020)	Cavite	Cañacao Bay				✓
Osorio et al. (2021)	Cavite, Bulacan, Metro Manila	Cañas River, Meycauayan River, Parañaque River, Pasig River, Tullahan River		✓	✓	
Pacilan and Bacosa (2022)	Lanao del Norte	Pagadian Baye				
Paler et al. (2019)	Batangas	Talim Bay	✓			
Paler et al. (2021)	Cebu	Tañon Strait				✓
Paler et al. (2022)	Cebu	Tañon Strait, Cebu Strait, Camotes Sea, Mactan Channel, Visayan Sea	✓			
Palermo et al. (2020)	Zamboanga del Norte, Lanao del Norte, Misamis Oriental, Agusan del Norte	Patawag Bay, Sindangan Bay, Dipolog Bay, Iligan Bay, Macajalar Bay, Gingoog Bay, Butuan Bay				✓
PlasMics (2021)	Metro Manila, Palawan	West Philippine Sea, Sulu Sea, Manila Bay	✓			
PlastiCount (2022)	Pangasinan, Metro Manila, Batangas, Palawan	West Philippine Sea, Sulu Sea, Manila Bay, Batangas Bay, Balayan Bay, Parañaque River	✓		✓	
REINVEST WPS (2022)	Palawan	West Philippine Sea	✓			
Requiron and Bacosa (2022)	Zamboanga del Norte	Pulauan River	✓			
Rubio et al. (2022)	Cavite	Imus River	✓	✓		
Sajorne et al. (2021)	Palawan	West Philippine Sea, Sulu Sea	✓			
Sajorne et al. (2022a)	Palawan	West Philippine Sea, Sulu Sea	✓			
Sajorne et al. (2022b)	Palawan	West Philippine Sea, Sulu Sea, Taytay Bay, Green Island Bay			✓	
van Emmerik et al. (2020)	Metro Manila, Bulacan	Meycauayan River, Tullan River, Pasig River	✓			
Yong et al. (2021)	Cebu	Cebu Strait				✓

would have an entry in *By Count* because of limitations discussed in the 5th challenge in Section 3.2. For stations with available count data, the amount of plastic items is recorded, along with identifying if the amount is a total or an average number. The reported coverage details the scope of the count depending on the authors' methodology (e.g., in 3 plots measuring 30 m each). The normalized coverage converts reported scopes into the recommended reporting units detailed in Table 4, depending on the focus. This unit conversion allows comparison between data gathered from different compartments and sample types. The average plastic density is derived by dividing the total amount with the

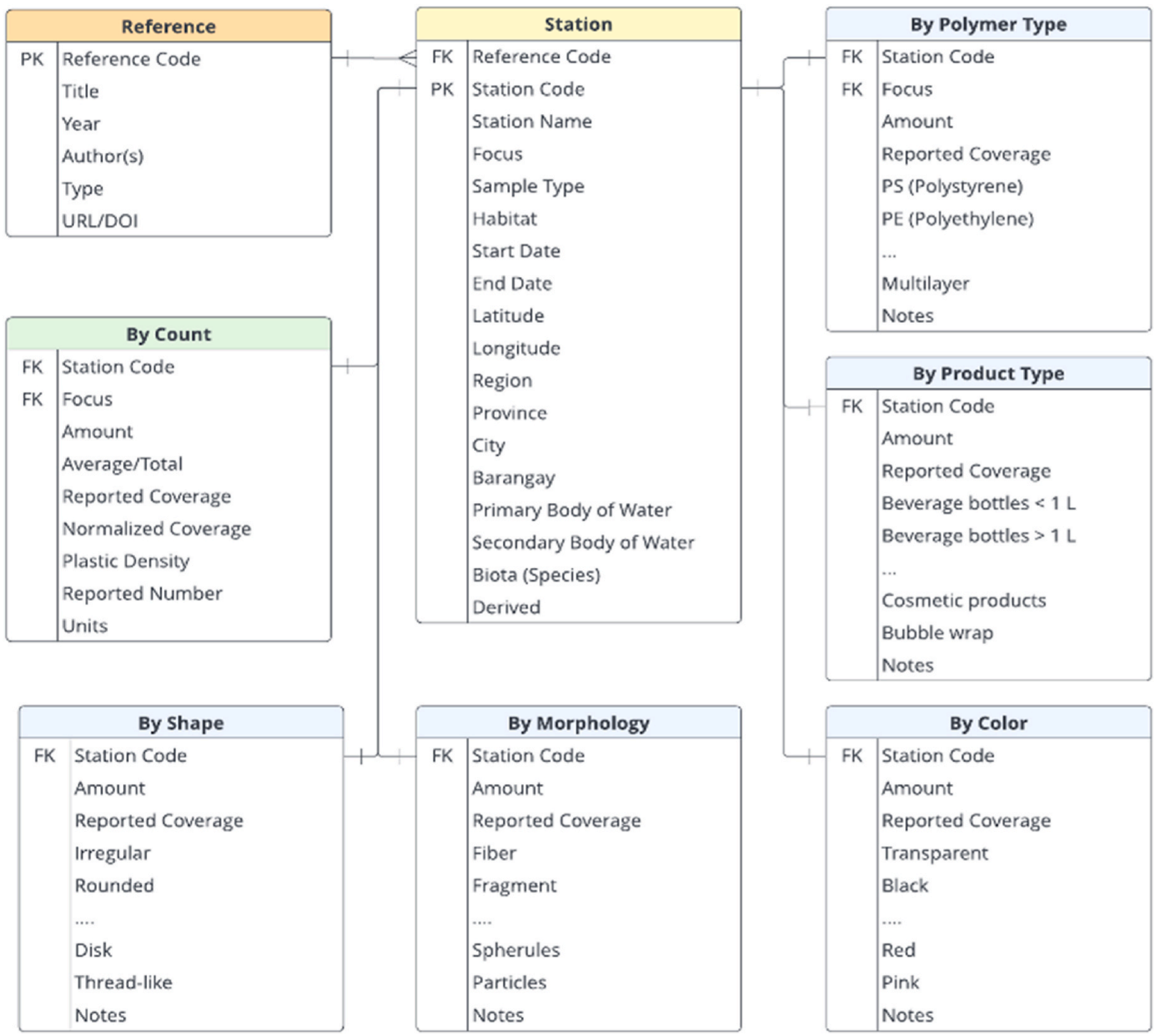

Fig. 2. Entity-relationship diagram for the *PlastiCount Pilipinas* database. PK - primary key, FK - foreign key.

Table 4
Units commonly used in the literature for the average count of plastic debris and microplastics.

Sample Type	Plastic debris density definition	Units
Area	Macro-plastics count per area sampled	items/m^2, items/km^2
Sediment	Micro-plastics count per mass	pieces/g, pieces/kg
Water	Micro-plastics count per volume	pieces/m^3, pieces/L
Biota	Micro-plastics count per biota sample	pieces/sample

normalized coverage. Average plastic densities reported by the publications are directly recorded into the *By Count* table. Lastly, the reported number rounds up plastic density and is reported accordingly in the map view of the web portal.

Classification tables (highlighted in blue) record plastic count data by shape, morphology, color and polymer type for microplastics, and product type and polymer type for macro-plastics. The station code is used as the FK to describe the relationship between the sampling station and the classification data. Additionally, the focus is added as an FK to the *By Polymer* table since the same classifications can be used for micro- and macro-plastics. The amount and reported coverage are recorded accordingly, while counts are added to each category in the table. The data from these five tables are reported in the graph view on the web portal. A complete list of categories used for all five tables are detailed in Table S3.

The initial seed data greatly informed the development of the database with key statistics summarized in Table 5. A thorough review of the references revealed data relationships used in the database schema. However, this design may be greatly improved after consultation with relevant academic and governmental stakeholders.

Table 5
Database statistics from initial seeding.

Table	Number of rows	Scope
Reference	44	Studies from 2019 to February 2023
Station	444	In 23 provinces and 14 regions
By Count	290	In 23 provinces and 14 regions
By Polymer Type	24	Bulacan, Cavite, Cebu, Lanao del Norte, Misamis Oriental, Negros Oriental, Zamboanga del Norte, Metro Manila
By Product Type	46	Cavite, Cebu, Batangas, Davao Oriental, Davao del Sur, Lanao del Norte, Palawan, Surigao del Sur, Metro Manila
By Morphology	63	Agusan del Norte, Batangas, Capiz, Cavite, Cebu, Eastern Samar, Iloilo, Lanao del Norte, Leyte, Misamis Occidental, Misamis Oriental, Palawan, Zamboanga del Norte, Zamboanga del Sur
By Shape	11	Batangas, Zamboanga del Norte
By Color	10	Agusan del Norte, Cebu, Cavite, Palawan, Zamboanga del Norte

3.4. Web portal design

The web repository is hosted at https://plasticount.ph/and can be accessed by users anytime and anywhere through an Internet connection. The corresponding system architecture of the website is described in Fig. 3.

Upon loading the website, the user is given the view of the *Plastics Tracker* page (enclosed in a grey box). Presented on this page is an interactive bubble map which is a visual representation of the national database (Fig. 4) where the density counts for both micro- and macro-plastics in each collection site are displayed. The size of each marker is directly proportional to the density of plastics sampled in the area. A total of seven size ranges are used to illustrate the differences in density which are color coded between micro- ($<10^{-3}$, 10^{-2}, 10^{-1}, 10°, 10^{1}, 10^{2}, $>10^{3}$ items per sample for biota, items per kg for sediment, or items per m^{3} for water) and macro-plastics (<1, 1–9, 10–99, 100–999, 1000–9999, 10000-99999, $>10^{5}$ items per m^{2}) for reference.

