Literature-based database to inform policy making on marine plastic pollution in ASEAN+3

Cheng Ling Lim[1], Youna Lyons[1]*, Yulu Liu[1], Mei Lin Neo[2], Moritz Müller[3], Changi Wong[3], Muhammad Reza Cordova[4], Sulistiowati Sulistiowati[5], Neil Angelo S. Abreo[6], Thanda Ko Gyi[7], Deo Florence Onda[8], Ronan Baculi[8], Chawalit Charoenpong[9], Japareng Lalung[10], Hai Anh Le Hoang[11], Daoji Li[12] and Lixin Zhu[12]

[1]Centre for International Law, National University of Singapore, Singapore, Singapore, [2]Tropical Marine Science Institute, National University of Singapore, Singapore, Singapore, [3]Swinburne University of Technology Sarawak Campus, Kuching, Malaysia, [4]Research Centre for Oceanography, National Research and Innovation Agency, Bogor, Indonesia, [5]Departement of Fisheries, Universitas Gadjah Mada, Depok City, Indonesia, [6]Mapua Malayan Colleges Mindanao, Davao, Philippines, [7]Myanmar Ocean Project, Myanmar, Myanmar, [8]The Marine Science Institute, University of the Philippines Diliman, Quezon City, Philippines, [9]Department of Marine Science, Chulalongkorn University, Bangkok, Thailand, [10]Universiti Sains Malaysia, George Town, Penang, Malaysia, [11]Can Tho University, Can Tho, Vietnam, [12]East China Normal University, Shanghai, China

The ASEAN+3 countries urgently need to present actual data on the state of their marine plastics pollution, so that they can respond to the criticisms of being the top-5 global sources of marine plastics based on modeled predictions, as well as to develop effective response policies based on sound data. While the research outputs on marine plastic pollution have increased spectacularly across these countries, their overall resource capacity to access the data remains lacking. This study describes a robust framework developed to use >700 peer-reviewed research publications from the region that can inform policy-making. First, detailed metadata fields were developed for this database focused on extracting information from the publications that are relevant to regional policy questions being asked to adequately respond to the threats posed by marine plastics. Second, the curation of research publications in this database greatly depended on a team of regional researchers, who were apt in the subject matter and a native language speaker. The latter was critical in the capture of non-English articles to boost the quality of database. Some of the key findings from the broad analyses included the rapid increase in research efforts on marine plastics between 2014 and 2021, which coincided with the growing concerns of this environmental crisis, the dominant publication language was English despite the diversity of countries, and the dominant research topic appeared to be of policy response measures. Overall, the database produced adequate and immediate data, where policy-makers can leverage for urgent actions. For example, the output on the status of marine plastic pollution is ever-increasing, but the region could start to focus on knowledge gaps (e.g., sampling in critical sensitive habitats like seagrasses and coral reefs). Finally, this study presented a comprehensive summary of the current state of marine plastic pollution and knowledge gaps (e.g., technical capacity and equipment) of the region that can facilitate discussions among target audience including the governments as well as international and regional regulating bodies, the research community and plastic waste management professionals.

KEYWORDS

plastic pollution, marine litter, macro-plastics, microplastics, database, ASEAN+3

1 Introduction

1.1 Background

Asia, in particular China and Southeast Asia, has been tagged as major sources of marine plastic pollution globally after the publication of Jambeck et al. (2015), Lebreton et al. (2017) and Meijer et al. (2021). In addition to being an uncomfortable position, the accusations feel unbalanced, if not unjust, when considering the lack of resources of some of the Asian countries to deal with the issues compared to the developed states. Furthermore, the latter are responsible for the export of a large portion of the plastic waste to these countries. China responded by banning any import of plastic waste in 2018 (China General Office of the State Council, 2017), thereby redirecting more export of plastic waste to Southeast Asia (Greenpeace, 2019). Headlines have continued pointing fingers at Southeast Asia, which referenced these original publications' findings that were based on "available data on solid waste with a model that uses population density and economic status to estimate the amount of land-based plastic waste entering the ocean." Indonesia, the Philippines, Vietnam, Thailand, and Malaysia are estimated to cumulatively contribute almost a third of marine plastic pollution to the world's oceans (Jambeck et al., 2015). Notably, these publications did not rely on actual measurements of marine plastic concentration nor distribution.

Pollution from marine plastic is an additional pressure on the marine ecosystems of Southeast Asia which overall holds the world's highest, regional biodiversity and endemism levels but is also one of the world's most threatened regions (Hughes, 2017). Marine plastics pose further threats to biodiversity and species that dwell and rely on aquatic ecosystems, by interfering with specific operational functions and impairing the provision of essential services (Wright et al., 2013; Galloway et al., 2017). The seas of Southeast Asia are also transboundary bodies of water in a central location surrounded by large coastal cities and highly populated coastlines. The pollution that the regional seas receive (unless it is to sink close to shore) is therefore highly transboundary and a concern to all. The flow of plastic debris in the ocean is intricate and can be affected by multiple factors, including ocean currents, wind patterns, and tidal movements (Iskandar et al., 2021, 2022). Once plastic litter is made present in the marine environment, it could travel vast distances before accumulating in distant regions detrimental to indigenous ecosystems and aquatic creatures (Sebille et al., 2020).

Three key drivers can be identified as having triggered the prompt reaction of countries in the region to respond to this new source of pollution at national and regional levels: (i) pressure from outside the region based on Jambeck et al. (2015), (ii) the parallel realization of the adverse impact of marine plastic pollution to the national economy; and (iii) the transboundary nature of the pollution. Since its first meeting in 2014, the United Nations Environment Assembly (UNEA) has highlighted the pressing nature of this issue and the need for urgent action, including at regional and subregional levels [See UNEA Resolutions 2/11 (2015), 3/7 (2018) and 4/6 (2019)]. Following the calls for action, the first action plan adopted by states at regional level was the marine litter plan of action (RAP MALI) adopted in 2018 by the Coordinating Body for the Seas of East Asia (COBSEA). In 2019,

the Association of the Southeast Asian Nations (ASEAN) adopted both the Bangkok Declaration on Combatting Marine Debris in the ASEAN Region and the ASEAN Framework of Action on Marine Debris in the same year. This has been followed in 2021 by the ASEAN Regional Action Plan for Combatting Marine Debris (ASEAN RAP).

ASEAN+3 countries rely on coastal, marine, and maritime sectors of activities such as fisheries, aquaculture, tourism, and maritime transport; all of which form part of their blue economy. Given the costs and risks of pollution from marine plastics to these sectors and more generally to the population which is heavily reliant on marine ecosystems, national policies and response measures called on by the regional action plans are urgently needed. These policies and measures should focus on reducing plastic waste at the source, promoting sustainable production and consumption patterns, and strengthening waste management systems (Knoblauch and Mederake, 2021). Moreover, to be effective, they need to be based on robust and accessible science. In this context, making environmentally relevant data publicly available through open-access databases would enable transboundary data sharing (Omeyer et al., 2022). Such databases would also provide a sound scientific basis to identify knowledge gaps that need filling to inform effective solutions as well as inform policy making (Lyons et al., 2020; Omeyer et al., 2022).

This paper provides the approach, rationale and methodology followed by the authors in designing a database of scientific research projects with findings on pollution from marine plastics in ASEAN+3, to serve as a scientific tool to inform policy making and provide time-efficient access to real data from research. Science, in this context, includes all relevant research fields that inform policy, such as natural sciences and humanities, written in English and regional languages (e.g., Thai, Indonesian, Malay, and Vietnamese). It seeks to substantiate the scientific robustness of the methodology, prior to highlighting early findings from the database and visualization platforms to demonstrate the usefulness of the data captured and therefore of the overall approach. It points to additional potential uses but does not seek to provide a comprehensive data analysis.

1.2 Existing data inventories and platforms and their limitations in the ASEAN+3 context

Marine plastic knowledge databases, inventories, and platforms recently started developing in the ASEAN region, through parallel projects. However, they do not include research findings verified through a peer-reviewed process Outside the region, there are some area-specific knowledge databases, inventories, and platforms that were examined to scope the data need and inform the design of the development methodology adopted for this ASEAN+3 regional data platform.

ASEAN+3 is an extremely linguistically diverse region (Kirkpatrick and Liddicoat, 2017) and the regional languages (e.g. Indonesian, Thai and Vietnamese) play an important role in local cultural and linguistic knowledge (Peter et al., 2022), as well as the acquisition of scientific knowledge and policy developments.

However, all but one of the comprehensive knowledge databases, inventories, and platforms we found and reviewed focused only on English publications and documents, therefore excluding non-English Asian languages, unless an English translation was available. The LITTERBASE online platform for marine litter (developed by the Alfred Wegener, Institute Helmholtz Center for Polar and Marine Research) is one such example that captures English-only publications and categorizes the articles by plastic size (microplastic or plastic litter) and "realm" where the publication focuses on (e.g. water surface, ice, beach/bank). The Regional Knowledge Center for Marine Plastic Debris by the Economic Research Institute for ASEAN and East Asia (ERIA) is another example of an inventory that captures English-only publications. The Regional Knowledge Center is an information clearinghouse that focuses on government actions such as regulations and initiatives, private sector actions on plastic and scientific knowledge on good practices in dealing with marine plastic debris issues. Another example of a data platform that captures English-only literature is The Circulate Initiative's Knowledge Bank. The Circulate Initiative's Knowledge Bank classifies publications as case studies, measurements, primary data and strategy that focuses on research, resources and tools on solutions to address ocean plastics and measures of impact. The only exception was, the Plastics Pollution Policy Inventory developed by Nicholas Institute for Environmental Policy Solutions as part of the Duke University Energy Initiative; it includes non-English publications. This inventory captures public policy documents, treaties and international and regional instruments targeting plastic pollution in both English and non-English languages such as Chinese, Malay, Thai and Vietnamese. However, the Plastics Pollution Policy Inventory is focused on public policy and does not capture information from scientific publications, which is the focus of the development of this regional data platform.

