CITIZEN SCIENCE:
THEORY AND PRACTICE

Exploring how citizen science projects measuring beach plastic debris can support UN Sustainable Development Goals

COLLECTION:
CONTRIBUTIONS OF CITIZEN SCIENCE TO THE UN SDGS

RESEARCH PAPER

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ABSTRACT

Plastic debris within marine environments is an issue of global concern, leading to commitments at international, regional, and national scales to remove plastics from the environment and prevent further entry. The United Nations (UN) created a global framework of 17 Sustainable Development Goals (SDGs), with several goals to advance the environmental dimension of sustainable development, with global and country progress tracked by targets and their indicators. Countries voluntarily report their progress on the basis of guidance provided by the UN on what data is needed. SDG 14, Life Below Water, contains one target to significantly reduce marine pollution, with specific mention of plastic debris. To date, however, national information on plastic debris has been sparse, although citizen science projects have been collecting data at a spatial and temporal coverage relevant to SDG reporting. This paper provides an overview to clarify the data requirements for reporting on the SDG indicator of plastic debris density and the complex process in which data for SDGs is requested from and provided by countries. We then explore the potential for citizen science to assist countries in filling evidence gaps, through providing data on plastic pollution. We focus on the sub-indicator for beach debris, which accounts for most citizen science projects collecting data on plastic pollution. Then, we unpack the opportunities and challenges of augmenting SDG reporting with information gathered from citizen science communities. Lastly, we recommend ways for citizen science communities and governments to synergize efforts monitoring plastics to inform pathways for preventing and reducing such pollution ending up in our marine environments.

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INTRODUCTION

Marine environments are increasingly contaminated by plastics, which pose risks to human and environmental health (Agamuthu et al. 2019). The widespread use of the material, inadequate and unsafe disposal, and its dispersion and ability to persist within the environment have continued to worsen the extent of plastic pollution (Edelson et al. 2021). Growing concern has prompted countries to reduce and remove plastic from the environment (Agamuthu et al. 2019). Interventions include bans on single-use plastics, container deposit schemes, and investment in waste management. Further, a recognition of the transboundary nature of plastic pollution led to international and regional efforts to coordinate responses to the challenge (Diana et al. 2022).

A prominent international framework to address marine pollution is the 2030 Agenda for Sustainable Development, which contains Sustainable Development Goals (SDGs) adopted by United Nations (UN) Member States in 2015 (UN General Assembly 2015). The SDGs provide a framework for countries to work and collaborate towards long-term peace and prosperity for people and the environment, through 17 goals and 169 targets, with progress tracked by a dynamic global indicator framework that currently contains 232 unique indicators (Figure 1). Marine pollution, and specifically plastic pollution, was flagged as an issue of global concern, where SDG 14 aims to "conserve and sustainably use the oceans, seas and marine resources for sustainable development" (UN DESA 2022). SDG Target 14.1 specifically aims to "prevent and significantly reduce marine debris ..." from land-based activities, with the reduction of marine debris tracked by an indicator (SDG Indicator 14.1.1b) that measures the "plastic debris density" in the marine environment (UNEP 2021c). These indicators provide an understanding of a country's progress towards reducing marine plastic pollution and identify if management efforts have been effective (UNEP 2021a).

The SDGs, targets, and indicators provide a means to organise actions addressing marine pollution across government, research institutes, the private sector, and society (Sachs 2012). The process to report data and the data needed, however, is complex as the UN agencies responsible for each SDG target differs, and guidance for the compilation of indicators has only recently been established (UNEP 2021c). While much attention has been given to aligning with SDG goals (Sachs et al. 2019), there is a need to raise awareness of how organisations, groups, and individuals could drive an understanding of environmental challenges through engaging with the SDG reporting process.

In general, government data on plastic pollution at the national scale, where most databases are maintained by a diverse range of non-government stakeholders, including organisations, businesses, and individuals, is limited. Groups around the world volunteer time, labour, and resources to clean up marine debris, including plastic, from habitats along the coastline. Some of these groups take additional action as part of a citizen science community, sorting and counting the recovered items, to collect data on abundance and composition (Nelms et al. 2017; Gacutan et al. 2022b).

There are many definitions of citizen science. Broadly speaking, citizen science is public participation in any aspect of scientific inquiry to increase collective knowledge (Shirk et