When a bubble is selected, a pop-up window will be displayed showing the details of the station, its location, compartment, and reference. Visibly, available microplastics data dominated in both number of sites and density. When zoomed in, users may observe that sampling sites tend to be clumped, leaving large gaps between coastal areas. Hence, enforcing the need for more studies across the country to address the sparsity of data.

Below the map view on the *Plastics Tracker* is the graph view, which visualizes classification data for both micro- and macro-plastics. Each graph may be generated by selecting a scope (macro or micro), category (morphology, shape, polymer type, color, product), and location (province). Once all choices have been made, a pie graph is generated illustrating the percent composition of plastics based on the choices made. This graph is available for viewing and downloading (Fig. 5).

Other pages were included in the website to provide additional information and resources to users (Table 6, with screenshots in Table S4). These features make the website not only a repository and database but effectively becomes a go-to hub for plastics information and education in the Philippines.

Data submission buttons were also placed on the web portal, to accept contributions from the public. Contributors who wish to submit peer-reviewed publications, results from ongoing studies, clean-up drives, and other resources may do so through the website's submission portal. They are also asked to fill out data sharing and consent forms during submission of any data or resources for proper credit attribution. Data consent is incorporated into the form as part of data sharing protocols. Any personal information obtained through the forms are bound by data privacy regulations in the Philippines. Lastly, the administrator reviews these materials submitted through this channel for quality checking before they are deposited into the database.

4. Discussion

4.1. Learning from existing databases and websites

A thorough examination of the 14 databases that passed quality filtering revealed that four databases had global scopes with specified geo-political boundaries, while one focused on bodies of water (i.e., South China Sea, Arctic Ocean). Notably, two of these global databases (GLOVE and Litterbase) had limited data points for the Philippines, with GLOVE having compiled only 12 sampling sites on plastic ingestion for biota, and the Litterbase only presenting two for microplastics and 10 for presence in biota (Monteiro et al., 2022; Tekman et al., n.d.). This is expected given their dependence on secondary references, which was greatly lacking in the country when these databases were being put up due to technical and methodological constraints (Abreo, 2018; Onda et al., 2020).

On the other hand, TIDES had the most comprehensive dataset for the Philippines with 1670 data points across the country. Compared to the previous two databases, TIDES employs a citizen science approach to be able to expand its scope dramatically all over the world. Notably, most of their data were contributed by the International Coastal Clean-up (ICC) efforts, which started in 1994 (ICC, 2020). Recently, the role of

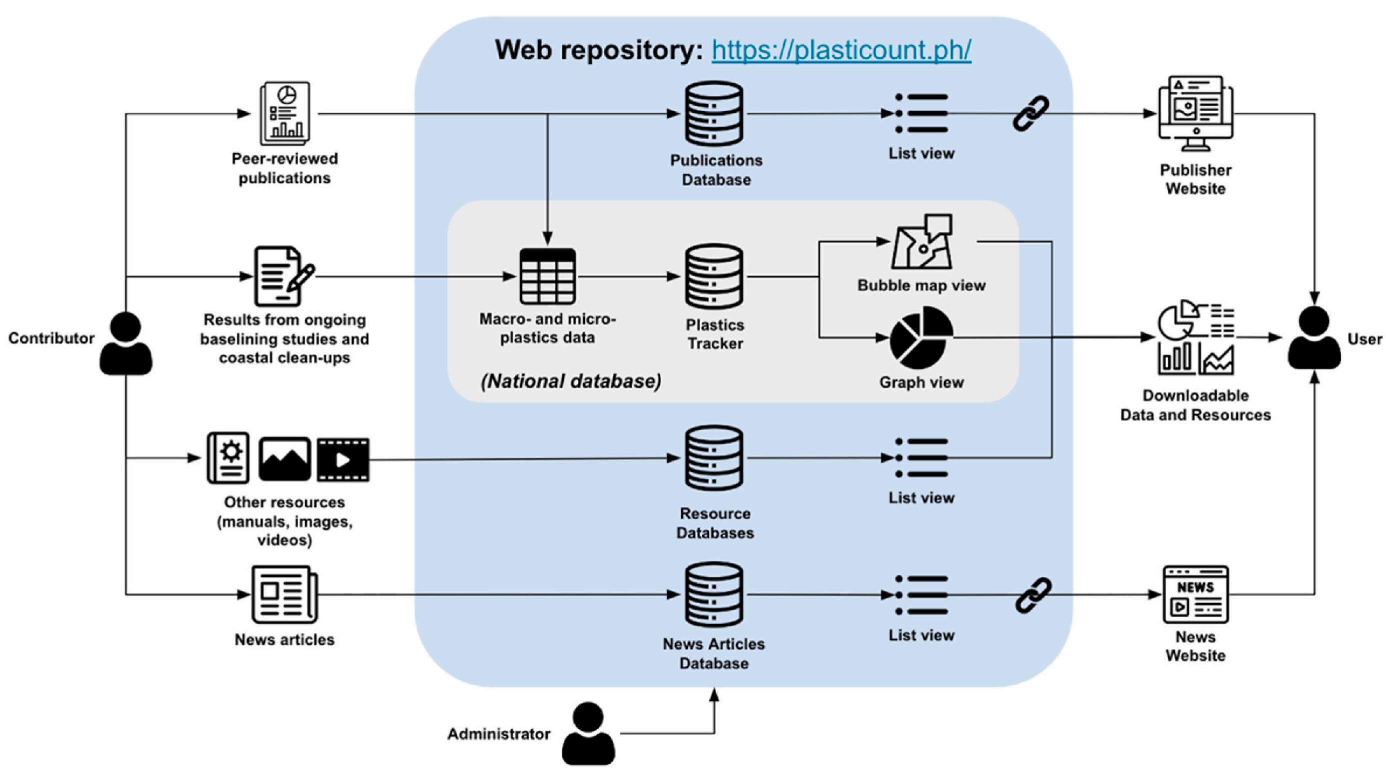

Fig. 3. System architecture of the *PlastiCount Pilipinas* web portal. The blue box covers the scope of the web repository, while the grey box covers the national baseline database.

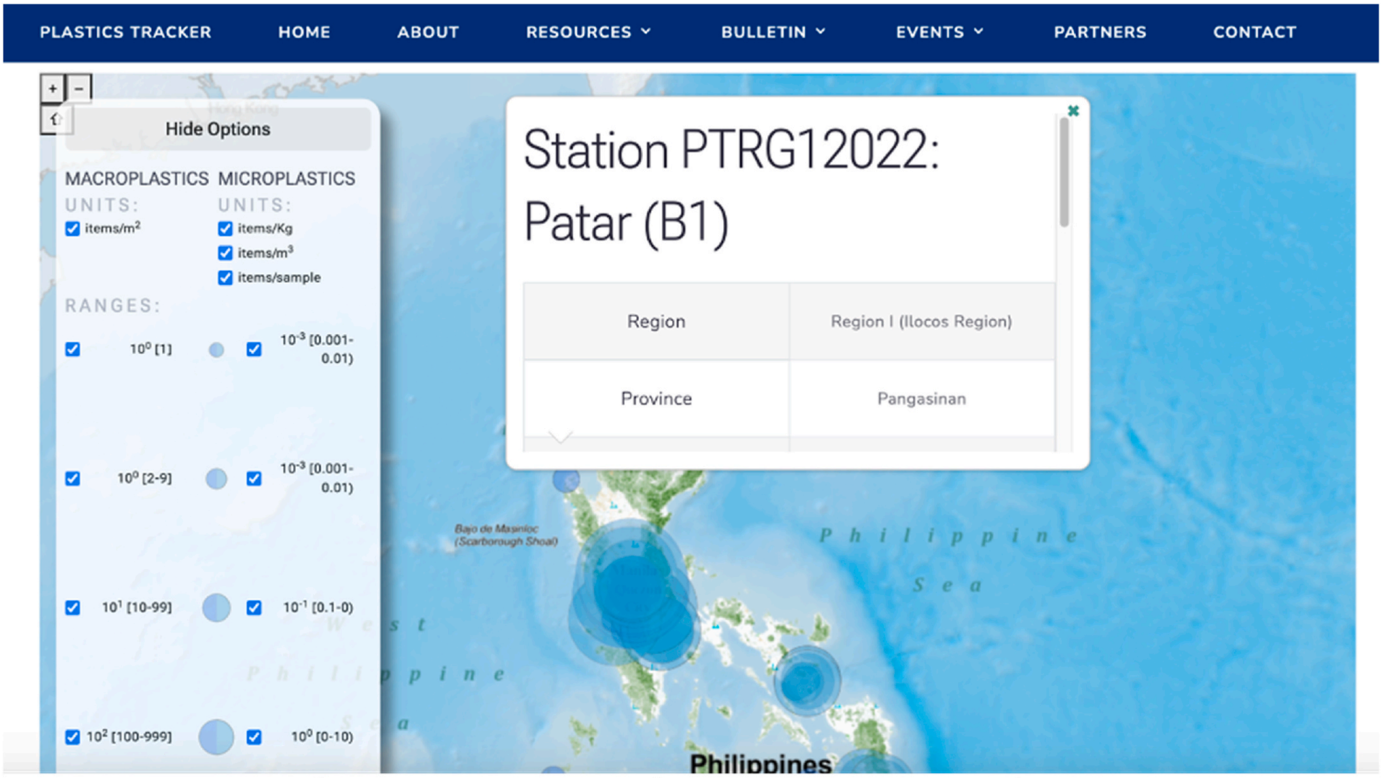

Fig. 4. Map view of the national database for count data. Retrieved from plasticount.ph. Photo taken on April 7, 2023.