Scientific publications and literature generally require a certain level of technical understanding for discovery, access, comprehension, and digestion of the knowledge for application. The approach taken was that developing an inventory with analysis of the captured data would provide added value, especially for non-technical users, such as policy-making specialists. This can be achieved, for example, through a global map display such as that of the LITTERBASE platform that informs locations where litter-biota interactions (e.g., plastic entanglement, plastic ingestion) have occurred. The LITTERBASE platform also has a global map showing litter quantities in different habitats as reported in the captured literature. The One Earth – One Ocean (OEOO) provides a Microplastic Pollution Map that displays data as collected regularly from water samples of the North Sea, the Atlantic and the Mediterranean through a cooperation with the Hamburg shipping line. The OEOO Microplastic Pollution Map provides detailed information on the collected samples and information derived from the examinations of the microplastics found within water samples, through clear data presentation and visualizations. Although the OEOO focus area is outside the ASEAN+3 region, the platform provides an example of research technicality and details made easily navigable for non-experts.

To address the knowledge gaps in the understanding of marine plastics pollution in ASEAN+3 and support the development of evidenced-based response measures, we developed the Regional Research Inventory Database (RRID) that contains data extracts that are relevant to science and policy. Having considered the learning points gathered from other knowledge databases, inventories, and platforms, the RRID aimed to capture publications (i.e., peer-reviewed natural and social sciences literature, and published reports) both in English and regional languages, with data extraction necessary for in-depth understanding and adequate use of the publication for policy making. To remain current and relevant, the inventory will need regular updating, revising, and maintaining by regional researchers with relevant expertise in natural and social sciences, in English and regional languages. National efforts such as the Philippine Plastics Monitoring Map by Plasticcount Pilipinas, which was established in the slipstream of the RRID, can be critical sources for its regular update.

2 Materials and methods

The development of the RRID required a team of regional researchers whocould access relevant publications in each ASEAN+3 countries (i.e., English and non-English articles) and ensure accurate data recording in the database, especially for regional articles that were not always available on global databases and platforms. We therefore first created and coordinated a regional research team to conduct a systematic literature search to identify relevant literature and adopt a selection process with inclusion and exclusion criteria. A framework using metadata was developed to standardize the characterization of each included publication and serve as a glossary of terms for users to navigate the inventory.

2.1 Regional research team

The regional team consisted of over 30 members from seven countries, with the involvement of 10 research institutions or research initiatives and organizations. The members came from an informal regional network of researchers working on marine plastics, established through past research collaborations and workshop encounters on marine plastics, and regional webinars organized by NUS on research on marine plastics. Apart from the initial team from the National University of Singapore (consisted of members familiar with several Asian languages), the core regional team involved in the development of the RRID also included researchers from the Universiti Sains Malaysia from Peninsular Malaysia and Swinburne University of Technology Sarawak Campus in Sarawak for East Malaysia, National Research and Innovation Agency in Indonesia, Can Tho University in Vietnam, the Mapua Malayan Colleges Mindanao and University of the Philippines Marine Science Institute in the Philippines, Chulalongkorn University in Thailand, The Myanmar Ocean Project in Myanmar, and, a team from East China Normal University in People's Republic of China.

2.2 Development of the Regional Research Inventory Database

The regional research team conducted a systematic review to capture publications that may not be accessible online globally through a standardized search (e.g., dissertations, reports, etc...), as well as those published in non-English languages. Specifically, the regional research team (i) conducted a systematic search for literature published in multiple written languages in the ASEAN+3 region, and selected literature based on a set of criteria, and (ii) applied the metadata developed to extract information from selected literature to populate the inventory. This methodology, elaborated in the sections below, was conducted alongside (iii) regular online check-ins with the regional research team members to ensure consistency in understanding and implementation. This collaborative research effort made it possible to capture research literature published in at least seven non-English languages including Indonesian, Filipino, Malaysian, Burmese, Vietnamese, Chinese, and Korean from across Southeast and East Asia for compilation, with data systematically characterized into an organized literature inventory.

2.2.1 Literature search and selection

A systematic meta-review was conducted to identify and evaluate the findings of relevant publications with a view to ensuring objectivity, rigor, and transparency. The data search was carried out between March 2020 and June 2021, based on searches conducted on mainstream databases (specifically Google Scholar, ScienceDirect, Wiley Libraries and Scopus) as well as locally-driven databases such as the Korean Studies Information Service System (KISS), the Research and Publication Home University of the Philippines Baguio, the Thailand Burapha Science Journal, the Indonesian scientific publications platform Garba Rujukan Digital (GARUDA), and relevant government sites, such as the Thailand Department of Marine and Coastal Resources (DMCR). The regional team also conducted searches for relevant dissertations and theses on their home universities and other academic institutional sites that they were able to access. Across the various platforms, searches were focused on publications produced between January 2015 and June 2021, using varying combinations of keywords "plastic" and "marine," and names of countries within Southeast and East Asia, e.g., "marine" AND "plastic" AND "Singapore." Publications dated before 2015 were examined briefly, but as they made up a much smaller proportion of the total articles (i.e., $n = 57$ between 2001 and 2014; Figure 1). In addition, the small pool of articles does not sufficiently provide a holistic understanding of the region's grasp to address the plastic pollution; therefore, these were omitted from further analyses.

A selection of literature from the results of the searches was made, driven by three criteria: (1) the research must involve plastics, (2) the research must be explicitly relevant to the regional countries, territories and/or water bodies and, (3) the context of the research must be explicitly related to the marine environment. In other words, articles that did not refer to marine environments, plastic, marine debris, or marine litter, and did not mention any relevant region, country or territory were omitted. The selected publications were compiled and input in a Google spreadsheet before conducting data extraction on the publications, using the inventory metadata. Research articles published after June 2021 were not captured in the latest version of the inventory.

2.2.2 Developing and applying the metadata

Metadata typically provides the descriptive information of data, informs about the structure of the data, and provides guidance to definitions of the categories within the data. In the design of the data inventory structure, it was a key consideration for the data to be flexible and adaptable, to cater to various users from the sciences, humanities, and policy world. Data columns were designed to hold specific elements of information which could later be combined with other columns (modular units, like Lego blocks) to suit different uses and users. Hence, the data could be analyzed from different angles and for the analysis to include different data combinations. Each element in the inventory metadata was given a definition to promote the consistent use of terms across application of data extraction from the various scientific, humanities and legal publications, as much as possible. The metadata served as a tool to guide both the regional research team in filling up the inventory, and users in navigating the large data sheet. Its structure loosely follows the general structure of research publications, based on four categories, relating to (a) article information, (b) research scope, (c) research methodology, and (d) research findings (Figure 2). The complete documentation of the metadata can be accessed here.

For the article information, it captured the general information of the publication (e.g., geographical scale of the research study), as well as the link to the publication for traceability. Each article captured in the inventory was given a unique identifier number and recorded as an entry. For research scope, it described the scope of research conducted such as the aim of research, location of research work, and plastic sizes examined. For research methodology, it described the methodologies implemented in the research study. The methodologies used were categorized, such as review, sampling, experimental work, and remote imagery. For example, if field sampling was conducted, field sampling information such as the depth of sediment sampling, field sampling frequency would be recorded. For research findings, it described the key findings as reported by the authors. In addition, the research topics covered in the publication were recorded based on a curated and adapting inductive list. The research topics were further classified into various categories and subcategories, such as movement of plastics in water bodies, fragmentation and degradation, microbial assemblages, human health/food safety, laws, administrative measures, and communication and coverage of marine plastic. This list may be of interest to researchers of different expertise allowing them to dive into different topics. Overall, the process of extracting this metadata involved the thorough reading of publication by the regional team members with technical expertise.
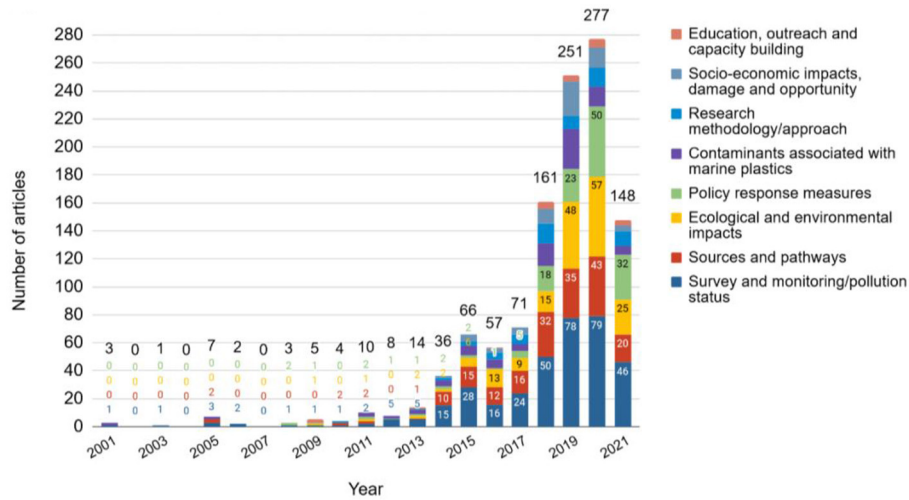
FIGURE 1
Research topics published on marine plastic pollution in Southeast and East Asia, as captured in the Regional Research Inventory Database, over the years between 2001 and June 2021.