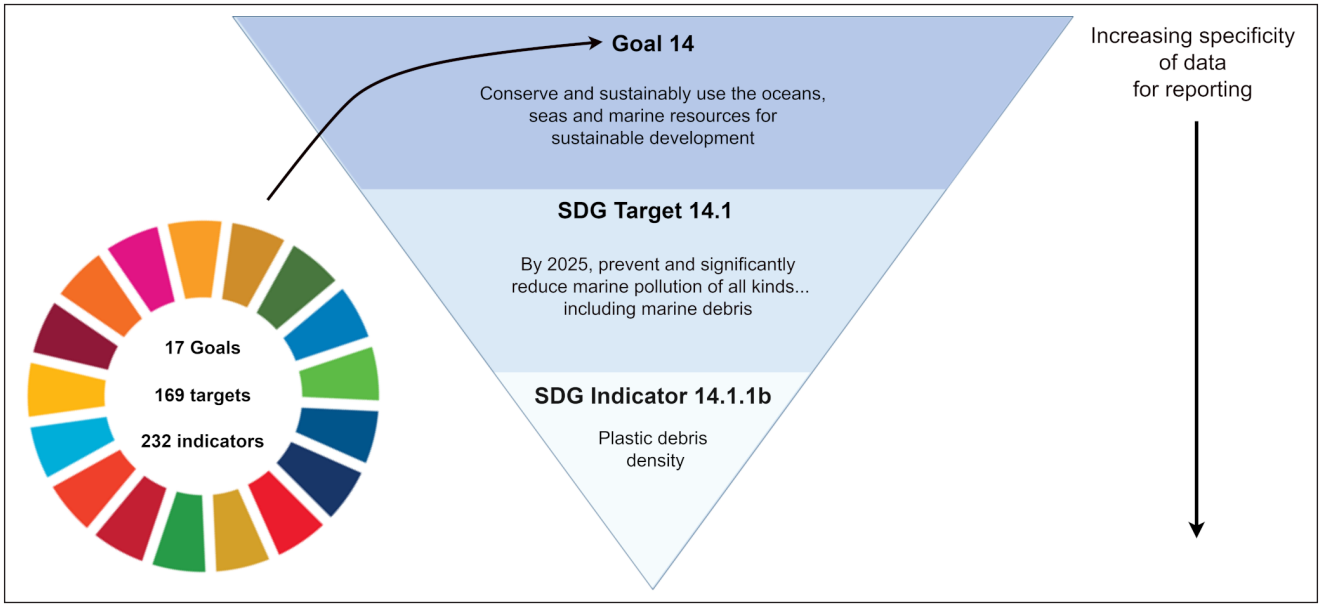

Figure 1 An overview of the United Nations Sustainable Development Goals, describing the hierarchy and number of goals, targets, and indicators.

al. 2012), and includes any activities that align with scientific process, such as forming research questions, data collection, analysis, project management, dissemination of outcomes, and advocacy (see Eitzel et al. 2017 for definitions). A prominent example within marine debris is *Científicos de la Basura* of Chile (Hidalgo-Ruz et al. 2018), which is a network of schools and other stakeholders across Chile and the western coast of South America that undertake debris monitoring and analysis, in addition to awareness and education efforts (Gallardo et al. 2021). The data collection aspect of citizen science projects could assist in SDG reporting and, more broadly, the management of plastic pollution.

Citizen science projects addressing marine plastic pollution also collect data to answer scientific questions about its impacts across different habitats, on wildlife, and its potential toxicity through chemical analysis (GESAMP 2019). The number and coverage of projects provides promise that data from citizen science can produce statistics and indicators of plastic pollution at the national scale for different applications (Nelms et al. 2017; Gacutan et al. 2022b) and therefore be used for SDG reporting (Fritz et al. 2019; Fraisl et al. 2020).

The plastic debris data required for SDG indicator reporting is constrained by specific criteria, where not all data may be fit for purpose. Plastics data is collected for differing motivations, such as understanding local conditions, identifying sources, and answering scientific questions (Hidalgo-Ruz and Thiel 2015). The use of different sampling protocols poses challenges for combining datasets in a coherent way (i.e., data harmonisation). To address these challenges, the international community has developed guidance on sampling protocols to assist all stakeholders (e.g., research institutions, individuals) globally in measuring plastic pollution in a comparable and standardised manner (GESAMP 2019).

Here, we attempt to clarify the complex process and data requirements for countries to report on progress towards the SDG target concerning plastic debris. We then explore the potential for citizen science projects to support such reporting, with a focus on plastic debris on beaches, which accounts for a large proportion of citizen science projects within this space. We suggest future directions that could strengthen relationships between the government institution responsible for SDG reporting and the citizen science community, including suggestions for authentic partnerships with citizen science projects to achieve co-benefits.

OVERVIEW OF PLASTICS DEBRIS SUB-INDICATORS

This section provides an overview of the sub-indicators related to measuring progress towards SDG Target 14.1 for the significant reduction of marine plastic pollution (SDG Indicator 14.1.1b, henceforth "plastic debris indicator"). This paper focuses on sub-indicators at the national level, and as beach debris monitoring is the most ubiquitous method employed by government, research, and citizen scientists projects (Kawabe et al. 2022; Serra-Gonçalves et al. 2019), this report further focuses on the plastic debris indicator concerning beach debris density.