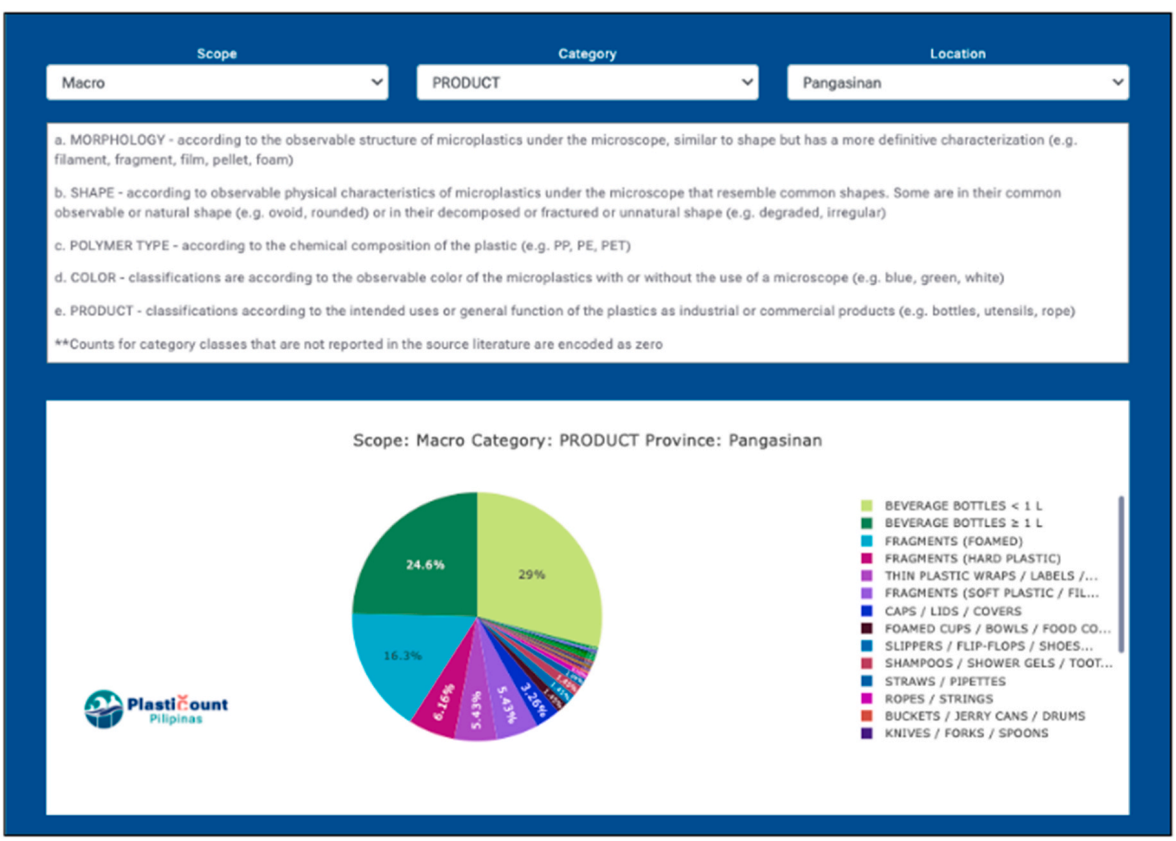

Fig. 5. Graph view of the national database for classification data. Retrieved from plasticount.ph. Photo taken on April 7, 2023.

Table 6
Summary of pages in the *PlastiCount Pilipinas* Portal.

Page	Content and Functionalities
Plastics Tracker	· An interactive bubble map depicting the presence of- and contrast between micro- and macro-plastic densities among sampled sites across the Philippines. Each bubble, when selected, displays further details of the sampling station, such as its geo-political location, type of compartment sampled, and data source from which it was retrieved. · An interactive pie graph tool which generates downloadable charts on the abundance of plastics pollution summarized into categories (morphology, shape, polymer type, color, product) based on the chosen scope (macro or micro) and location (province). · Contains a statement on data release and contributions.
Home	· An overview of the *PlastiCount Pilipinas*, with emphasis on the problem of mismanaged plastics in the Philippines, project goals, funding support, and gallery of activities.
About	· A detailed introduction on the *PlastiCount Pilipinas* Project- its motivations, goals, funding, and personnel involvements.
Resources/ Publications	· A list of available studies focused on micro- and macro-plastics quantification in the Philippines.
Resources/Guides	· A set of manuals used for the sampling, and processing of micro- and macro-plastics co-developed by project.
Resources/Facilities	· showcases two facilities that were established through the funding of the *PlastiCount Pilipinas* Project which houses laboratory resources and equipment and caters to the development of micro and macro-plastics quantification methods.
Resources/Gallery	· A compilation of the photo-documentations taken during the activities held by the project.
Bulletin/Latest News	· A short list of recent news articles on the situation of plastics pollution in the Philippines.
Bulletin/Project Updates	· A list of feature articles on the progress of the project.
Events/Conferences	· A page dedicated to conferences spearheaded by the project proponents for the founding and growth of the Plastics Research Network Philippines.
Events/Training Program	· A page featuring the training programs that were conducted by the project personnel to impart the knowledge and technology developed for micro and macro-plastics quantification.
Partners	· A list of agencies and organizations that were directly involved in either funding/supporting the project or collaboration for the impartation of knowledge and technology.
Contact	· Contains information regarding the contact details and addresses of the facilities and institutions directly implementing the project · Users can use the form provided to directly email the *PlastiCount Pilipinas* Team.

citizen science towards monitoring plastic pollution has again been identified as a potent alternative approach to aid in data collection over large areas, especially with the growing amounts of litter exacerbated by the COVID-19 pandemic (Ammendolia and Walker, 2022; Popa et al., 2022). Despite this, however, criticisms about the lack of quality control on citizen-collected data puts forward the need for well-defined criteria in accepting or rejecting data from public contributions (Zettler et al., 2017). This is specifically problematic since harmonized methods have not yet been established, resulting in the difficulty in data integration and comparison (Galarpe et al., 2021). Additionally, TIDES only focuses on macro-plastics despite the clear domination of microplastics in terms of absolute count, which is an essential parameter considered for inclusion in monitoring programs (Ryan et al., 2020). A clear trade-off is presented in this light. On one hand, solely focusing on secondary peer-reviewed references assures the user of the veracity of the data presented at the expense of having a smaller geographical scope and longer turnaround time because of the relatively low number of trained researchers that can provide in-depth analyses. Conversely, solely relying on citizen science can lead to faster turnaround time in sharing results, but techniques are often limited resulting in lower quality data that affects the integrity of the results. From this, a balance between research-driven datasets and citizen science efforts will help refine the national baseline for MPP.

Further, four of the databases examined having regional scopes in Europe (2), East Asia, and the Pacific (1), and in the Mediterranean Sea (1), are mainly informed by regional measures. In Europe for example, databases are associated with the implementation of OSPAR Regional Action Plans on Marine Litter, HELCOM, and the EU Marine Strategy Framework Directive (Dias et al., 2022). For the Philippines and the region, the ASEAN Regional Action Plan for Combating Marine Debris in the ASEAN Member States (2021–2025) is the only regional agreement that has been signed for MPP to date (ASEAN, 2021). In Southeast Asia, regional baselining has been noted to remain a problem due to limited technology that enables data collection (Omeyer et al., 2022). Efforts to contribute to regional baselining then should consider possible interoperability and integration with other marine litter databases.

Finally, the last four websites examined were very specific to a country. Of these, one is situated in Scandinavia (Norway) and three are in the Indo-Pacific (Australia, New Zealand, Indonesia). All three databases covering the Indo-Pacific region focused only on macro-plastics pollution with no regard for microplastics. Of these databases, the Australian Marine Debris Database is the most mature with over a decade's worth of coastal clean-up data. This database was vital in the development of data-driven policies for source reduction in the country (Gacutan et al., 2022). For the SEA region, only Indonesia's *MarineDebris.ID* was available, presenting 33 sites across its archipelago (MarineDebrisID, 2016). Notably, it is not fully functional when any of the sampling sites are selected. In addition, Vietnam has a conceptual database in line with its own national plan for marine litter, but a public website is yet to be developed (Walker et al., 2021). These do not indicate a lack of data but rather emphasize the need for an operational marine litter database that collates, reports, and makes data publicly available in any country in Southeast Asia.

Hence, the development of the *PlastiCount Pilipinas* website is a timely endeavor for the Philippines to validate prior statistical models (Jambeck et al., 2015; Law et al., 2020) and to serve as the national baseline for appropriate intervention. Although data remains to be scarce for the country, baselining efforts as well as initiatives have started to gain momentum as supported by the increasing number of published studies (see Results), providing an ease of collation and data integration early on.

4.2. *Challenges in data retrieval from systematic review*

Six main challenges were encountered while retrieving data from secondary sources, mostly relating to the differences in data reporting strategies and methodologies used:

1. Each study had its own data reporting formats for both count and classification (categories) data. In this context, 'format' refers to visual aids such as tables, graphs or charts. Oftentimes, it was simpler to retrieve data in a tabular format, as the needed information can be easily identified. Other publications directly provided their raw data in spreadsheet format, which made retrieval even more convenient (van Emmerik et al., 2020; Yong et al., 2021). Alternatively, retrieving data from graphs and charts was challenging since they required additional estimations and calculations to derive absolute values. For example, pie charts provide classification data in percentages, and hard counts can be calculated by multiplying each percentage value by the total number of plastics reported. Some bar graphs do not report exact total counts, only visual representations of such. Hence, approximation of such counts by projecting the bar onto an appropriate axis resulted in subjective estimates. These extra steps, which may have led to possible round-off errors, were still incorporated into the initial database, nonetheless, and were marked accordingly with the potential inaccuracy in another column.