FIGURE 2
An overview of the metadata used for developing the Regional Research Inventory Database (RRID). Four categories: article information, research scope, research methodology and research findings were used to describe the general and technical information for respective publications.

2.2.3 Data input verification and inventory compilation

Completed entries of publications were reviewed to check for congruence of input information with the respective metadata requirement and understandability of the input information. Where required, entries that needed editing were highlighted to the team member who conducted the review for amendments. Publication entries that satisfied the metadata requirements were added into the inventory.

2.2.4 Data analysis and visualization

As the aim of this inventory database was to inform policy making, the last step of the methodology was to investigate the data collected with a view to determining the information and

TABLE 1 Themes that guided the analysis of publications captured in the inventory database.

Themes	Guiding questions
(1) Research landscape and capacity	What is the research landscape on pollution from marine plastics in ASEAN+3? What are some of the common research topics in the region by country/territory and waterbody? Which areas of research are expertise and capacities available (including technical equipment available), and where does further capacity need building? What are the differences in research efforts in different countries and water bodies in the region? What research topics do regional languages cover?
(2) Recording of plastic presence or absence in the marine environment	How much marine plastic is present in the marine environment? Where has sampling occurred and in which part of the marine environment? Can any quantitative assessment of the quantity and distribution of marine plastic debris be derived? What are the variations in polymer types, size, shapes, or color? Are any indicators of marine plastic pollution shaping or proposed?
(3) Sources and pathways	What knowledge do we have and/or can we derive on the commonly found sources of marine plastics by country/territory/water body on sources and pathways of these marine plastics?
(4) Impacts	What is the knowledge of direct/indirect impacts of marine plastic particles on the marine environment? In addition to the direct threats from marine plastic as a pollutant, are they other indirect ecological risks created by the introduction of plastic particles in the marine environment (e.g., as a pathway of non-native species or the adsorption of POPs and heavy metals or a suitable substrate for the development of pathogens present in the marine environment)?
(5) Policy and response measures	What policy and response measures have been tested and/or are proposed? What is proposed as a regulatory approach? What are the barriers to law and policy resolving the plastic crisis? What is compliance or social behavior issues to consider?
(6) Education, training, and outreach	How are education, training, capacity building in general and outreach efforts conducted? What are the barriers to information flow that require education and training? How can they be more effective?

knowledge that could be derived from (i) scientific publications; (ii) publications in humanities; and (iii) both taken together. We based our investigations, inductively, on the many questions raised in the marine plastic literature to solve the marine plastic crisis (Maes et al., 2019). They could be broadly grouped into the six sets of questions, which serve as research topics in the inventory (Table 1).

3 Results

The inventory contained 701 articles with a database containing 82 columns of data derived from each of these publications (updated as of June 2021). Of the 701 articles recorded, 77.9% were scientific publications ($n = 546$), 17.2% were humanities publications ($n = 121$), and 4.9% publications were of both scientific and humanities ($n = 34$). Each research publication may conduct plastic research concerning one or more countries or territories. According to this inventory, the top five countries where the largest number of research studies have been conducted were the People's Republic of China ($n = 250$), followed by Indonesia ($n = 141$), the Republic of Korea ($n = 89$), Malaysia ($n = 76$), and Japan ($n = 67$).

Given the size of the database, only a limited selection of the data analyses and visualization was presented before an overall assessment of the extent to which the database answers the research questions. The subset of various data visualizations that have been conducted can be accessed here. The database is also available on the datahub of the Global Partnership on Marine Litter (GPML). The website of the GPML regional node for the Seas of East Asia embeds both the database and the data visualization and analytics platform. A simplified search tool for the database has also been developed for easier non-technical consultations.
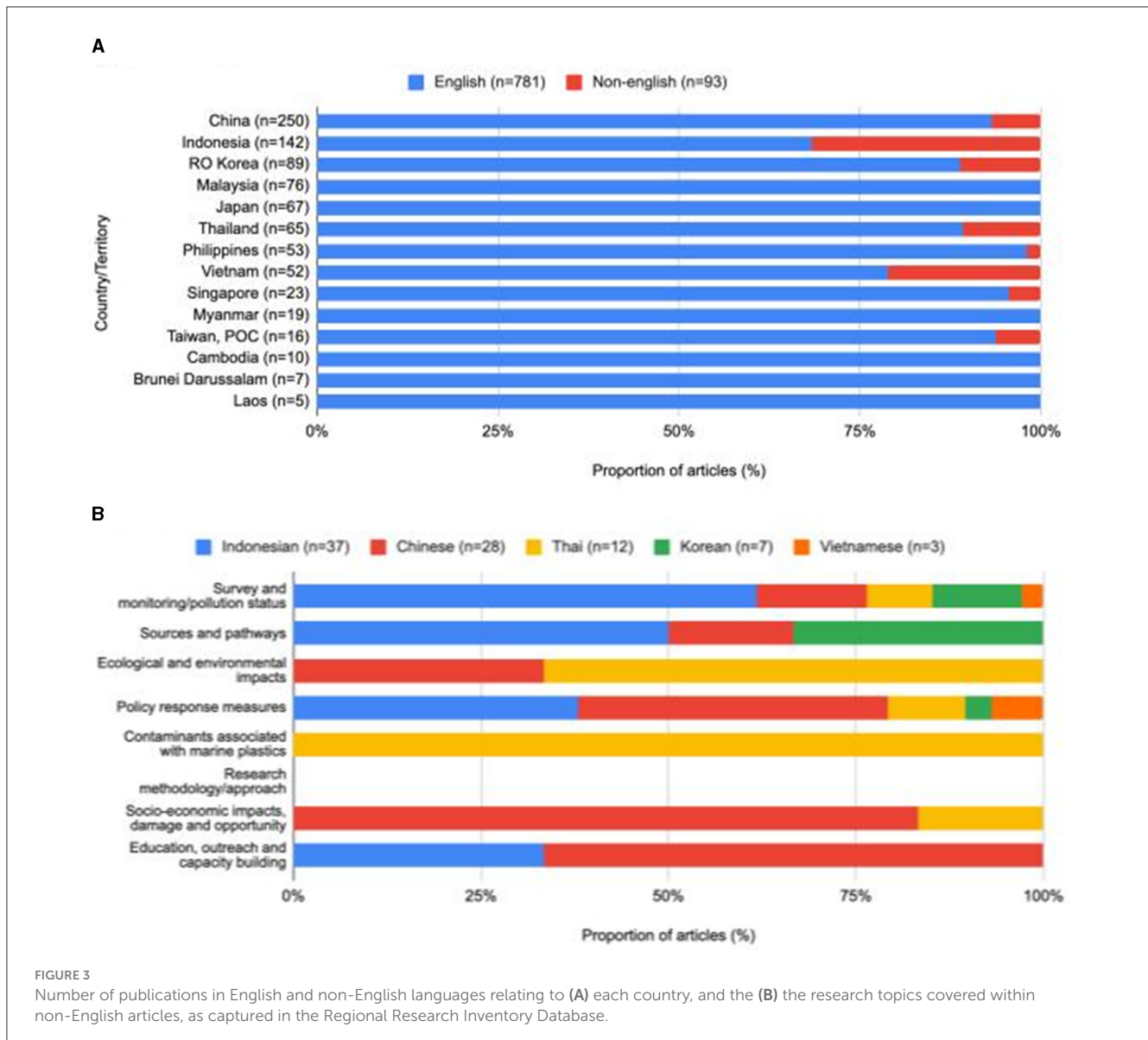
3.1 Evolution of research efforts over the years

The inventory captured articles largely published in 2018 (22.8%), 2019 (35.9%), and 2020 (39.1%; Figure 1). Research publications that were focused on surveying and monitoring of pollution status made up most of the articles from 2015 to 2021 (Figure 1). Research on ecological and environmental impacts have risen in recent years, from 2018 ($n = 15$) to 2019 ($n = 48$) and 2020 ($n = 57$; Figure 1). Research on sources and pathways of plastic pollution doubled from 2017 to 2018 ($n = 16$ to $n = 32$) and continued to increase after 2018 ($n = 35$ in 2019 and $n = 43$ in 2020, Figure 1). Research relating to policy response measures also rose from 2017 ($n = 3$) to 2020 ($n = 47$).

On the other hand, the number of research articles on contaminants associated with marine plastics fell from 2019 to 2020 ($n = 29$, $n = 14$, Figure 1). Similarly, publications on socio-economic impacts, damages, and opportunity, rose from 2018 to 2019, then fell again in 2020 ($n = 11$, $n = 25$, $n = 14$, Figure 1). The number of publications that focused on topics relating to education, outreach and capacity building relating to marine plastics, and topics relating to research methodology and approaches on marine plastics research remained consistent over the years (Figure 1).