Although the SDGs and their targets were adopted in 2015, the indicators to measure their progress continue to be developed, with the plastic debris indicator re-defined in July 2020 (UNSD 2020a). The UN Environmental Program (UNEP) is the custodian agency for the SDG Indicator on plastic debris, meaning that it is responsible for developing sub-indicators, offering associated guidance, and coordinating data collection from each country (UNEP 2021c). The UNEP has established guidance for sub-indicators at different scales: global, national, and sub-national (e.g., provinces, states, or territories). Only data and statistics for national-level indicators are requested from countries by the UNEP for SDG reporting (Figure 2).

Two global sub-indicators are produced by the UNEP. The first measures floating plastic patches greater than 10 m in size, whereas the second estimates the proportion of plastic debris on beaches by domestic or foreign origin via computational modelling (UNEP 2021c). For example, the model estimated beached plastic in Kenya, finding 11% was sourced domestically, 60% from other African countries, and 29% from outside the region (OceanParcels v2.0; Van Sebille et al. 2020).

Sub-national indicators are considered supplementary, in that the UNEP does not request such data from countries for SDG reporting, although it may be voluntarily reported. They concern microplastics, plastic ingestion by fauna, recycling, and impacts on human health (UNEP 2021c). These sub-indicators are important for understanding the risks posed by marine plastics to environmental and human health (Gacutan et al. 2022a), although guidance has yet to be endorsed by the UNEP.

The national-level sub-indicators provide a measure of plastic debris density for a habitat across an entire country, with a focus on density across beaches, the sea surface, water column, and seafloor (UNEP 2021c). The specificity of beach plastic debris (counts/km^2), as opposed to the entire coastline, is important as it excludes other habitats such as rocky shores, mangroves, and estuaries. These different coastal habitats significantly differ in debris accumulation (Olivelli et al. 2020). It should be noted that data from projects could be collected at a variety of spatial scales (e.g., local, regional), but SDG reporting requires the aggregation of data into a single statistic to represent debris for beaches across the country. Numerous datasets will need to be combined in a coherent way to estimate beach debris density.