Additionally, some tables, graphs, and charts contained incomplete information that made the derivation of complete data impossible. Hence, these were excluded to avoid any overarching assumptions that may affect data integrity.

2. Some publications had incomplete metadata describing their sampling events. In particular, thirteen publications did not specify when their samples or surveys were collected (Abreo et al., 2020; Avila et al., 2021; Bilugan et al., 2021; Bonifacio et al., 2022; Cabansag et al., 2021; Castro et al., 2021; Colacion et al., 2020; de Castro, 2021; Esquinas et al., 2020; Insigne et al., 2022; Jambre, 2021; Navarro et al., 2022; Obanan et al., 2020). Hence, data from these sources are left without any temporal tags. On the other hand, thirteen publications did not provide any coordinates for their sampling sites (Avila et al., 2021; Bingham, 2019; Bonifacio et al., 2022; Bucol et al., 2020; Cabansag et al., 2021; de Castro, 2021; Espiritu et al., 2023; Insigne et al., 2022; Jambre, 2021; Paler et al., 2021; 2022; 2019; Rubio et al., 2022). Spatial tags for these sources were estimated based on the given maps in the publication. Finally, some biota samples procured from the market had no reference as to where these samples were actually harvested (e.g., shellfish) or caught (e.g., fish). In such cases, either the market location or sampling site for water was used as a spatial tag (Abiñon et al., 2020; Espiritu et al., 2019).
3. Several publications reported average results from multiple sampling stations. As a result, a "derived" station was used to attribute locations to these results, taken from the average of the coordinates of the sampling stations. A total of 25 stations were derived from the publications.
4. The units used in the reporting of results strongly varied among authors (e.g., items per m^2 for sediments, or items per gram for biota), requiring additional unit conversion to allow for intercomparison among studies. The units used for reporting were based on the United Nations SDG 14.1 indicator for plastic debris density as summarized in Table 4. A majority of publications (95%) shared its results with the recommended reporting units, however, some studies had nuances in reporting which needed reconciliation. For example, some publications did not report plastic debris density directly and needed to be derived by retrieving the needed values from the results and methodology sections of the publication. This was particularly prevalent among studies that focused on biota, which usually reported the total number of plastics isolated from a number of individuals. Other publications used different units of measuring plastic debris density and needed to be converted to match the standard reporting unit. Acot et al. (2022), Kalnasa et al. (2019), Paler et al. (2019), Esquinas et al. (2020), Inocente and Bacosa (2022) and Sajorne et al. (2021) used the clean-coast index (CCI) to classify sites according to cleanliness (Alkalay et al., 2007). The CCI multiplies a fixed constant of 20 to the macro-plastics debris density in items/m^2 to allow for convenience in comparison. These values needed to be converted back to the original plastic debris density to allow for a standardized comparison with other studies. Bonifacio et al. (2022) reported plastic debris density for sediments with respect to the sampling area (items/m^2) rather than the weight of the samples. The values were converted to a per mass basis (in items/kg) since the weight of the sediment sample was explicitly stated in the methodology section of their paper.
5. Some publications had different methods to answer very specific research questions. For example, although Yong et al. (2021) reported microplastic density in pieces per gram of scat sample from *the* whale shark (*Rhincodon typus*), the sample does not represent the entire volume of the organism. On the other hand, Van Emmerik et al. (2020) reported its macro-plastic survey in items per hour (plastic flux), which made it difficult to be incorporated in the same bubble map as the others given its dynamic nature. On another instance, Abreo and Kobayashi (2021) and Sajorne et al. (2022b) conducted macro-plastics surveys specifically for PPE waste in relation to the COVID-19 pandemic. While valuable and interesting, their data were not incorporated into the count database because other potential plastic wastes other than PPE that may have been present at the sampling locations were not recorded. Hence, these four publications were not included in the count database, but still reported classification data which proved useful for the initial baseline.
6. Categories used for micro- and macro-plastics classification (and criteria for inclusion in these categories) varied across publications. For example, Bonifacio et al. (2022) considered microplastic fibers and filaments to be in the same category, while Castro et al. (2021) considered them different. For macro-plastics, the three baselining studies (PlasMics by DOST-NRCP, PlastiCount by DOST-PCIEERD, and REINVEST WPS by DOST-PCAARRD) classified beverage bottles either as greater or lower than 1 L, while Paler et al. (2022) used 2L as the threshold divider. These resonate with the experience of other studies (Cowger et al., 2020; Hartmann et al., 2019) that micro- and macro-plastics in general are subject to many differing categories, making intercomparison among studies particularly difficult.

Indeed, the absence of a common reference with harmonized methods has led to local researchers using different protocols, further leading to varying data reporting styles that hinder ease of comparison among studies (Galarpe et al., 2021). This again highlights the need for harmonized protocols to assist in the development of the national baseline for MPP in the Philippines, as included in the NPOA-ML Strategy 1.

4.3. Scope of initial baseline for MPP

A total of 419 sampling stations or 1.15 stations per 100 km of coastline were identified from the publications and ongoing studies. From the national perspective, the number of sampling stations is well-below the benchmark compared to other national databases such as Australia with approximately 12.19 stations per 100 km (Gacutan et al., 2022) and New Zealand with 10.80 stations per 100 km (Sustainable Coastlines, n.d.). This indicates the need for the Philippines to ramp up its plastic debris monitoring capabilities through information dissemination and capacity building.

The baseline represents 14 out of 16 non-landlocked regions in the country (Fig. 6 a.). The regions without any data include the Bangsamoro Autonomous Region in Muslim Mindanao (BARMM) and Region II (Cagayan Valley). Additionally, only 23 out of 66 coastal provinces excluding Metro Manila are represented in the initial baseline with each region not having equitable representation within its provinces (Fig. 6 b.). For example, while Region IV-B had the most number of sampling stations, only Palawan is represented, omitting the island provinces of Mindoro, Romblon, and Marinduque. Additionally, availability of data is correlated to the presence of research institutions involved in plastics research in the area. This information presents an opportunity for relevant government agencies to prioritize certain regions and provinces for baselining work.

4.4. Initial research themes and trends

The systematic review elucidated dominant themes in plastics research in the Philippines. Most studies focused on macro-plastics (36.4%), followed by microplastics in biota (29.1%), then microplastics in sediments (20%), and lastly microplastics in water (14.5%). Several publications have also combined themes into a single publication. We conjecture that macro-plastics research dominates the literature because of the relatively simple and accessible methodology needed to conduct such studies due largely to macroplastics' inherent manageable sizes compared to microplastics. Materials needed, such as transect tapes, are also readily available, allowing researchers to easily replicate methodologies. For microplastics, research in biota dominated

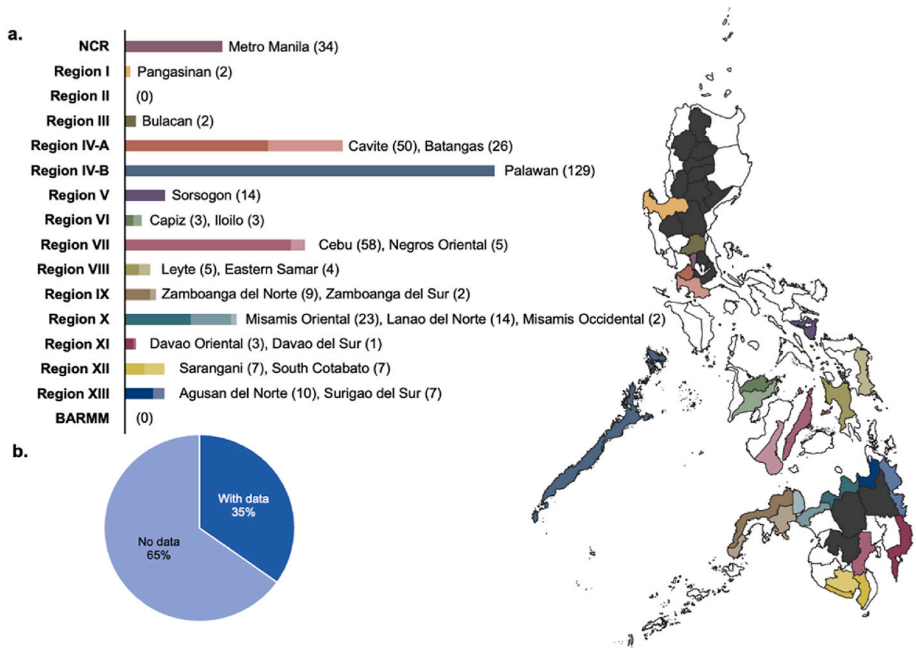

Fig. 6. **a.** Number of unique sampling stations per region and province. Only provinces with data are highlighted in color. Landlocked areas are highlighted in dark grey. **b.** Number of coastal provinces with data vs. without data.

the literature, likely reflecting the appreciation on the potential direct effects to humans via consumption and ingestion. Notably, most biota studies were on economically valuable species such as mussels, oysters, and common reef or pelagic fishes, which are mainly the significant protein sources in many coastal communities in the country. Additionally, biota studies are of high economic interest due to the potential risks on yield security and fitness for consumption of marine species produced in the aquaculture sector.

As for studies on sediments, the accessibility of materials for sampling and their perceived role as accumulation points (Zhang, 2017) might have influenced their dominance in the dataset. In contrast, water sampling often uses a fine-mesh net, which can be difficult to procure, leading researchers to use improvised nets or to adjust protocols. Most studies in these compartments were also mainly focused on source-sink dynamics or accumulation patterns, relating them to potential contributors such as population density and water transport.