3.2 Language of publications and their research topics

Publications in non-English languages accounted for 10.8% of the inventory ($n = 76$). Non-English publications made up 31.9% of publications relating to marine plastics in Indonesia, 21.1% of publications relating to Vietnam, 11.2% of publications relating to Republic of Korea, 10.8% of publications relating to Thailand, and 6.8% of publications on China (Figure 3A). The countries for which the inventory did not capture non-English

FIGURE 3
Number of publications in English and non-English languages relating to **(A)** each country, and the **(B)** the research topics covered within non-English articles, as captured in the Regional Research Inventory Database.

publications were Malaysia, Japan, Myanmar, Cambodia, Brunei, and Laos (Figure 3A).

Like the general observation across the entire RRID, the most frequently reported research topics were surveying and monitoring of marine plastic pollution status within the non-English publications (39.1%) with the majority published in Indonesian ($n = 21$). Policy response measures (33.3%) was the second most frequently captured research topic in non-English articles, with the majority published in Chinese ($n = 12$, Figure 3B). There were no non-English research publications captured relating to research methodology or approaches (Figure 3B).
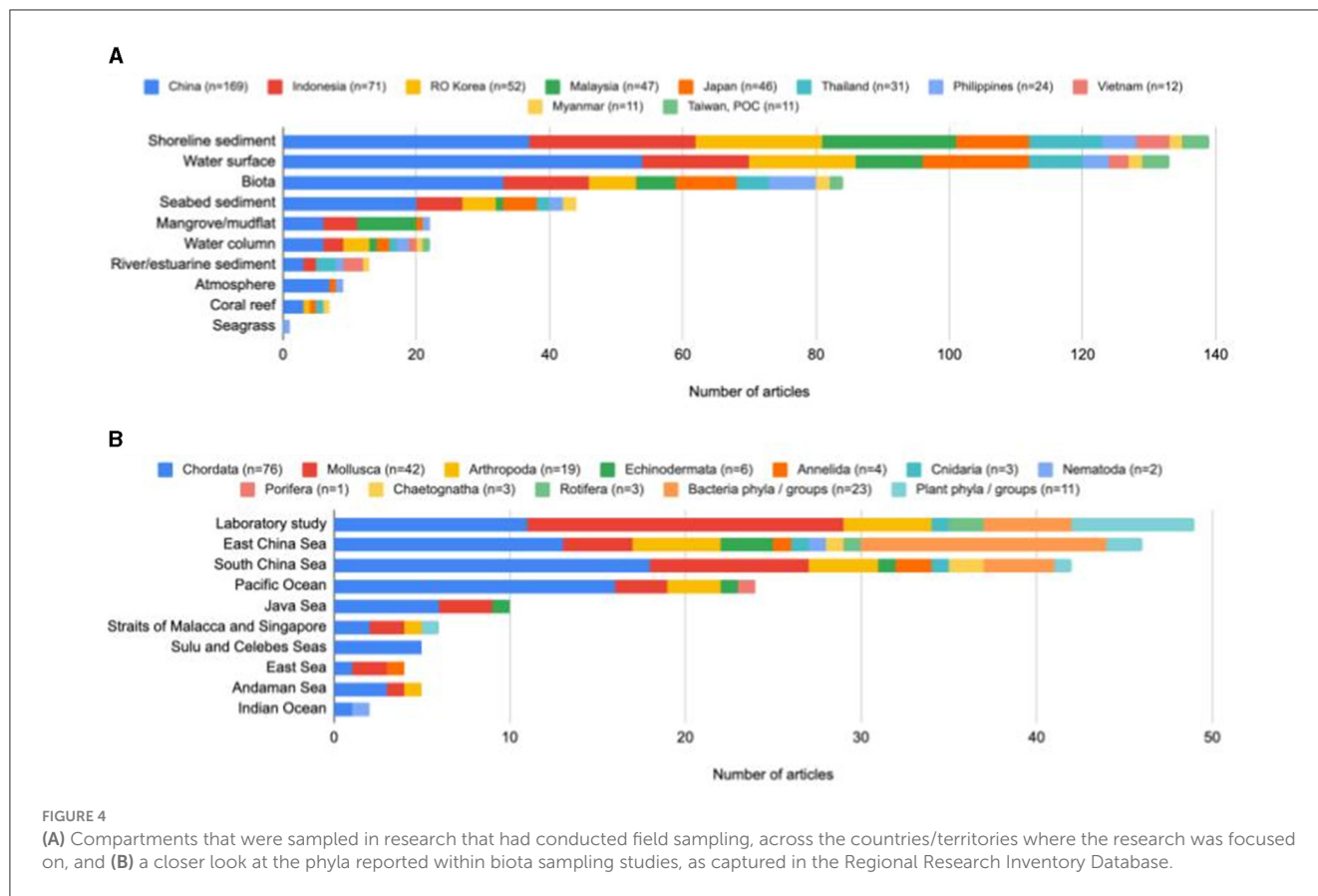
3.3 Field sampling

More than half of the publications captured in the RRID conducted field sampling (53.4%, $n = 374$). Field sampling was

conducted in a variety of compartments with the majority taking place on shoreline sediments (20.4% of the RRID, $n = 143$), such as the intertidal zone and beaches, except in China. In publications relating to China, water surface, shoreline sediment and biota were the most sampled compartments, demonstrating more diverse expertise in fieldwork research of marine plastic pollution (Figure 4A).

3.3.1 Marine life sampling

Biota sampling was conducted in 12.3% ($n = 86$) of the publications. This included marine life retrieved through field sampling, through opportunistic sampling of landings and purchased organisms (such as from markets). In most water bodies, sampling of the phylum Chordata, or bony fish, dominated, followed by phylum Mollusca, or mollusc, except in the Sulu and Celebes Seas and the Indian Ocean (Figure 4B). This may be influenced by the high reliance of the region on fishing and fisheries

(A) Compartments that were sampled in research that had conducted field sampling, across the countries/territories where the research was focused on, and (B) a closer look at the phyla reported within biota sampling studies, as captured in the Regional Research Inventory Database.

products, given that China and Southeast Asia are some of the largest producers in aquaculture and fisheries (Ottinger et al., 2016). As bony fishes and molluscs are commonly consumed, the concern of human exposure to plastic pollution through the consumption of these products are likely to influence the choice of organisms for marine biota sampling.