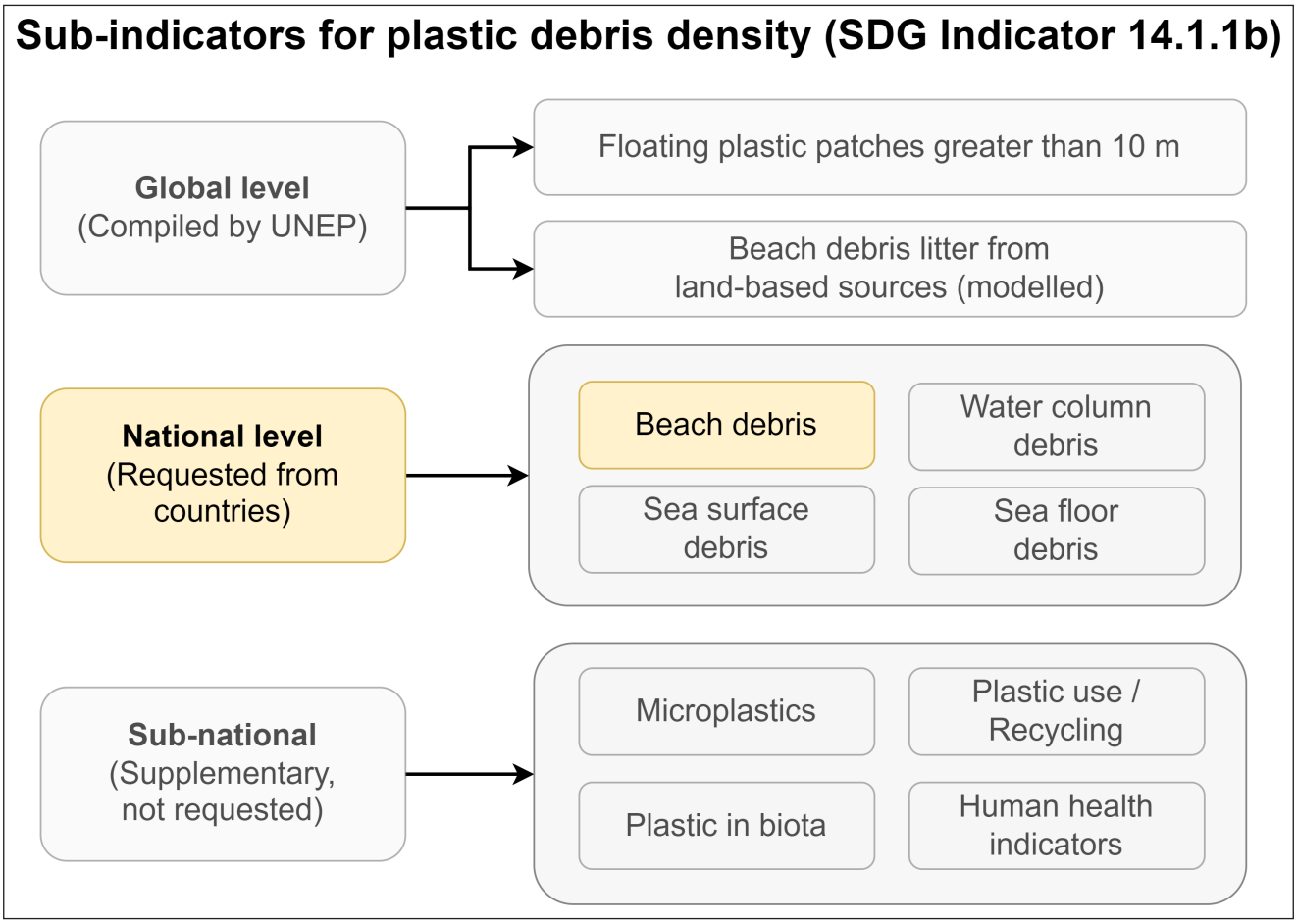

Figure 2 The sub-indicators related to plastic debris density (SDG indicator 14.1.1b), with an overview of the spatial scales (global, national, and sub-national) and their respective sub-indicators. Note that only national-level indicators are expected from countries, whereas the indicator for beach debris is the focus of this paper (*yellow*).

The underlying data for the SDG sub-indicator of beach plastic density would need, at minimum:

- a description of where and when the sampling occurred,
- the total area surveyed, and
- separate counts of plastics from the other debris recovered on the beach.

In our view, datasets on beach plastic debris would benefit from the development of national standards that define the information describing the data collected (i.e., metadata). Metadata provides contextual information about plastic debris observations, which allows people to identify whether the data is structured in a way that is fit for their purpose (Fritz et al. 2019). Such guidance should ensure the data is fit-for-purpose (e.g., for SDG reporting), but should also maintain flexibility to reflect community needs and other uses both at present and into the future.

Discussions on the formation of data standards should begin with the sub-indicator for beach debris (explored in Table 1), given the prevalence of the activity across government, research institutions, and the citizen science community. Within the European Union, for example, a nested classification system has been developed, which assists in harmonising datasets across material types, items, size, or colour (Fleet et al. 2021). Citizen science projects have also developed protocols relevant to national aggregation. For example, the Australian Marine Debris Initiative collaborated with academics from four universities to develop monitoring for beaches and other environments (AMDI 2022). The standard should align with international efforts for comparability and be developed alongside the organisations maintaining databases, including citizen science groups.

CITIZEN SCIENCE PROJECTS ON BEACH PLASTIC DEBRIS

Citizen science projects could contribute to the entire range of indicators (e.g., microplastics, plastic ingestion by biota) across different habitats (e.g., seafloor, sea surface; Table 2).

DATA COLUMN	DATA TYPE	RATIONALE
Date of survey	Date	Understand the temporal spread of data during aggregation.
Site name	Text	Allows identification of sites within the same area, especially for repeat events.
Site identifier	Text	Single combination of words or numbers (e.g., alpha-numeric) that simplifies identification of site.
Site geographic coordinates	Spatial (Latitude, Longitude)	Spatial identification of clean-up for aggregation and understanding spatial representation during aggregation. The sub-indicator for shorelines makes specific mention of "beaches." Site coordinates allow the UNEP/Regional Sea to verify the data point as a beach.
Spatial reference system of coordinates	Text	Facilitates harmonization of multiple spatial datasets. Text code could be a code under the EPSG Geodetic Parameter Dataset, a registry of spatial reference systems.
Area surveyed	Numerical (km^2)	Report the value (total area) surveyed per event used to calculate debris density.
Survey duration	Numerical (hours)	Report the number of hours sampling debris within the survey area to allow for a calculation of effort.
Number of surveyors	Numerical (integer)	Report the number of surveyors to allow for a calculation of effort.

Table 1 Example information concerning the collection of beach debris density data (i.e., metadata) that could be included in standards for marine debris data.

Projects concerning beach debris are particularly widespread and active (GESAMP 2019), and we explore in this section the diversity of approaches to projects and how their data is collected.

The extent of data collection of citizen science projects varies in approach, differing in how data is collected, the number of sites, frequency of data collection, and breadth of items reported (Kawabe et al. 2022). For example, annual collection events are performed by the UK Marine Conservation Society organising the Great British Beach Clean (MCS 2022). By contrast, other citizen science programmes may aggregate data from several sources, including other citizen science projects, leading to the collection of data at a large spatial scale and over time. For example, Save Our Shores collates clean-ups across central California (Save Our Shores 2021) and the Marine Conservation Society (MCS 2022) submit data from across the UK to the International Coastal Clean-up database (ICC 2021). The ICC provides training resources and a mobile application in English and Spanish to broaden the reach of the database, of data access, and of data sharing, as exemplified by data now coming from more than 90 countries (ICC 2021).