In terms of explored research questions, baselining was most often the primary gap addressed by publications, with several exceptions. Espiritu et al. (2019), van Emmerik et al. (2020) and Requiron and Bacosa (2022) discussed plastics transport through rivers as they leak into the marine environment while Gomez and Onda (2023) discussed degradation of potential bacterial communities that can degrade low-density polyethylene (LDPE). While the necessity of baselining studies cannot be overstated, there is a strong opportunity to address other questions, such as the research framework presented by Omeyer et al. (2022) for the ASEAN region, while still accomplishing specific objectives aligned with baselining studies.

Several insights may already be lifted from the preliminary baseline. For count data, the National Capital Region presents the highest count for macro-plastic pollution along its coastlines and waterbodies with an average of 10.86 items/m^2 as measured by Gomez and Onda (2023). This may be attributed to population density being seen as a contributing factor to higher macro-plastic pollution densities by Sajorne et al. (2021) and was clearly evident in the summarized data. Microplastics exhibited similar trends with Central Luzon having the highest concentration for water samples (288,325 pieces/m^3) and sediments (5033.33 pieces/kg) measured by Osorio et al. (2021), and the Zamboanga Peninsula for biota samples (6.71 pieces/sample) measured by Bonifacio et al. (2022). For classification data on macro-plastics, single-use plastics have been found to dominate almost all regions and provinces in the Philippines, with the exception of Palawan province which mostly contains debris from the fishing industries (Gomez et al., preprint). For microplastics, the majority of morphologies identified were fibers, followed by fragments and foam. More insights may be derived from the data to merit their own research investigations but are not covered in this study. Although these statistics present initial insights on the state of plastic pollution in the Philippines, it still has its limitations with differing methodologies and the lack of data in certain areas.

4.5. Database and web portal evaluation

We used the framework proposed by Walker et al. (2021) for evaluating marine litter data websites based on its compliance level on best practices, existing legislations, and recommendations by international organizations. We noted that the *PlastiCount Pilipinas* portal complied with all ten criteria (Table 7) used in this evaluation framework.

Given the compliance to SDG guidelines for reporting, *PlastiCount Pilipinas* can be readily compared and integrated with other national or international databases (Criteria Nos. 1 and 8). This has been one of the top considerations during development, as interoperability allows for data to be readily contributed to form larger datasets. This has the potential to inform policy at the regional and global levels given the transboundary nature of plastics pollution (Maximenko et al., 2019; Ramos et al., 2022).

Data retrieval was also based on rigorous methodologies by retrieving data from peer-reviewed and research-driven studies (Criteria No. 2). The size ranges for both micro- and macro-plastics (Criteria No. 3) and location metadata (Criteria No. 4) were incorporated into the database. Adherence to these criteria recognize the different methods used to derive MPP data but simultaneously report them following guidelines provided in SDG Goal 14.1.

The *PlastiCount Pilipinas* portal is well-equipped to receive data from automated technologies (Criteria No. 5) and citizen science (Criteria No. 6). For the former, two facilities have already been established with the goal of increased automation for both micro- and macro-plastics

Table 7
Evaluation criteria for marine litter monitoring databases based on Walker et al. (2021).

	Criteria	Definition	Compliance
1	Interoperability	Refers to the ease of the database to be integrated into regional and global databases.	Reporting units align with other databases
2	Effective monitoring	Refers to the rigor of the sampling and analysis methods used by the data source.	Data derived from peer-reviewed publications
3	Data capturing	Refers to the representation of size ranges for marine debris data.	Micro and macro-plastics data included in the portal
4	Heterogeneity of marine debris	Refers to the acknowledgement of different protocols for measuring marine debris and consolidating the data into a uniform reporting format.	Includes location, scope, and compartment data
5	Sampling automation	Refers to the incorporation of automated technologies to increase data throughput.	Equipment available for automation
6	Citizen science	Refers to the involvement of citizen scientists, particularly on macro-litter monitoring of beaches and coastlines.	Submission portal for data and resources
7	Effective partnerships	Refers to the ongoing structures that support the operationalization of the portal such as funding and maintenance.	Portal was co-developed with relevant government agencies and shall be integrated into DENR operations
8	SDG alignment and reporting	Refers to the alignment of the data reporting to SDG 14.1 on average plastic debris density.	Reporting units align with SDG metadata
9	Commonly proposed operational features	Refers to the incorporation of common web portal features such as data visualization, resource sharing and other criteria.	Interactive map and pie graphs, downloadable resources
10	UNEP digital ecosystem elements	Refers to four key elements: data, infrastructure, analytics and insights/applications	Raw data and visualizations readily available in public website

quantification. The Microplastics Quantification, Identification and Biodegradation (MicroQuIB) Facility contains an imaging counter that automates the counting of microplastics from images of Nile Red-stained samples (Maes et al., 2017). The Quantification, Identification, Classification, and Mapping of Plastics Pollution (QuICMaPP) Facility hosts a customized workstation that can automate the generation of count and classification data based on phone and drone images (Kako et al., 2020). Notably, most databases in the review by Walker et al. (2021) are either partially or poorly compliant to this criteria given the lack of automation technologies. Lastly, manuals and a submission form are uploaded onto the portal to allow volunteers to replicate the methods and share their data, allowing for a larger geographical scope.

Existing databases often fall into the trap of remaining in the pilot phase due to the lack of effective partnerships, which the *PlastiCount Pilipinas* addressed through co-development with relevant government agencies (Criteria No. 7). A hands-on training program was conducted for representatives of the Philippine Coast Guard (PCG) and the Department of Environment and Natural Resources (DENR) to understand the functionalities of the web portal, along with the methods and reporting guidelines for data contribution. As such, the portal is in a good position towards its sustainability by integration into the agencies' existing operations (Alanano, 2023; Bungabong, 2022).

Lastly, the web portal was developed with key elements that allow users to readily interact with the data (Criteria No. 9) and derive insights (Criteria No. 10). The portal features an interactive map and pie graphs for data visualization, contains readily downloadable resources for knowledge sharing, and integrates all of these into a publicly accessible website for any user to access at any time. Additionally, four key pillars are identified by UNEP (2019) as crucial in the digital age: raw data, infrastructure, algorithms/analytics and insights/applications. Raw data is readily available to access in the portal and is supported by infrastructure such as the relational database management system and the web hosting platform itself. Analytics in the form of bubble maps and pie graphs convert this data into a visual format that allows for insight generation. Lastly, the application is readily accessible through a public website without any need for signing up for an account.

5. Conclusion

The biggest challenge in developing the initial baseline for the Philippines was the lack of a unified approach towards measuring and reporting plastic pollution. Sampling methodologies, laboratory processing techniques, and data reporting varied across publications and studies, leading to incomparable or lacking results. The harmonization of methods resolves this issue by clearly outlining all available methods and identifying their scope of measurement, allowing for ease of comparison.

Overall, the *PlastiCount Pilipinas* portal shall serve as the starting point towards developing a national harmonized data collation and integration system that allows for open data and access to the public for the Philippines. The portal contributes directly to the implementation of Strategy 1 (National Marine Litter Baselining) of the NPOA-ML. Additionally, as a public website, the *PlastiCount Pilipinas* portal can be utilized by academics, policymakers, entrepreneurs, and the general public to generate data-driven solutions for combating plastic pollution. Given that the marine litter problem extends from the Philippines to the rest of the region, other researchers and policymakers can gain insights from this study to develop the regional marine litter database and web repository for Southeast Asia. Other developments that platforms such as the *PlastiCount Pilipinas* Portal should consider is the expansion of tools that may be used by citizen scientists to increase the rate of data generation but without compromising data integrity and quality.

CRediT authorship contribution statement

RCA: Conceptualization, methodology, formal analysis, investigation, data curation, visualization, writing – original draft, writing – review & editing; LOCL: Conceptualization, methodology, software, formal analysis, data curation, visualization; RLL: Conceptualization, investigation, data curation; PSPI: Conceptualization, supervision, writing - review & editing; DFLO: Conceptualization, resources, writing – review & editing, supervision, funding acquisition.

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

Data will be made available on request.

Acknowledgements

The authors would like to acknowledge the support extended through the JST-UKRI-DOST Science and Technology and Action Nexus for Development (STAND)-funded and DOST-Philippine Council for

Industry, Energy, and Emerging Technology Research and Development (DOST-PCIEERD)-monitored "*PlastiCount Pilipinas*: Counting and Visualizing Marine Plastics Pollution in the Philippines" (Project No. 9861). Additionally, the authors would like to acknowledge the Department of Science and Technology – National Research Council of the Philippines (DOST-NRCP)-funded "Plastics in the marine environment, trophic systems, and aquaculture (PlasMics)" project, the United Kingdom Research and Innovation (UKRI)-funded "Microbial Transformation of Plastics in South East Asian Seas: A Hazard and A Solution (MicroSEAP)" project, the National Security Council (NSC)-funded "Upgrading Capability, Infrastructure, and Assets for Marine Scientific Research in the Philippines (UPGRADE-CIA)" project, and the Department of Environment and Natural Resources Biodiversity Management Bureau (DENR-BMB)-funded "Predicting Responses between Ocean Transport and Ecological Connectivity of Threatened Ecosystems in the West Philippine Sea (PROTECT-WPS)" project for data contributions to the portal. We also would like to express our gratitude towards the members of the Microbial Oceanography Laboratory of the University of the Philippines, The Marine Science Institute, especially Robert Bryan Casauay, Norchel Corcia Gomez, Daniel John Purganan, Noe Reyes, and Laurence Insigne for providing their data to the web portal. Icons used in this work were provided by Freepik on https://flaticon.com/.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ocecoaman.2023.106771.