3.4 Plastic characterization

Within the RRID, 45.5% ($n = 319$) of all captured publications conducted plastic characterization, whether of color, shape, polymer, or a combination of the three. Color characterization was conducted in 25.8% ($n = 185$) with blue, black, and red being the most reported colors ($n = 145$, $n = 135$ and $n = 134$ respectively). Shape characterization was conducted in 39.4% ($n = 276$), with fragments, fibers and films being the most reported shapes ($n = 241$, $n = 229$ and $n = 172$ respectively).
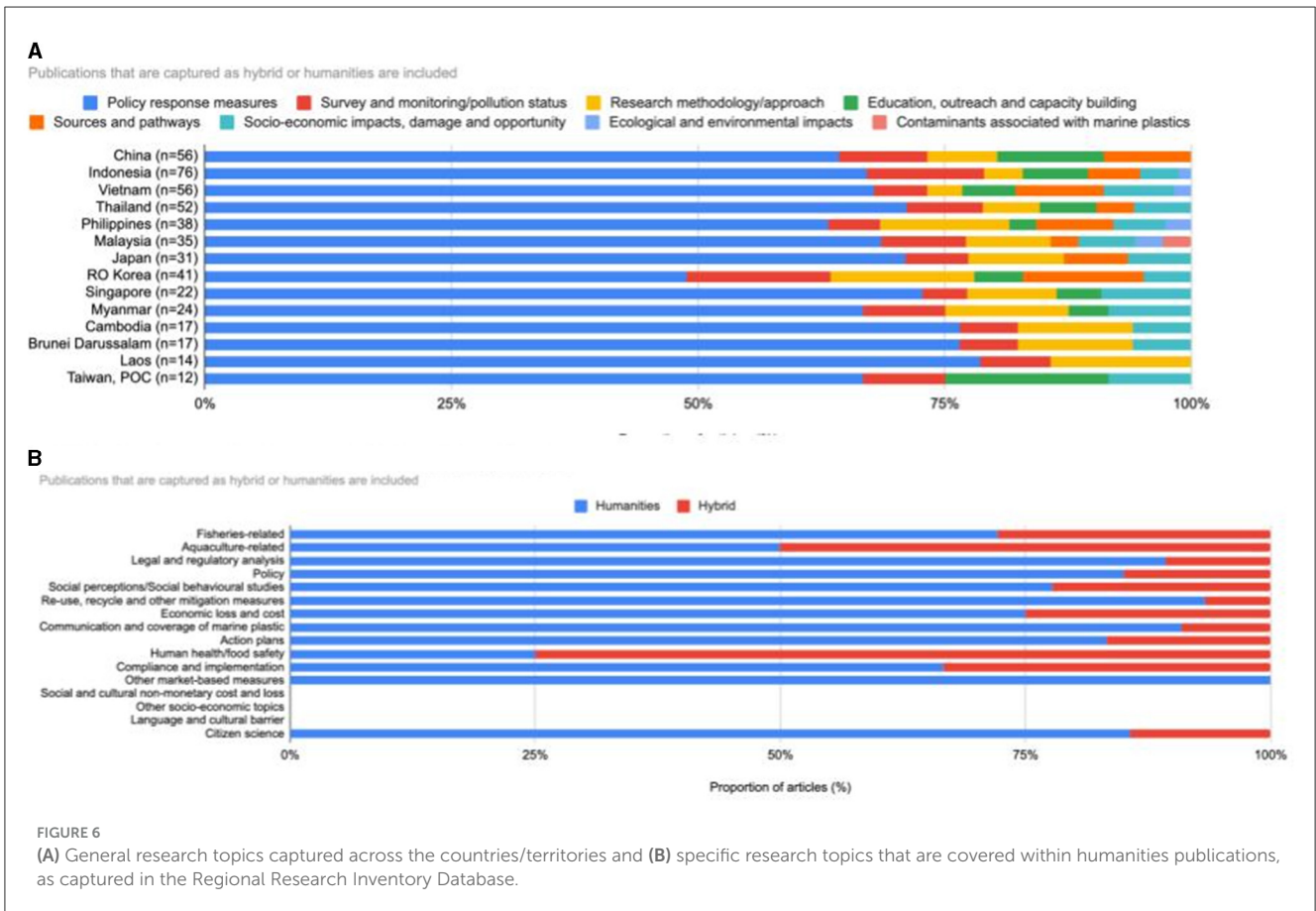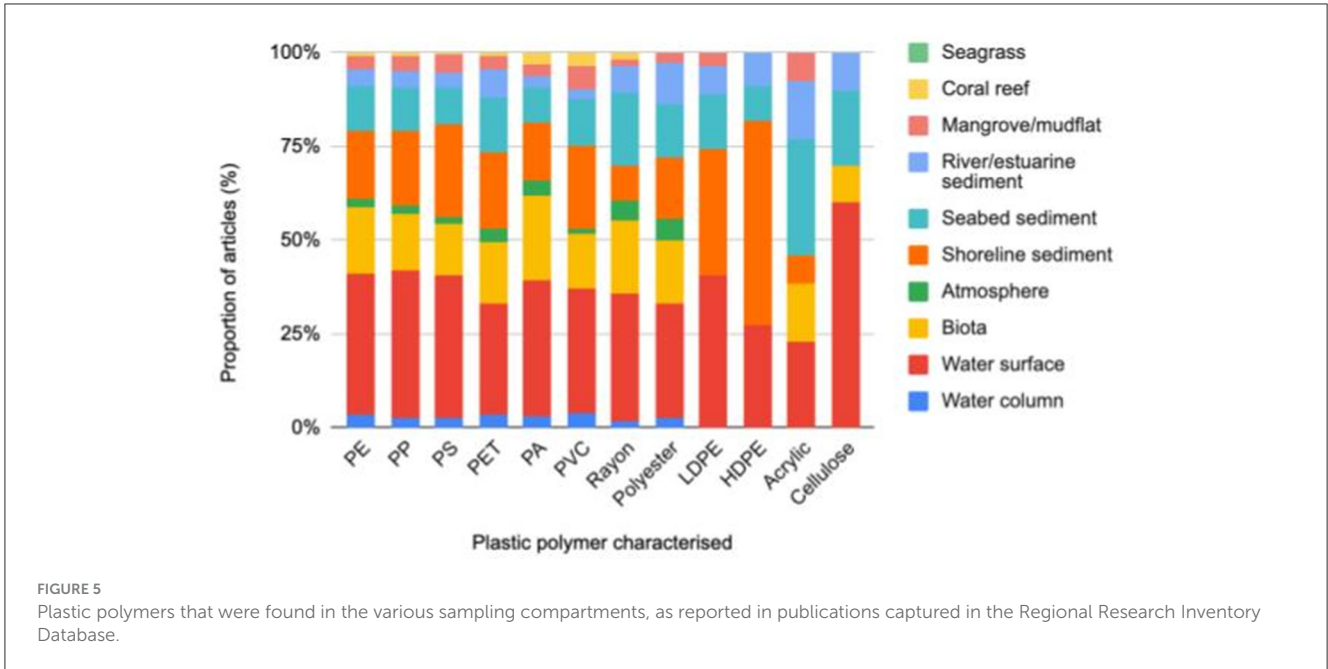
3.4.1 Polymer characterization

Polymer characterization was conducted in 35.1% ($n = 246$, Figure 5) of all captured publications. Among the polymers characterized, polyethylene (PE), a widely used polymer in commercial packaging, was reported in 98.4% of publications ($n = 242$ out of 246, Figure 5), and was the most commonly reported polymer. This was followed by Polypropylene which

was reported in 203 publications (PP, example uses: bottles and straws) and Polystyrene which was reported in 153 publications (PS, example use: commercial packaging; Figure 5). All mentioned polymers were found in most sampling compartments, particularly on water surfaces, but not in seagrass compartments (Figure 5).

3.5 Research in humanities

Humanities research made up 22.5% ($n = 156$ out of 701) of the RRID, including publications categorized as hybrid (relating to both natural sciences and humanities). Most of the humanities research topics found were focused on policy and response measures across the various countries/territories (Figure 6A).

Within the general research topic of policy and response measure, most publications were related to only two of the sub-topics: policy, and legal and regulatory analysis (Figure 6B). No publications were found in several humanities research topics: Social and cultural non-monetary costs and loss from marine plastic pollution, other socio-economic topics (such as specific impacts that were not captured in the metadata), and language and cultural barrier (Figure 6B), despite these having been recognized as barriers to change in waste management and generally effectiveness of response measures to pollution from marine plastics (Garcia-Vazquez et al., 2022).

FIGURE 5
Plastic polymers that were found in the various sampling compartments, as reported in publications captured in the Regional Research Inventory Database.

FIGURE 6
(A) General research topics captured across the countries/territories and **(B)** specific research topics that are covered within humanities publications, as captured in the Regional Research Inventory Database.

3.6 Information for policy making

Some policy-relevant information could be derived from considering findings from research publications in science or humanities or combining data extracted from both broad types of research. One of the most asked policy questions on pollution from marine plastics relates to the sources of the marine plastics, so that leakages into the marine environment could be adequately
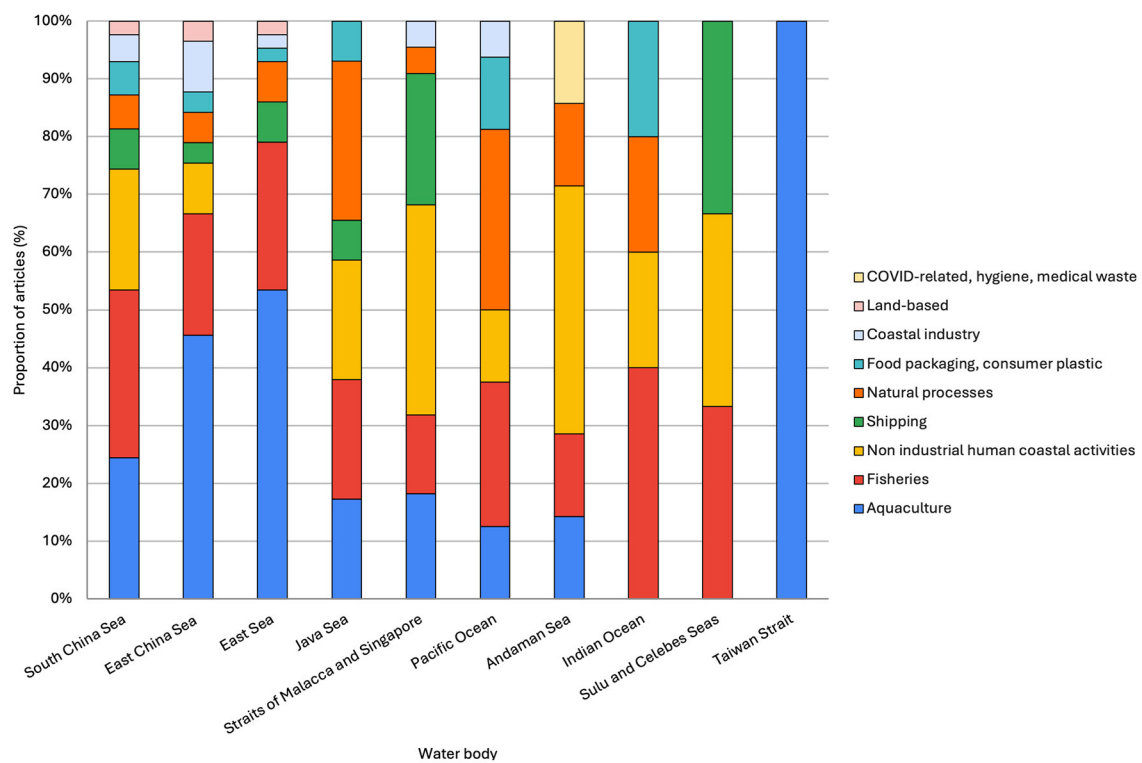
FIGURE 7
General categories of sources of marine plastics, as reported in publications captured in the Regional Research Inventory Database.

tackled and avoided. Although very few publications were focused on the identification of sources, many mention the sources of plastic debris they studied showing a dominance of studies on plastic from fisheries and aquaculture, though not in all water bodies (Figure 7). Non-industrial human coastal activities were another dominant source of plastic identified (Figure 7). This is consistent with commonly reported macro debris items being single-use plastics (SUPs), cigarette buds, clothing and appliances. SUPs are composed of bottles, bags, food packs, styrofoam, cups and straws. Sea-based sources came in second with fisheries material and ropes.