Other organisations focus on strengthening national networks through forging partnerships, centralising data, providing data collection methods and classification systems, and broadening experiences. For instance, the national Australian Marine Debris Initiative (AMDI) Database contains marine debris records from more than 1,400 organisations since its launch in 2004 (Gacutan et al. 2022b). Marine debris databases also differ in how they classify debris. The ICC database contains approximately 50 categories, with 22 of those categories related to plastics (ICC 2021); whereas for the AMDI Database, debris is classified into 142 categories, with 72 of those categories relating to plastic (Gacutan et al. 2022b). The information can then be used and added to by different organisations, community groups, or individuals via a centralised platform.

It is our view that most citizen science projects collect data relevant to SDG reporting, and a first step is convening a national discussion within the citizen science community to identify the existing data and methods used. The measure of the indicator as "density" allows for the use of data across different data collection protocols and item classifications. A non-exhaustive list of citizen science programmes that meet such criteria include the Australian Marine Debris Initiative within Australia (AMDI 2022; Gacutan et al. 2022b), *Científicos de la Basura* of Chile (Hidalgo-Ruz et al. 2018), Coastal Clean-up and Monitoring Project of China (Chen et al. 2020), The Great British Clean-up within the UK (Nelms et al. 2017), and Marine Litter Watch across the European Union (Jack et al. 2019). Managers of citizen science databases could determine if the three criteria previously described are met through analysing the recorded "data about the data" (i.e., metadata; Tables 1 and 3). New and existing projects may consider minor adaptations to both their methods and classifications to allow for the inclusion of future plastic debris data into SDG reporting.

There are also opportunities for projects to go beyond the requirements of SDGs in measuring other aspects of beaches and sampling, which would add value in analyses of plastic pollution management at different spatial scales (see Table 3). Projects maintaining their own databases and data management systems could consider collecting metadata described by guidelines on beach plastic debris developed

BENEFITS IN ENGAGING WITH THE CITIZEN SCIENCE COMMUNITY	HOW GOVERNMENT SUPPORT COULD FURTHER SUPPORT DATA COLLECTION FOR SDG REPORTING
• Increase spatial scales to better capture plastic debris density on beaches (e.g., Nelms et al. 2017; Gacutan et al. 2022b). • Some projects contain data from the same site over time, identifying temporal trends for SDG reporting (e.g., Ambrose et al. 2019). • Some projects already use scientific monitoring techniques and train project participants in such methods (McKinley et al. 2017; Brown and Williams 2019).	• Resource projects to enable training on data collection and to improve how data is recorded and stored. • Establish national standards for sampling methods to provide representative estimates of beach debris density. • Establish national standards on debris classifications to enable different projects to harmonise data. • Provide grant incentives and collaborate with projects to identify how data gaps could be filled (e.g., under-sampled locations).

Table 2 How citizen science enables SDG reporting of a national-level indicator for beach debris density and how governments could support citizen science activities.

VARIABLES INFLUENCING BEACH DEBRIS COUNT	ASSOCIATED METADATA	STRATEGIES FOR AGGREGATING DATA NATIONALLY FOR SDG INDICATOR REPORTING
Local geomorphology (shape of beach and physical characteristics of sediment) (Olivelli et al. 2020, Critchell and Lambrechts, 2016).	Substrate type (sand, mud, gravel), beach width, beach type, embayment.	Assess the influence of each factor at within physical or administrative boundaries. (Gacutan et al. 2022b)
Spatial distribution of beaches (Underwood et al. 2017).	Location (latitude, longitude)	Filter or weight data to ensure equal representation of coastlines across the country, where possible. (Gacutan et al. 2022b)
Temporal distribution of sampling events, by seasonal influence (Browne et al. 2015)	Date of survey Relevant season	Aggregate by season or available months of sampling. (Vincent et al. 2017, Browne et al. 2015)
Data collection effort (Browne et al. 2015, Underwood et al. 2017)	Number of volunteers Time spent surveying Time spent classifying debris	Weight data to standardise for sampling effort (Bird et al. 2014)

Table 3 Variables influencing counts of plastic debris density on beaches (count/km^2) and the related metadata worth considering, and why it is useful for national aggregation.

internationally by the UNEP (UNEP 2021c) or the European Commission (Fleet et al. 2021). Projects with monitoring programs could also consider the timing of sampling, the use of transects, and calculating accumulation of beach debris as explored in GESAMP (2019).

THE PLASTICS DEBRIS INDICATOR PROCESS

This section clarifies the process by which the UNEP requests national-level data for the plastic debris indicator from countries and the modalities in which they may respond to such requests. To our knowledge, this is one of the first articles to document the emergent process, established through informal communication with representatives from the UNEP and its Regional Seas Programme. First, we describe the UNEP process for requesting marine debris data from countries. Then, we describe the role of the government agency or other body (henceforth, "data aggregating body") designated by a country to respond to such requests as the "focal point." In doing so, we highlight the role of the data aggregating body and its relevance to discussions with the citizen science community concerning data and data sharing.