References

Abiñon, B.S.F., Camporedondo, B.S., Mercadal, E.M.B., Olegario, K.M.R., Ypil, C.W.R., Tambuli, A.E., 2020. Abundance and Characteristics of Microplastics in Commercially Sold Fishes from Cebu Island, Philippines.

Abreo, N.A.S., 2018. Marine plastics in the Philippines: a call for research. Philippine Sci. Lett. 11 (1), 20–21.

Abreo, N.A., Kobayashi, V., 2021. First evidence of marine litter associated with COVID-19 in davao gulf, Mindanao, Philippines. Philipp. J. Sci. 150 (5) https://doi.org/10.56899/150.05.23.

Abreo, N., Siblos, S., Macusi, E., 2020. Anthropogenic marine debris (AMD) in mangrove forests of pujada bay, davao oriental, Philippines. J. Mar. Island Cultures 9 (1). https://doi.org/10.21463/jmic.2020.09.1.03.

Abreo, N.A.S., Aurelio, R.M., Kobayashi, V.B., Thompson, K.F., 2023. 'Eye in the sky': off-the-shelf unmanned aerial vehicle (UAV) highlights exposure of marine turtles to floating litter (FML) in nearshore waters of Mayo Bay, Philippines. Mar. Pollut. Bull. 186, 114489 https://doi.org/10.1016/j.marpolbul.2022.114489.

Acot, F.T., Sajorne, R.E., Omar, N.-A.K., Suson, P.D., Rallos, L.E.E., Bacosa, H.P., 2022. Unraveling macroplastic pollution in rural and urban beaches in sarangani bay protected seascape, Mindanao, Philippines. J. Mar. Sci. Eng. 10 (10), 1532. https://doi.org/10.3390/jmse10101532.

Alanano, K.A., 2023. ERDB-WWRRDEC, THWRDEC Staff Attend the Graduation Ceremony of the *PlastiCount Pilipinas* Training Program. Ecosystems Research and Development Bureau. https://erdb.denr.gov.ph/erdb-wwrrdec-staff-attend-the-graduation-ceremony-of-the-plasticount-pilipinas-training-program/.

Alkalay, R., Pasternak, G., Zask, A., 2007. Clean-coast index—a new approach for beach cleanliness assessment. Ocean Coast Manag. 50 (5–6), 352–362. https://doi.org/10.1016/j.ocecoaman.2006.10.002.

Ammendolia, J., Walker, T.R., 2022. Citizen science: a way forward in tackling the plastic pollution crisis during and beyond the COVID-19 pandemic. Sci. Total Environ. 805, 149957 https://doi.org/10.1016/j.scitotenv.2021.149957.

ASEAN, 2021. ASEAN Regional Action Plan for Combating Marine Debris in the ASEAN Member States (2021-2025.

Avila, M.J., Bajado, A.L., Narca, A.M., Morata-Fuentes, J., 2021. Characterization and Analysis of Microplastics in Aquatic Ecosystems in Tacloban City. https://doi.org/10.13140/RG.2.2.14281.21601. Unpublished.

Bhuyan, Simul, Md, S., V, S.S., Szabo, S., Maruf Hossain, Md, Rashed-Un-Nabi, Md, C. r., P., M.p., J., Shafiqul Islam, Md, 2021. Plastics in marine ecosystem: a review of their sources and pollution conduits. Region.Stud. Mar. Sci. 41, 101539 https://doi.org/10.1016/j.rsma.2020.101539.

Bilugan, Q.M., Limbago, J.S., Gutierrez, R.L., 2021. Detection and quantification of microplastics from cultured green mussel Perna viridis in Bacoor Bay, Cavite, Philippines. Sustinere: J. Environ. Sustain. 5 (2), 90–102. https://doi.org/10.22515/sustinere.jes.v5i2.166.

Bingham, P.R., 2019. The Abundance and Composition of Shoreline Litter on Malapascua Island, the Philippines: Approaches to the Solid Waste Management Problem.

Bissen, R., Chawchai, S., 2020. Microplastics on beaches along the eastern Gulf of Thailand – a preliminary study. Mar. Pollut. Bull. 157, 111345 https://doi.org/10.1016/j.marpolbul.2020.111345.

Bonifacio, P.S.P., Metillo, E.B., Romano, E.F., 2022. Microplastic in sediments and ingestion rates in three edible bivalve mollusc species in a southern philippine estuary. Water, Air, Soil Pollut. 233 (11), 455. https://doi.org/10.1007/s11270-022-05926-w.

Braña, A.S.S., Celestial, M.L.P., Molina, R.J.M., Mediodia, C.J.A., 2021. Microplastics in farmed oysters (Crassostrea iredalei) from Capiz, Philippines. Publiscience 4 (1), 8–13.

Bucol, L.A., Romano, E.F., Cabcaban, S.M., Siplon, L.M.D., Madrid, G.C., Bucol, A.A., Polidoro, B., 2020. Microplastics in marine sediments and rabbitfish (Siganus fuscescens) from selected coastal areas of Negros Oriental, Philippines. Mar. Pollut. Bull. 150, 110685 https://doi.org/10.1016/j.marpolbul.2019.110685.

Bueta, G.R.P., 2022. Circular economy policy initiatives and experiences in the Philippines: lessons for Asia and the pacific and beyond. In: Prospects for Transitioning from a Linear to Circular Economy in Developing Asia. Asian Development Bank Institute, pp. 78–92.

Bungabong, R.W., 2022. PlastiCount Trainees Re- Echo Learnings to WWRRDEC Co-researchers, Headstart Case Study in Balili River. https://erdb.denr.gov.ph/plasticount-trainees-re-echo-learnings-to-wwrrdec-co-researchers-headstart-case-study-in-balili-river/.

Cabansag, J.B.P., Olimberio, R.B., Villanobos, Z.M.T., 2021. Microplastics in some fish species and their environs in Eastern Visayas, Philippines. Mar. Pollut. Bull. 167, 112312 https://doi.org/10.1016/j.marpolbul.2021.112312.

Castro, L.J.A., Monsada, A.M., Cruz, K.D., 2021. Occurrence of microplastics in the sediments of baseco port area at Manila bay, Philippines. IOP Conf. Ser. Earth Environ. Sci. 958 (1), 012009 https://doi.org/10.1088/1755-1315/958/1/012009.

Colacion, D.A., San Diego, E.M., Secondes, J.R., Oberio, Z., 2020. Microplastic occurrence in the coastal sediments of selected barangays of Anilao, Iloilo, Philippines. Publiscience 3 (1), 122–126.

Cowger, W., Booth, A.M., Hamilton, B.M., Thaysen, C., Primpke, S., Munno, K., Lusher, A.L., Dehaut, A., Vaz, V.P., Liboiron, M., Devriese, L.I., Hermabessiere, L., Rochman, C., Athey, S.N., Lynch, J.M., De Frond, H., Gray, A., Jones, O.A.H., Brander, S., et al., 2020. Reporting guidelines to increase the reproducibility and comparability of research on microplastics. Appl. Spectrosc. 74 (9), 1066–1077. https://doi.org/10.1177/0003702820930292.

da Costa, J.P., Mouneyrac, C., Costa, M., Duarte, A.C., Rocha-Santos, T., 2020. The role of legislation, regulatory initiatives and guidelines on the control of plastic pollution. Front. Environ. Sci. 8, 104. https://doi.org/10.3389/fenvs.2020.00104.

de Castro, J.H., 2021. Physical Characterization and Spatial Variability of Microplastics in Coastal Surface Waters in Roxas, Palawan, Philippines.

DENR, 2021. National Plan of Action for the Prevention, Reduction and Management of Marine Litter.

Deocaris, C.C., Allosada, J.O., Ardiente, L.T., Bitang, L.G.G., Dulohan, C.L., Lapuz, J.K.I., Padilla, L.M., Ramos, V.P., Padolina, J.B.P., 2019. Occurrence of microplastic fragments in the pasig river. H2Open Journal 2 (1), 92–100. https://doi.org/10.2166/h2oj.2019.001.

Dias, L.C., Cunha, M.C., Watkins, E., Triantaphyllidis, G., 2022. A multi-criteria assessment of policies to achieve the objectives of the EU marine litter strategy. Mar. Pollut. Bull. 180, 113803 https://doi.org/10.1016/j.marpolbul.2022.113803.

DOST-NRCP, 2021. Plastics in the Marine Environment, Trophic Systems, and Aquaculture.

DOST-PCAARRD, 2022. Resource Inventory, Valuation and Policy in Ecosystem Services under Threat (Re-INVEST): the Case of the West Philippine Sea.

DOST-PCIEERD, 2022. *PlastiCount Pilipinas*: Counting and Visualizing Marine Plastics Pollution in the Philippines.

Espiritu, E.Q., Dayrit, S.A.S., Coronel, A.S.O., Paz, N.S.C., Ronquillo, P.I.L., Castillo, V.C.G., Enriquez, E.P., 2019. Assessment of Quantity and Quality of Microplastics in the Sediments, Waters, Oysters, and Selected Fish Species in Key Sites Along the Bombong Estuary and the Coastal Waters of Ticalan in San Juan, Batangas 148 (4).

Espiritu, E.Q., Rodolfo, R.S., Evangelista, S.M.J., Feliciano, J.J.G., Sumaway, A.M.N., Pauco, J.L.R., Alvarez, K.V.N., Enriquez, E.P., 2023. Microplastics contamination in the fishes of selected sites in pasig river and marikina river in the Philippines. Mar. Pollut. Bull. 187, 114573 https://doi.org/10.1016/j.marpolbul.2023.114573.