With respect to notable references, the GESAMP Guidelines for the Monitoring and Assessment of Plastic Litter in the Ocean (GESAMP, 2019) were generally recognized as the global reference. However, their usage was not homogeneous geographically, with far better penetration in China ($n = 172$), followed by Indonesia ($n = 34$) and Republic of Korea ($n = 20$) far behind.

3.7 Overall findings

Leveraging on the database, the findings from this study were guided based on six themes identified in Table 1. A summary of these findings can be found in Table 2, which described the region's responses to the issues on marine plastic pollution, as well as the current knowledge gaps and challenges that could be addressed in the near future. Key highlights from each theme are set out below.

For the research landscape and capacity, there has been an increasing interest in the issue of marine plastic pollution as the number of publications produced by the region is ever-increasing. However, there remains weak to no research efforts in topics of known importance for this region such as the discharge from offshore installations, marine plastic pathways for introduction of non-indigenous and potentially invasive species, and the environmental and ecological impacts on marine organisms.

For the recording of plastic presence or absence in the marine environment, there was a strong emphasis in sampling the shoreline sediment, water surface and biota for marine plastics, but much fewer studies focused on sensitive habitats including mangroves, coral reefs and seagrass beds; the water column and seabed sediment were also less surveyed. This skewed understanding makes it challenging to identify key areas for priorities with respect to developing policy actions (e.g., known critical coastal habitats may receive less attention because of paucity of knowledge).

For the sources and pathways, the current level of understanding was considered poor due to the low proportion of articles available in the RRID. Despite the fewer resources, aquaculture, fisheries and non-industrial human coastal activities were often reported as potential sources of marine plastics, especially in the South China Sea, East China Sea, and East Sea. The lack of information on source differentiation could pose challenges for developing priorities and adequately targeted regulatory responses (e.g., directed to relevant contributing

TABLE 2 Summary of findings and analysis of publications captured in the Regional Research Inventory Database (RRID).

Type of query	Response	Gaps	Challenges
(1) Research landscape and capacity	■ Variation in research intensity across countries with China far dominating (35.6%) ■ Number of research publications has been increasing ■ 58.9% of publications focus on survey and monitoring of marine plastics ■ 10% of publications in non-English language ■ Three times more scientific than humanities research ■ Microplastics are most studied (77.0%), with macro-plastics being a far second (43.8%)	■ No publications found in several topics including port reception facilities, fiberglass-reinforced plastic vessels, marine plastics as pathways for introduction of alien/non-native/invasive species, non-monetary cost and loss and language and cultural barrier ■ Weak research effort found in topics of known importance to the region including discharge from offshore installations, several aspects of environmental and ecological impacts such as branchial uptake, microbial assemblages, and trophic transfer	■ Some research topics appear to be of limited interest to funders, such as entanglement of megafauna
(2) Recording of plastic presence or absence in the marine environment	■ Sampling most frequently conducted in shoreline sediment, water surface and biota (19.7%, 18.5%, and 12.3%) ■ PE, PP and PS were most frequently reported polymers sampled (30.5%, 24.8%, and 20.4%) ■ Bottles, fishing gear items and plastic bags were most frequently reported macro litter items ■ Sampling in biota dominated by Chordata phylum (bony fish)	■ Very few samplings of sensitive habitats such as seagrass, coral reef and mangroves ■ Plastic characterization mostly focuses on shape, color, and polymer, with little analysis done with shape and color	■ Lack of data integration between and within certain compartments, such as biota
(3) Sources and pathways	■ Aquaculture, fisheries, and non-industrial human coastal activities are frequently reported as likely sources of plastics, especially in the South China Sea, East China Sea, and East Sea ■ Other sources are not, and potential sources are often cited together, without differentiation	■ Publications on sources and pathways make up a low proportion of the RRID ■ General lack of differentiation of sources ■ Lack of data on transboundary transport of marine plastics, fragmentation, and degradation of different polymers once in the marine environment	■ Source differentiation requires particular research focus
(4) Impacts	■ Research on impact is more focus on human health as shown by the focus on fisheries and aquaculture species ■ Research on the ingestion of plastics in the wild is the most common ecological and environmental impact studied (15.1%, $n = 106$) ■ Overall, laboratory studies show early stage of research on impacts ■ Some publications on economic loss and cost of marine plastics and debris on tourism and clean-up of public spaces	■ No common understanding of marine plastics hotspots and their impact on the surrounding environment ■ Lack of research on branchial uptake of plastic in the wild, entanglement by plastic in the wild, microbial assemblages, trophic transfer of plastic, impacts on endangered species, and non-monetary social and cultural costs	■ Research on impacts require different equipment, instruments, and facilities than surveying and identification that have been the first research focus
(5) Policy and response measures	■ Adoption of GESAMP plastic sizes in studies on China but not commonly referred to in other countries/territories, though the categorization adopted can be generally consistent ■ Adoption of national action plans for marine plastics	■ Lack of reporting of implementation status ■ Limited social perception and behavior studies ■ Specific scientific findings (such as those in the 4 prior themes) are rarely addressed. Conversely, data from scientific research publications is generally context specific and requires further analysis and consideration with other papers to derive policy-ready data	■ Divide between science and holistic policy approach of governments (natural sciences, social sciences, economics, and law) is a barrier to overcome
(6) Education, training, and outreach	■ Lowest number of publications of all main research topics ■ Some publications conducted social surveys to assess "awareness, attitude and behavior" on marine plastics issues (e.g., for plastic usage, waste management and recycling) ■ Citizen science used primarily to conduct sampling surveys as a means for education and outreach while collecting data	■ Lack of research on language and cultural barriers is particularly important to remedy ■ Majority of studies focus on households and individuals in society at local scale, with a lack of research on education, training, and outreach to commercial sector	■ The lack of research papers may be explained by the fact that, generally, the topic lends itself less to studies by academic disciplines

sectors of activity) to reduce flow of marine plastics into the oceans.

For impacts, much of the research reported in the RRID focused on reporting the ecological impacts in areas of fisheries and aquaculture species, with a strong emphasis on human health. However, the most commonly examined impact is the ingestion of plastics by wild biota, with large knowledge gaps in other aspects including entanglement by plastics, microbial assemblages,

trophic transfers of microplastics, impacts on endangered species, and non-monetary social and cultural costs. On the other hand, to cater for this variety of research areas will require different equipment, instruments and facilities, which can be a challenge for regional researchers.

For policy and response measures, the adoption of guidelines such as GESAMP plastic sizes was uncommon in studies, with exception of those studies from China. There were other knowledge

gaps such as lack of reporting of implementation status, and very limited research in social and economics, including social perceptions and behavior studies. There is a clear gap in research that would take a holistic policy approach and encompass natural and social sciences to develop policy-relevant recommendations on responses to pollution from marine plastics.

For education, training, and outreach, these topics appeared to have the fewest number of publications, suggesting a poor understanding of these issues. Most of the studies reviewed focused on the awareness, attitude and behavior of households and individuals at local scales, while lacking in larger commercial sectors.

From a geographic perspective, the proportion of research efforts (in number of publications) in different research areas was interestingly comparable across countries and water basins, with some notable features. First, two areas of research are notably discrepant from this general comparability: research on sources and pathways, and research on socio-economic impact, damages and opportunity. Given the close link with policy making, this may reflect different countries' political and cultural approach to marine plastic pollution. Second, some research areas are absent from publications in countries where research on pollution from marine plastics is less advanced; these are in particular research on contaminants associated with marine plastics and on education, outreach and capacity building that may appear at a certain stage of maturity of research in pollution from marine plastics.

The spread of research in different water basins is also generally comparable, with the South China Sea being the most researched. Despite its regional importance, including due to its exceptional marine biodiversity, the Sulu Celebes Sea appears largely understudied.

4 Discussion

The discussion focuses on the 'so what' of this research database. It distinguishes a range of immediate benefits from an even larger range of potential benefits that would require additional research using the findings to frame hypotheses and research questions.

4.1 Immediate benefits

4.1.1 Time-sensitive access to unbiased data for all stakeholders

The inventory can provide a platform to quickly investigate research that has been conducted on the Southeast and East Asian seas. The convenient availability of literature and data gathered in the RRI helps to augment traditional systematic literature reviews and supplement research analysis, as evidenced by peer-reviewed publications that have utilized the RRID (Harris et al., 2021; Omeyer et al., 2022). The adequate representation of the multi-country research in the RRID benefited from involving scientists at the local level, whereas the existing inventories were spearheaded by groups with limited diversity. This inventory was developed by a consortium of researchers from academic institutions and/or organization, reduced biases, and added a certain level of rigor as it was done by a team of regional researchers with technical expertise.