SDG reporting is voluntary and country-led, with UN agencies playing a coordinating and capacity-building role to support countries in acquiring and compiling relevant data. As the custodian agency, the UNEP is responsible for collecting country data relevant to the plastics debris indicator, and manages this process predominantly through its Regional Seas Programme (UNEP 2016; UNEP 2021b). The programme was established in 1974, to provide an organising structure for the multiple regional conventions and action plans addressing marine and coastal management. Each convention or action plan covers a regional sea, with adjacent signatory countries as "contracting parties." Examples of Regional Seas conventions include the Oslo-Paris (OSPAR) convention for the North-East Atlantic, the Nairobi Convention for the Western Indian Ocean, and coordinating bodies such as the Secretariat of the Pacific Regional Environment Programme (SPREP) for the Pacific Ocean (Ferreira et al. 2022).

The UNEP is mandated to engage all relevant countries (i.e., those with marine areas) for national reporting on SDG Indicators related to plastic debris (UNEP 2021b). The mode of the UNEP engagement for reporting varies, depending on whether a country is party to a Regional Sea Convention or Action Plan. For countries that are not members, the UNEP

engages with the country directly (Figure 3a). The UNEP first requests a country's government to designate a focal point of contact, which will respond to communication and data requests. This body will be responsible for the aggregation of data to produce a national statistic for beach plastic pollution and is usually the National Statistics Office, although it could also be a relevant environment-related ministry, research institution, or non-government organisation. For countries that are part of a Regional Sea, requests are performed by the relevant secretariat of the relevant Regional Sea Convention or Action Plan (rather than the UNEP) (Figure 3b).

A limited number of countries have submitted plastic debris data in support of SDG reporting (although, see Olen 2022) as of the previous progress update for SDGs in 2021 (UNSD 2021). This is to be expected, as the plastic debris density indicator was established only in December 2020 (UNSD 2020b), with associated guidance in February 2021 (UNEP 2021c). The UNEP is raising awareness of the indicator through direct engagement with countries or through the Regional Seas Programme. We expect, however, that even with increasing awareness of the plastic debris indicator, sub-indicators, and related guidance, there would be a lag in submitting data. As identified in the previous section, there are issues such as the lack of (i) relevant data, (ii) harmonisation approaches for existing data, and (iii) standards to follow when collecting future data. Reporting may increase alongside an increased awareness of the indicators and growing support from international institutions in meeting harmonisation and standardisation needs.