Esquinas, G.G.M.S., Mantala, A.P., Atilano, M.G., Apugan, R.P., Galarpe, V.R.K.R., 2020. Physical characterization of litter and microplastic along the urban coast of Cagayan de Oro in Macajalar Bay, Philippines. Mar. Pollut. Bull. 154, 111083 https://doi.org/10.1016/j.marpolbul.2020.111083.

Gaboy, S.M.M., Guihawan, J.Q., Leopardas, V.E., Bacosa, H.P., 2022. Unravelling macroplastic pollution in seagrass beds of Iligan City, Mindanao, Philippines. Mar. Pollut. Bull. 185, 114233 https://doi.org/10.1016/j.marpolbul.2022.114233.

Gacutan, J., Johnston, E.L., Tait, H., Smith, W., Clark, G.F., 2022. Continental patterns in marine debris revealed by a decade of citizen science. Sci. Total Environ. 807, 150742 https://doi.org/10.1016/j.scitotenv.2021.150742.

Gago, J., Galgani, F., Maes, T., Thompson, R.C., 2016. Microplastics in seawater: recommendations from the marine strategy framework directive implementation process. Front. Mar. Sci. 3 https://doi.org/10.3389/fmars.2016.00219.

Galarpe, V.R.K.R., Jaraula, C.M.B., Paler, M.K.O., 2021. The nexus of macroplastic and microplastic research and plastic regulation policies in the Philippines marine coastal environments. Mar. Pollut. Bull. 167, 112343 https://doi.org/10.1016/j.marpolbul.2021.112343.

Galgani, F., Hanke, G., Werner, S., De Vrees, L., 2013. Marine litter within the European marine strategy framework directive. ICES (Int. Counc. Explor. Sea) J. Mar. Sci. 70 (6), 1055–1064. https://doi.org/10.1093/icesjms/fst122.

GESAMP (Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection), 2019. Guidelines for the Monitoring and Assessment of Plastic Litter in the Ocean. United Nations Environment Programme (UNEP), Nairobi, Kenya.

Golumbeanu, M., Nenciu, M., Galatchi, M., Nita, V., Anton, E., Oros, A., Ioakeimidis, C., Belchior, C., 2017. Marine Litter Watch App as a tool for ecological education and awareness raising along the Romanian Black Sea coast. J.Environ.Protect.Ecol. 18 (1), 348–362.
Gomez, N.C.F., Onda, D.F.L., 2023. Potential of sediment bacterial communities from Manila Bay (Philippines) to degrade low-density polyethylene (LDPE). Arch. Microbiol. 205 (1), 38. https://doi.org/10.1007/s00203-022-03366-y.
Gomez, N. C. F., Cragg, S. M., Ghiglione, J. and Onda, D. F. L. (preprint). Single-Use Plastics (Sups) Assessed as 'High Risk' Based on Abundance and Occurrence of Debris in the Coastal Western Philippine Archipelago. Available at SSRN: https://doi.org/10.2139/ssrn.4441553.
Haarr, M.L., Falk-Andersson, J., Fabres, J., 2022. Global marine litter research 2015–2020: geographical and methodological trends. Sci. Total Environ. 820, 153162 https://doi.org/10.1016/j.scitotenv.2022.153162.
Hartmann, N.B., Hüffer, T., Thompson, R.C., Hassellöv, M., Verschoor, A., Daugaard, A. E., Rist, S., Karlsson, T., Brennholt, N., Cole, M., Herrling, M.P., Hess, M.C., Ivleva, N. P., Lusher, A.L., Wagner, M., 2019. Are we speaking the same language? Recommendations for a definition and categorization framework for plastic debris. Environ. Sci. Technol. 53 (3), 1039–1047. https://doi.org/10.1021/acs.est.8b05297.
Hermawan, S., Astuti, W., 2021. Analysing several ASEAN countries' policy for combating marine plastic litter. Environ. Law Rev. 23 (1), 9–22. https://doi.org/10.1177/1461452921991731.
ICC, 2020. History of ICC in the Philippines. Int.Coast. Clean-up Philippines. https://sites.google.com/site/iccphilippines/home.
Inocente, S.A., Bacosa, H., 2022. Assessment of macroplastic pollution on selected tourism beaches of barobo, surigao del sur, Philippines. J. Mar. Island Cultures 11 (1). https://doi.org/10.21463/jmic.2022.11.1.14.
Insigne, L.C., Salivio, U.L.D., Buenavente, J., Sagun, A.C.F., 2022. Preliminary Study on Microplastics in Bivalves Perna Viridis, Crassostrea Iredalei, and Venerupis Philippinarum Harvested from Bacoor Bay. City of Bacoor, Cavite.
Jambeck, J.R., Geyer, R., Wilcox, C., Siegler, T.R., Perryman, M., Andrady, A., Narayan, R., Law, K.L., 2015. Plastic waste inputs from land into the ocean. Science 347 (6223), 768–771. https://doi.org/10.1126/science.1260352.
Jambre, K.G.E., 2021. Density Microplast. Philip.Cup.Oyster (Crassostrea iredalei) 1 (4).
Kako, S., Morita, S., Taneda, T., 2020. Estimation of plastic marine debris volumes on beaches using unmanned aerial vehicles and image processing based on deep learning. Mar. Pollut. Bull. 155, 111127 https://doi.org/10.1016/j.marpolbul.2020.111127.
Kalnasa, M.L., Lantaca, S.M.O., Boter, L.C., Flores, G.J.T., Galarpe, V.R.K.R., 2019. Occurrence of surface sand microplastic and litter in Macajalar Bay, Philippines. Mar. Pollut. Bull. 149, 110521 https://doi.org/10.1016/j.marpolbul.2019.110521.
Law, K.L., Starr, N., Siegler, T.R., Jambeck, J.R., Mallos, N.J., Leonard, G.H., 2020. The United States' contribution of plastic waste to land and ocean. Sci. Adv. 6 (44), eabd0288 https://doi.org/10.1126/sciadv.abd0288.
Löhr, A., Savelli, H., Beunen, R., Kalz, M., Ragas, A., Van Belleghem, F., 2017. Solutions for global marine litter pollution. Curr. Opin. Environ. Sustain. 28, 90–99. https://doi.org/10.1016/j.cosust.2017.08.009.
Lyons, Y., Neo, M.L., Lim, A., Tay, Y.L., Dang, V.H., 2020. Status of Research, Legal and Policy Efforts on Marine Plastics in ASEAN+3: A Gap Analysis at the Interface of Science, Law and Policy, COBSEA and NUS. https://cil.nus.edu.sg/research/special-projects/#polllution-from-marine-plastics-in-the-seas-of-asean-plus-three.
Maes, T., Jessop, R., Wellner, N., Haupt, K., Mayes, A.G., 2017. A rapid-screening approach to detect and quantify microplastics based on fluorescent tagging with Nile Red. Sci. Rep. 7 (1), 44501 https://doi.org/10.1038/srep44501.
Malto, M.A.D., Mendoza, A.B., 2022. Suspended microplastic in sorsogon bay attributing Perna viridis and Atrina pectinata contamination. Open J. Mar. Sci. 12 (2), 27–43. https://doi.org/10.4236/ojms.2022.122003.
MarineDebrisID, 2016. Marine Debris Indonesia. https://marinedebris.id/.
Maximenko, N., Corradi, P., Law, K.L., Van Sebille, E., Garaba, S.P., Lampitt, R.S., Galgani, F., Martinez-Vicente, V., Goddijn-Murphy, L., Veiga, J.M., Thompson, R.C., Maes, C., Moller, D., Löscher, C.R., Addamo, A.M., Lamson, M.R., Centurioni, L.R., Posth, N.R., Lumpkin, R., et al., 2019. Toward the integrated marine debris observing system. Front. Mar. Sci. 6, 447. https://doi.org/10.3389/fmars.2019.00447.
Meijer, L.J.J., van Emmerik, T., van der Ent, R., Schmidt, C., Lebreton, L., 2021. More than 1000 rivers account for 80% of global riverine plastic emissions into the ocean. Sci. Adv. 7 (18) https://doi.org/10.1126/sciadv.aaz5803 eaaz5803.
Molina Jack, M.E., Chaves Montero, M., del, M., Galgani, F., Giorgetti, A., Vinci, M., Le Moigne, M., Brosich, A., 2019. EMODnet marine litter data management at pan-European scale. Ocean Coast Manag. 181, 104930 https://doi.org/10.1016/j.ocecoaman.2019.104930.
Monteiro, R., Andrades, R., Noleto-Filho, E., Pegado, T., Morais, L., Gonçalves, M., Santos, R., Sbrana, A., Franceschini, S., Soares, M.O., Russo, T., Giarrizzo, T., 2022. GLOVE: the global plastic ingestion initiative for a cleaner world. Mar. Pollut. Bull. 185, 114244 https://doi.org/10.1016/j.marpolbul.2022.114244.
Navarro, C.K.P., Arcadio, C.G.L.A., Similatan, K.M., Inocente, S.A.T., Banda, M.H.T., Capangpangan, R.Y., Torres, A.G., Bacosa, H.P., 2022. Unraveling microplastic pollution in mangrove sediments of butuan bay, Philippines. Sustainability 14 (21), 14469. https://doi.org/10.3390/su142114469.
Obanan, S.P., Leon, E.L.D., Salva, G.R., Santos, D.K.T., Segovia, D.E., Uybarreta, R.J., 2020. Characterization and Quantification of Microplastics in Slipper-Cupped Oyster, Crassostrea Iredalei (Faustino, 1932) from Cañacao Bay, Cavite City, Philippines.
Olen, S.M., 2022. Citizen science tackles plastics in Ghana. Nat. Sustain. 5 (10), 814–815. https://doi.org/10.1038/s41893-022-00980-y.
Omeyer, L.C.M., Duncan, E.M., Aiemsomboon, K., Beaumont, N., Bureekul, S., Cao, B., Carrasco, L.R., Chavanich, S., Clark, J.R., Cordova, M.R., Couceiro, F., Cragg, S.M., Dickson, N., Failler, P., Ferraro, G., Fletcher, S., Fong, J., Ford, A.T., Gutierrez, T., et al., 2022. Priorities to inform research on marine plastic pollution in Southeast Asia. Sci. Total Environ. 841, 156704 https://doi.org/10.1016/j.scitotenv.2022.156704.
Onda, D.F., Gomez, N.C., Purganan, D.J., Tolentino, M.P., Bitalac, J.M., Calpito, J.V., Perez, J.N., Viernes, A.C., 2020. Marine microbes and plastic debris: research status and opportunities in the Philippines. Philipp. J. Sci. 149 (1) https://doi.org/10.56899/149.01.07.
Osorio, E.D., Tanchuling, M.A.N., Diola, Ma B.L. D., 2021. Microplastics occurrence in surface waters and sediments in five river mouths of Manila bay. Front. Environ. Sci. 9, 719274 https://doi.org/10.3389/fenvs.2021.719274.
Pacilan, C.J., Bacosa, H., 2022. Assessment of macroplastic litter on the coastal seabeds of sultan naga dimaporo, lanao del norte, Philippines. J. Mar. Island Cultures 11 (2). https://doi.org/10.21463/jmic.2022.11.2.02.
Paler, Ma K.O., Malenab, Ma C.T., Maralit, J.R., Nacorda, H.M., 2019. Plastic waste occurrence on a beach off southwestern Luzon, Philippines. Mar. Pollut. Bull. 141, 416–419. https://doi.org/10.1016/j.marpolbul.2019.02.006.
Paler, M.K.O., Leistenschneider, C., Migo, V., Burkhardt-Holm, P., 2021. Low microplastic abundance in Siganus spp. from the tañon strait, Central Philippines. Environ. Pollut. 284, 117166 https://doi.org/10.1016/j.envpol.2021.117166.
Paler, M.K.O., Tabañag, I.D.F., Siacor, F.D.C., Geraldino, P.J.L., Walton, M.E.M., Dunn, C., Skov, M.W., Hiddink, J.G., Taboada, E.B., 2022. Elucidating the surface macroplastic load, types and distribution in mangrove areas around Cebu Island, Philippines and its policy implications. Sci. Total Environ. 838, 156408 https://doi.org/10.1016/j.scitotenv.2022.156408.
Palermo, J.D.H., Labrador, K.L., Follante, J.D., Agmata, A.B., Pante, M.J.R., Rollon, R.N., David, L.T., 2020. Susceptibility of Sardinella lemuru to emerging marine microplastic pollution. Glob.J. Environ.Sci.Manag. 6 (3) https://doi.org/10.22034/gjesm.2020.03.07.
Peng, Y., Wu, P., Schartup, A.T., Zhang, Y., 2021. Plastic waste release caused by COVID-19 and its fate in the global ocean. Proc. Natl. Acad. Sci. USA 118 (47), e2111530118. https://doi.org/10.1073/pnas.2111530118.
Popa, C.L., Dontu, S.I., Savastru, D., Carstea, E.M., 2022. Role of citizen scientists in environmental plastic litter research—a systematic review. Sustainability 14 (20), 13265. https://doi.org/10.3390/su142013265.
Ramos, B. de, Lima, T. M. de, Costa, M. F. da, 2022. Where are Brazil's marine litter scientific data? Front. Sustain. 3, 947343 https://doi.org/10.3389/frsus.2022.947343.
Requiron, J.C., Bacosa, H., 2022. Macroplastic transport and deposition in the environs of pulauan river, dapitan city, Philippines. Philipp. J. Sci. 151 (3) https://doi.org/10.56899/151.03.33.
Rubio, J., Mercurio, A., Ching, J., Guyamin, M., Zamora, G., Bala, J., 2022. Survey on Plastic Litters along Imus River, Cavite, Philippines.
Ryan, P.G., Moore, C.J., Franeker, J. A. van, Moloney, C.L., 2009. Monitoring the abundance of plastic debris in the marine environment. Phil. Trans. Biol. Sci. 364 (1526), 1999. https://doi.org/10.1098/rstb.2008.0207.
Ryan, P.G., Pichegru, L., Perold, V., Moloney, C.L., 2020. Monitoring marine plastics – will we know if we are making a difference? South Afr. J. Sci. 116 (5/6) https://doi.org/10.17159/sajs.2020/7678.
Sajorne, R.E., Bacosa, H.P., Cayabo, G.D.B., Ardines, L.B., Sumeldan, J.D.C., Omar, J.M., Creencia, L.A., 2021. Plastic litter pollution along sandy beaches in puerto princesa, palawan island, Philippines. Mar. Pollut. Bull. 169, 112520 https://doi.org/10.1016/j.marpolbul.2021.112520.
Sajorne, R.E., Cayabo, G.D.B., Gajardo, L.J.A., Mabuhay-Omar, J.A., Creencia, L.A., Bacosa, H.P., 2022a. Disentangling microplastic pollution on beach sand of Puerto Princesa, Palawan Island, Philippines: abundance and characteristic. Sustainability 14 (22), 15303. https://doi.org/10.3390/su142215303.
Sajorne, R.E., Cayabo, G.D.B., Madarcos, J.R.V., Madarcos, K.G., Omar, D.M., Ardines, L. B., Sabtal, S.A., Mabuhay-Omar, J.A., Cheung, V., Creencia, L.A., Bacosa, H.P., 2022b. Occurrence of COVID-19 personal protective equipment (PPE) litters along the eastern coast of Palawan Island, Philippines. Mar. Pollut. Bull. 182, 113934 https://doi.org/10.1016/j.marpolbul.2022.113934.
Shams, M., Alam, I., Mahbub, M.S., 2021. Plastic pollution during COVID-19: plastic waste directives and its long-term impact on the environment. Environ.Adv. 5, 100119 https://doi.org/10.1016/j.envadv.2021.100119.
Sustainable Coastlines. Litter intelligence. n.d.Retrieved March 8, 2023, from. https://litterintelligence.org/.
Tan, E., Jaafar, N.F., Aileen Tan, S.H., Mohd Zanuri, N.B., 2022. A review of plastic and microplastic pollution towards the Malaysian marine environment. IOP Conf. Ser. Earth Environ. Sci. 1013 (1), 012012 https://doi.org/10.1088/1755-1315/1013/1/012012.
Tekman, M. B., Gutow, L., Macario, A., Haas, A., Walter, A., & Bergmann, M. (n.d.). Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research.
Thushari, G.G.N., Senevirathna, J.D.M., 2020. Plastic pollution in the marine environment. Heliyon 6 (8), e04709. https://doi.org/10.1016/j.heliyon.2020.e04709.
UNEP, 2019. Resolution Adopted by the United Nations Environment Assembly on 15 March 2019: Marine Plastic Litter and Microplastics.
UNEP, 2022. UNEA Resolution 5/14 Entitled "End Plastic Pollution: towards an International Legally Binding Instrument".
United Nations, 2015. Transforming Our World: the 2030 Agenda for Sustainable Development.
van Emmerik, T., van Klaveren, J., Meijer, L.J.J., Krooshof, J.W., Palmos, D.A.A., Tanchuling, M.A., 2020. Manila River mouths act as temporary sinks for