4.1.2 Identification of gaps, capacity needs and response to grants

This section builds on presentation of the findings in section 3.7 to discuss possible uses. The identification of gaps in research areas (e.g. surveys in sensitive and regionally critical habitats such as mangrove, coral reefs and seagrass beds and research on environmental and ecological impacts) is useful information for policymakers who are able to stimulate more research in these areas. Another gap in research, research in survey and monitoring of pollution status, and sources and pathways of marine plastics in the region has been identified as s a major topic of interest for the region (Omeyer et al., 2022). There also appears to be an increase in studies as a response to the calls for research regarding the ecological impacts of marine plastic pollution on marine biodiversity (Willoughby et al., 1997; Harrison et al., 2011; Nelms et al., 2016). However, the gaps in knowledge in topics relating to issues associated with hazardous chemicals and substances of concern found in plastics required more attention and studies (Akenji et al., 2020). Informed decision-making and sound priority settings would require data on the current situation in each country, including contaminants relating to plastics. Health and environmental hazards associated with plastics and additives (e.g., colorants, plasticizers, etc.) need to be clarified (Akenji et al., 2020).

4.1.3 Visibility of and access to non-English language publications and local expertise

It has been frequently identified that marine debris studies were often conducted at a local or regional scale and are not always published in peer-reviewed journals (Browne et al., 2015). The lack of multi-language literature reviews have also been flagged as limitations in multiple research studies, acknowledging the possibility of a gap in literature discovery, especially those conducted in the highly diverse ASEAN+3 region (Luo et al., 2021). The proportion of Chinese, Indonesian, Korean, and Vietnamese literature captured in the inventory showed the importance of consulting regional language papers which are rarely included in global inventories.

4.2 Potential benefits

4.2.1 Data integration for comparing marine plastic concentration and distribution

Although many publications (47.4%, $n = 332$) provided a measure of volume and/or abundance of marine plastics found in their samples, the units varied greatly. For example, the units of measurements for abundance of marine plastics found in water samples captured in the RRID included items per liter, particles per meter square, count per meter cube, pieces per kilometer square. Although some of these values could be converted with a view of comparing the results, such an approach might be scientifically inaccurate or bring with it unacceptable levels of unreliability due to the differences in surveying procedures employed to collect and analyse samples of (macro- and micro-) plastics, some of which were also dictated by the differences in marine compartments. This points to the importance of harmonization or consistency on plastic

waste surveying and monitoring methods for the integration of research findings to be possible. In addition, standardized protocols can aid in enhancing the comprehension of plastic pollution trends by enabling data comparison across diverse regions and time intervals. However, a full protocol standardization can encounter a diversity of barriers. These may relate to particularities of the marine ecosystems concerned (e.g., inaccessibility at different times of the year), to technical issues or to capacity limitations, thereby rendering such standardized protocols unusable.

The RRID can therefore provide a basis for a research effort focused on overcoming this difficulty in envisaging regionally adapted research protocols that can be used in support of policy-making (e.g., to set regional indicators of marine plastic pollution that can be used to track progress).

More generally, collaboration among stakeholders and researchers may assist in identifying research gaps for tackling targeted solutions to diminish the adverse effects of plastic waste on marine ecosystems. This approach ensures an academic strategy toward effective management correlated with ecological sustainability practices. Such integration could provide the baselines and monitoring assessments needed by policymakers to test the effectiveness of policy that have been adopted. Moreover, some research used visual observation to quantify microplastic particles, whereas others analyzed a subset of particles to determine their chemical composition (polymer) form. All of these factors impact the underestimating or overestimating (macro- and micro-) plastics and the comparability of various datasets.

4.2.2 User-friendly features of the RRID

The RRID was developed with features to make the information more accessible and understandable. For instance, the category labels of the columns were clearly defined using layman terminology, the descriptors avoided technical language, and the choice of using a Microsoft Excel spreadsheet catered to the wider masses of users (e.g., data columns could be easily filtered and sorted). In addition, the data platform for visualization has built in easy-to-use filters to help users analyse the data efficiently. Another advantage of the RRID is the ease of examining and accessing specialized data to answer policy questions such as the understanding (and gaps) on microplastics in the marine environment in ASEAN+3. Other factsheets can be created on many topics such as plastic particles found throughout the region in different compartments, the extent of knowledge and research needed on the plastisphere, or which biota is the most sampled for marine plastics and could be envisaged as regional reference indicator of plastic pollution in different parts of the marine environment.

4.2.3 Development and organization of a regional research community through the updating and revision of the database

The highly collaborative nature of the development of the RRID naturally created a multidisciplinary network that also involved in the continuous update of the database, thereby creating an on-going activity to continue nourishing the network and thereby further supporting its development. Inputs for updates will require the same technical expertise as that that was needed for the establishment of the RRID. The updating process involves the identification of the full text of the publication, whether in English or other languages, the vetting of the publication content to ensure suitability for inclusion and then extraction of information in the 82 fields, according to the metadata. Regional contributors must come from the different countries/territories studied to be able to better understand the context of the research and support a more accurate data transcription as well as access and import in the database research content in local languages. Furthermore, many of these publications can only be accessed through expensive subscriptions, making them mostly accessible through university libraries.

4.3 Limitations

Just as any research inventories and databases, some limitations in data use flow from the choices made in the design, including the framing of the metadata and therefore, data captured. For example, specific information that is outside of the metadata scope has not been extracted into the RRID such that their examination could not rely solely on the database and would require a review of the source publications. For example, the reported effects of plastics on marine biodiversity were captured in the RRID as part of input fields relating to the research scope and findings. Investigations on biodiversity impacts may require additional steps in the analysis or consultation of the source articles. To be accurate and reliable, interpretation of the data captured may also require context and detailed methodology verification in the source articles.

In addition, not every important question on pollution from marine plastics have yet been asked through research and or included in a publication. The limited availability of complete metadata may impede the replicability of research trials and consequently obstruct advancements in science. Hence, there is an imperative need to constantly enhance the formulation of metadata frameworks that conform to standardized guidelines, ensuring all pertinent information is comprehensively documented. This includes questions that research is expected to catch-up on soon such as those relating to the implementation strategies and effectiveness of specific policy response measures like single-use plastic bans.

Given the on-going and evolving nature of the plastic crisis, the scientific understanding of impacts (Hong et al., 2013; Thiel et al., 2018; Beaumont et al., 2019) and the response law and policies adopted and envisaged at international, regional and local levels (Lyons et al., 2020; Fadeeva and Van Berkel, 2021; Xuan Son, 2021), the database must integrate this evolution to remain always current and useful. Longevity is also necessary for monitoring purposes. This requires on-going financial support. The current version of the RRID contains data published until 2020 and an update is therefore needed. Fortunately, a focus on keeping operational costs as low as possible has been part of the design. RRID utilizes open-access libraries (React.js and Material UI) and software, such as Google sheets. The website codebase is readily available publicly on Github.

5 Conclusion

A key feature of the ASEAN+3 RRID on marine plastic pollution is the specific use of peer-reviewed research data curated by a multidisciplinary regional team of researchers, which aims to provide information that can support and inform policy making by government and regional policy making bodies, as well as inform research community and funders. The four key design features of the RRID includes (1) its comprehensive scope covering topics of natural sciences and humanities relevant to marine plastic pollution; (2) the high level of data granularity available in the database (such as methodology, equipment, and findings); (3) the engagement of regional experts on this topic as contributors to ensure accuracy and representation (e.g., adding materials in native languages); and (4) the co-development of a data platform for visualizing data appropriate for a non-scientific audience, especially policy-makers. This approach of developing a regional-level database is particularly useful for regions with large marine areas, such as ASEAN+3, which includes numerous developing states with no regional scientific research institution or repository to fulfill knowledge gaps (e.g., International Council for the Exploration of the Sea in Europe). This approach of curating research data is not only replicable and verifiable, it provides accessibility to regional research, which may not always be globally accessible through international research networks. Furthermore, the involvement of >30 academic contributors from the region provided a bridge between research and policy making, and an opportunity to identify research and capacity building needs for ASEAN+3. In addition to informing regional policy developments, this research database can also support better representation of regional research findings in global reports and policy developments on pollution related to marine plastics.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found in the article/supplementary material.