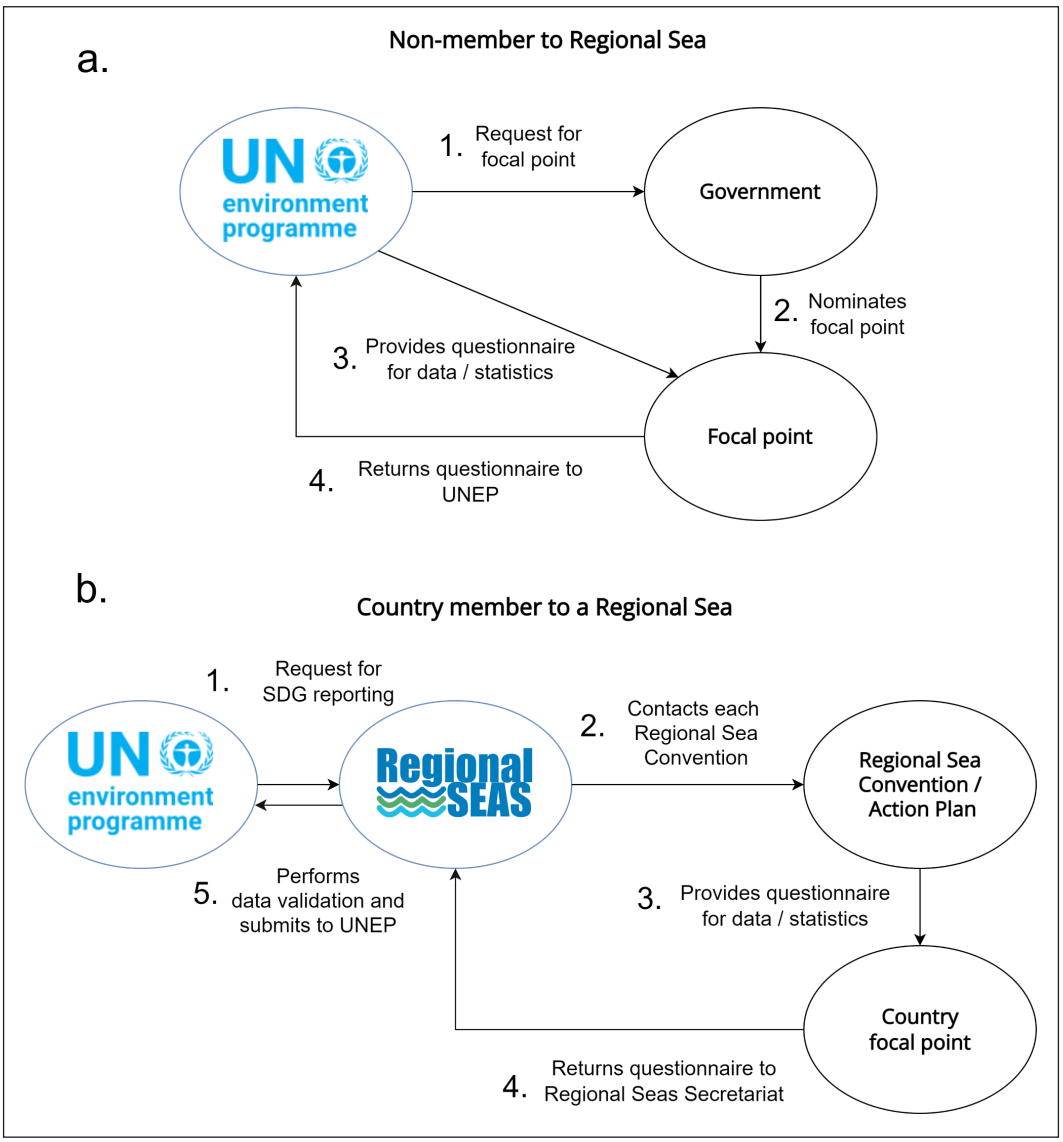

Figure 3 The process for reporting national-level plastic debris data to UNEP. These stages differ for **(a)** countries that are not Regional Seas Programme members, and **(b)** countries that are Regional Seas Programme members. SDG: Sustainable Development Goals, UNEP: United Nations Environmental Programme.

ENGAGING WITH THE SDG REPORTING PROCESS

Many citizen science projects engage participants with collecting information on plastic pollution, which can serve as evidence to advocate for management actions to curb future plastic pollution (Gacutan et al. 2022a; Syberg et al. 2020). If the citizen science community and the data aggregating body share data effectively, then it holds promise to enter the national system. From there, the data could be used to inform domestic policy, strategic plans, and legislation to remove and reduce plastic pollution. For example, outputs from the Australian Marine Debris Initiative (AMDI) were featured in both the Australian 2021 State of the Environment Report (DCCEEW 2022) and the risk management plans for marine debris for New South Wales, Australia (Gacutan et al. 2022a; DPE 2022). Citizen science projects quantifying plastics pollution can support revealing areas of high plastic debris density ("hotspots," Nel et al. 2020), suggesting management strategies (Ambrose et al. 2019), or evaluating effectiveness of single-use plastic bans (Harris et al. 2021). Data that has entered a government system has potential to support decision-making beyond SDGs (Figure 4). In our view, working towards SDG reporting is a catalyst to establish these systems that allow citizen science projects to contribute valuable evidence for the management of marine debris from global, national, and local levels.

As the UNEP increasingly engages with countries regarding plastic debris density, we envision that the data aggregating body will initiate more dialogues with relevant stakeholders, including the citizen science community, to advance data collection and access. Such discussions may explore how existing data on plastics pollution can be used towards SDGs and how future data can be collected in line with marine debris indicator needs. As explored earlier, however, much of the plastic pollution data collected by projects can also already be applied to plastic pollution monitoring and decision-making (Nelms et al. 2022, Gacutan et al. 2022a). These dialogues provide opportunities for the citizen science community to establish relationships with government bodies and other key stakeholders (Figure 4). The more citizen science is contributing to the SDGs, the greater leveraging power the citizen science community has in advocating for change to reduce plastic pollution within their respective countries.

Authentic partnerships between the government focal point and the citizen science community require early and maintained engagement to progress the SDGs (Fraisl et al. 2020). There are several challenges to the continuity of citizen science projects that could be addressed, in part through government partnerships (see suggestions, Hulbert et al. 2019). Expectations for data sharing between citizen science projects and the data aggregator could include, for example, fee-for-service agreements for the supply and use of data; plans and resource needs to further expand project capacity; and appropriate formal recognition of outcomes