macroplastic pollution. Front. Mar. Sci. 7, 545812 https://doi.org/10.3389/fmars.2020.545812.
Vriend, P., Hidayat, H., van Leeuwen, J., Cordova, M.R., Purba, N.P., Löhr, A.J., Faizal, I., Ningsih, N.S., Agustina, K., Husrin, S., Suryono, D.D., Hantoro, I., Widianarko, B., Lestari, P., Vermeulen, B., van Emmerik, T., 2021. Plastic pollution research in Indonesia: state of science and future research directions to reduce impacts. Front. Environ. Sci. 9, 692907 https://doi.org/10.3389/fenvs.2021.692907.
Walker, T.R., McGuinty, E., Hickman, D., 2021. Marine debris database development using international best practices: a case study in Vietnam. Mar. Pollut. Bull. 173, 112948 https://doi.org/10.1016/j.marpolbul.2021.112948.
Watt, E., Picard, M., Maldonado, B., Abdelwahab, M.A., Mielewski, D.F., Drzal, L.T., Misra, M., Mohanty, A.K., 2021. Ocean plastics: environmental implications and potential routes for mitigation – a perspective. RSC Adv. 11 (35), 21447–21462. https://doi.org/10.1039/D1RA00353D.
Yong, M.M.H., Leistenschneider, C., Miranda, J.A., Paler, M.K., Legaspi, C., Germanov, E., Araujo, G., Burkhardt-Holm, P., Erni-Cassola, G., 2021. Microplastics in fecal samples of whale sharks (Rhincodon typus) and from surface water in the Philippines. Microplast. Nanoplast. 1 (1), 17. https://doi.org/10.1186/s43591-021-00017-9.
Zettler, E.R., Takada, H., Monteleone, B., Mallos, N., Eriksen, M., Amaral-Zettler, L.A., 2017. Incorporating citizen science to study plastics in the environment. Anal. Methods 9 (9), 1392–1403. https://doi.org/10.1039/C6AY02716D.
Zhang, H., 2017. Transport of microplastics in coastal seas. Estuarine. Coast. Shelf Sci. 199, 74–86. https://doi.org/10.1016/j.ecss.2017.09.032.