Author contributions

CL: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Visualization, Writing – original draft, Writing – review & editing. YLy: Conceptualization, Funding acquisition, Investigation, Project administration, Resources, Supervision, Visualization, Writing – original draft, Writing – review & editing. YLi: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Supervision, Writing – original draft, Writing – review & editing. MN: Data curation, Investigation, Methodology, Writing – review & editing. MM: Data curation, Investigation, Methodology, Writing – review & editing. CW: Data curation, Investigation, Methodology, Writing – review & editing. MC: Data curation, Investigation, Methodology, Writing – review & editing. SS: Data curation, Investigation, Methodology, Writing – review & editing. NA: Data curation, Investigation, Methodology, Writing – review & editing. TK: Data curation, Investigation, Methodology, Writing – review & editing. DO: Data curation, Investigation, Methodology, Writing – review & editing. RB: Data curation, Investigation, Methodology, Writing – review & editing. CC: Data curation, Investigation, Methodology, Writing – review & editing. JL: Data curation, Investigation, Methodology, Writing – review & editing. HL: Data curation, Investigation, Methodology, Writing – review & editing. DL: Data curation, Investigation, Methodology, Writing – review & editing. LZ: Data curation, Investigation, Methodology, Writing – review & editing.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

Akenji, L., Bengtsson, M., Hotta, Y., Kato, M., and Hengesbaugh, M. (2020). "Chapter 21 - Policy responses to plastic pollution in Asia: summary of a regional gap analysis1," in *Plastic Waste and Recycling*, ed. T. M. Letcher (New York, NY: Academic Press), 531–567. doi: 10.1016/B978-0-12-817880-5.00021-9

Beaumont, N. J., Aanesen, M., Austen, M. C., Börger, T., Clark, J. R., Cole, M., et al. (2019). Global ecological, social and economic impacts of marine plastic. *Mar. Pollut. Bull.* 142, 189–195. doi: 10.1016/j.marpolbul.2019.03.022

Browne, M. A., Chapman, M. G., Thompson, R. C., Amaral Zettler, L. A., Jambeck, J., Mallos, N. J., et al. (2015). Spatial and temporal patterns of stranded intertidal marine debris: is there a picture of global change? *Environ. Sci. Technol.* 49, 7082–7094. doi: 10.1021/es5060572

China General Office of the State Council (2017). 国务院办公厅关于印发禁止洋垃圾入境推进固体废物进口管理制度改革实施方案的通知国办发(2017)70号(*Author's Translation: Notice of the General Office of the State Council on Issuance of Reform and Implementation Plan to Enhance Solid Waste Import Management System by Prohibiting the Entry of Foreign Waste, Guo Ban Fa [2017] No. 70)*. Available at: http://www.gov.cn/zhengce/content/2017-07/27/content_5213738.htm (accessed June 25, 2024) in Chinese.

Fadeeva, Z., and Van Berkel, R. (2021). Unlocking circular economy for prevention of marine plastic pollution: an exploration of G20 policy and initiatives. *J. Environ. Manag.* 277:111457. doi: 10.1016/j.jenvman.2020.111457

Galloway, T. S., Cole, M., and Lewis, C. (2017). Interactions of microplastic debris throughout the marine ecosystem. *Nat. Ecol. Evol.* 1, 1–8. doi: 10.1038/s41559-017-0116

Garcia-Vazquez, E., Garcia-Ael, C., Mesa, M. L. C., Dopico, E., and Rodriguez, N. (2022). Enhancing marine citizenship as a strategy to promote the reduction of single-use plastics consumption in different cultures. *Front. Mar. Sci.* 9:941694. doi: 10.3389/fmars.2022.941694

GESAMP (2019). *Guidelines for the Monitoring and Assessment of Plastic Litter in the Ocean*. Available at: http://www.gesamp.org/publications/guidelines-for-the-monitoring-and-assessment-of-plastic-litter-in-the-ocean (accessed April 26, 2023).

Greenpeace (2019). *Southeast Asia's struggle against the plastic waste trade. A policy brief for ASEAN member states*. Available at: https://www.greenpeace.org/southeastasia/publication/2559/southeast-asias-struggle-against-the-plastic-waste-trade/ (accessed June 25, 2024).

Harris, P., Tamelander, J., Lyons, Y., Neo, M. L., and Maes, T. (2021). Taking a mass-balance approach to assess marine plastics in the South China Sea. *Mar. Pollut. Bull.* 171:112708. doi: 10.1016/j.marpolbul.2021.112708

Harrison, J. P., Sapp, M., Schratzberger, M., and Osborn, A. M. (2011). Interactions between microorganisms and marine microplastics: a call for research. *Mar. Technol. Soc. J.* 45, 12–20. doi: 10.4031/MTSJ.45.2.2

Hong, G. H., Kim, C. J., Yeemin, T., Siringan, F. P., Zhang, J., Lee, H. M., et al. (2013). Potential release of PCBs from plastic scientific gear to fringing coral reef sediments in the Gulf of Thailand. *Deep Sea Res. Part II: Top. Stud. Oceanogr.* 96, 41–49. doi: 10.1016/j.dsr2.2013.02.012

Hughes, A. C. (2017). Understanding the drivers of Southeast Asian biodiversity loss. *Ecosphere* 8:e01624. doi: 10.1002/ecs2.1624

Iskandar, M. R., Cordova, M. R., and Park, Y. G. (2022). Pathways and destinations of floating marine plastic debris from 10 major rivers in Java and Bali, Indonesia: A Lagrangian particle tracking perspective. *Mar. Pollut. Bull.* 185:114331. doi: 10.1016/j.marpolbul.2022.114331

Iskandar, M. R., Surinati, D., Cordova, M. R., and Siong, K. (2021). Pathways of floating marine debris in Jakarta Bay, Indonesia. *Mar. Pollut. Bull.* 169:112511. doi: 10.1016/j.marpolbul.2021.112511

Jambeck, J. R., Geyer, R., Wilcox, C., Siegler, T. R., Perryman, M., Andrady, A., et al. (2015). Marine pollution. Plastic waste inputs from land into the ocean. *Science* 347, 768–771. doi: 10.1126/science.1260352

Kirkpatrick, A., and Liddicoat, A. J. (2017). Language education policy and practice in East and Southeast Asia. *Lang. Teach.* 50, 155–188. doi: 10.1017/S0261444817000027

Knoblauch, D., and Mederake, L. (2021). Government policies combatting plastic pollution. *Curr. Opin. Toxicol.* 28, 87–96. doi: 10.1016/j.cotox.2021.10.003

Lebreton, L. C. M., van der Zwet, J., Damsteeg, J.-W., Slat, B., Andrady, A., Reisser, J., et al. (2017). River plastic emissions to the world's oceans. *Nat. Commun.* 8:15611. doi: 10.1038/ncomms15611

Luo, Y. Y., Not, C., and Cannicci, S. (2021). Mangroves as unique but understudied traps for anthropogenic marine debris: a review of present information and the way forward. *Environ. Pollut.* 271:116291. doi: 10.1016/j.envpol.2020.116291

Lyons, Y., Vu, H. D., Neo, M. L., Lim, A., and Tay, Y. L. (2020). Status of Research, Legal and Policy Efforts on Marine Plastics in ASEAN+3: A Gap Analysis at the Interface of Science. *Law Policy*. Available at: https://www.unep.org/cobsea/resources/reports/status-research-legal-and-policy-efforts-marine-plastics-asean3

Maes, T., Perry, J., Alliji, K., Clarke, C., and Birchenough, S. N. R. (2019). Shades of grey: marine litter research developments in Europe. *Mar. Pollut. Bull.* 146, 274–281. doi: 10.1016/j.marpolbul.2019.06.019

Meijer, L. J. J., van Emmerik, T., van der Ent, R., Schmidt, C., and Lebreton, L. (2021). More than 1000 rivers account for 80% of global riverine plastic emissions into the ocean. *Sci. Adv.* 7:eaaz5803. doi: 10.1126/sciadv.aaz5803

Nelms, S. E., Duncan, E. M., Broderick, A. C., Galloway, T. S., Godfrey, M. H., Hamann, M., et al. (2016). Plastic and marine turtles: a review and call for research. *ICES J. Mar. Sci.* 73, 165–181. doi: 10.1093/icesjms/fsv165

Omeyer, L. C. M., Duncan, E. M., Aiemsomboon, K., Beaumont, N., Bureekul, S., Cao, B., et al. (2022). Priorities to inform research on marine plastic pollution in Southeast Asia. *Sci. Total Environ.* 841:156704. doi: 10.1016/j.scitotenv.2022.156704

Ottinger, M., Clauss, K., and Kuenzer, C. (2016). Aquaculture: relevance, distribution, impacts and spatial assessments – a review. *Ocean Coast. Manag.* 119, 244–266. doi: 10.1016/j.ocecoaman.2015.10.015

Peter, C., Mustika, P. L. K., Acebes, J. M. V., Chansue, N., Dolar, L., Ham, G. S., et al. (2022). Commentary on Coram et al. (2021) on the use of Facebook to understand marine mammal stranding issues in Southeast Asia. *Biodivers. Conserv.* 31, 1987–1994. doi: 10.1007/s10531-022-02401-0

Sebille, E. van, Aliani, S., Law, K. L., Maximenko, N., Alsina, J. M., Bagaev, A., et al. (2020). The physical oceanography of the transport of floating marine debris. *Environ. Res. Lett.* 15:023003. doi: 10.1088/1748-9326/ab6d7d

Thiel, M., Luna-Jorquera, G., Álvarez-Varas, R., Gallardo, C., Hinojosa, I. A., Luna, N., et al. (2018). Impacts of marine plastic pollution from continental coasts to subtropical gyres—fish, seabirds, and other vertebrates in the SE pacific. *Front. Mar. Sci.* 5:238. doi: 10.3389/fmars.2018.00238

Willoughby, N. G., Sangkoyo, H., and Lakaseru, B. O. (1997). Beach litter: an increasing and changing problem for Indonesia. *Mar. Pollut. Bull.* 34, 469–478. doi: 10.1016/S0025-326X(96)00141-5

Wright, S. L., Thompson, R. C., and Galloway, T. S. (2013). The physical impacts of microplastics on marine organisms: a review. *Environ. Pollut.* 178, 483–492. doi: 10.1016/j.envpol.2013.02.031

Xuan Son, N. T. (2021). Policy on marine plastic waste in Asean and Viet Nam. *Environ. Claims J.* 33, 41–53. doi: 10.1080/10406026.2020.1775347