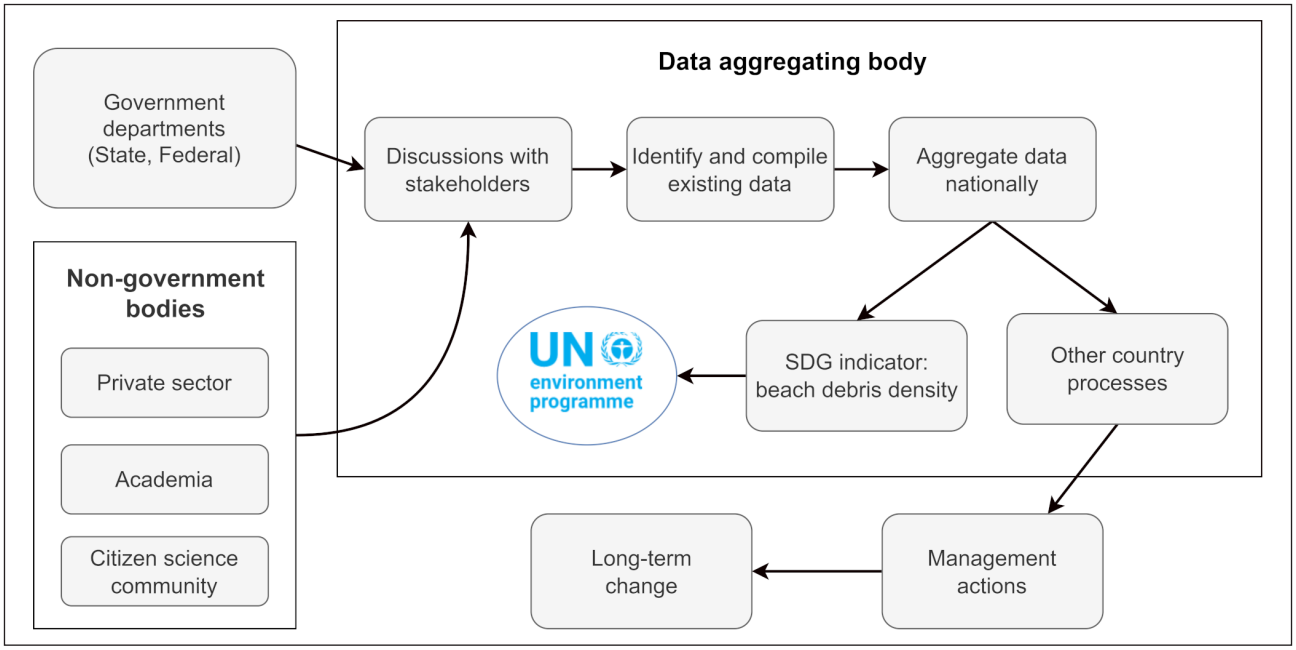

Figure 4 A proposed process for the data aggregating body and focal point to engage relevant stakeholders in requesting and compiling data relevant to the national-level SDG indicators, including beach plastic debris. We highlight the role of the SDG process in compiling data that could further be used in management actions that lead to long-term change.

(e.g., within national SDG reports, citizen science websites). Any commitments in the use of data, recognition of the project, and authority to rescind provided data should be formalised through agreements, whether non-binding (e.g., memorandums of understanding) or legally binding (i.e., licenses and contracts).

CONSIDER IMPLEMENTATION OF OPEN DATA GOVERNANCE

Engagement with citizen science projects within countries may prove challenging if they cannot be identified and contacted. Citizen science projects could consider data governance principles that further open, findable, accessible, interoperable (can be exchanged between systems), and reusable (i.e., FAIR Principles, Wilkinson et al. 2016) data. The European Marine Observation and Data Network (EMODnet), for instance, adopted the FAIR Principles, and plastics debris data, collected via citizen science projects and more broadly, was contributed from 17 counties across Europe (Addamo et al. 2018; Calewaert et al. 2020).

With citizen science, the ability to easily find projects is paramount for diverse stakeholders, whether to participate, to encourage participation, or to learn about projects. Specifically, stakeholders may be interested in the methods used, areas surveyed, data, and project impacts. The Public Participation In Scientific Research (PPSR) Core data standards offer a systematic approach for collecting information about projects, which has guided the development of several databases supporting people to find projects around the world (Budnicki and Newman 2021).

EMBEDDING COMMUNITY VALUES

The SDGs reflect the UN values for promoting the health and prosperity of people, which aligns with the community values that have led to local participation in addressing plastic pollution within marine environments (Fraisl et al. 2020). It is important to identify how such interests align and understand broader values knowledge, practices, and cultures of respective communities (e.g., Ganzevoort et al. 2017), as they pertain to sharing information about the plastic debris problem. Careful consideration is required, for example, with Indigenous data to "address concerns related to people and purpose of data; Collective benefit, Authority to control, Responsibility, and Ethics, and their respective sub-principles" (i.e., CARE Principles for Indigenous Data Governance) (Carroll et al. 2021, p. 2). Some aspects of these principles share similar sentiments held within the global citizen science community. Principles for citizen science, for example, were first drafted in Europe (Robinson et al. 2018), and later modified for the Australian context (ACSA 2020). Both sets of principles highlight overarching themes of authentic partnerships with cooperation, respect, reciprocity, and community empowerment. When exploring potential SDG and citizen science synergies, it's important to bear in mind that:

- information from the citizen science community should be included only if done so respectfully and per project community expectations;
- partnerships involving the citizen science community involve an exchange of information and feedback, as well as sharing of subsequent outcomes, such as the adoption of protocols, scientific discoveries, inclusion in policy, or societal influences;
- acknowledgement must be given to projects, and community participants, with explicit recognition of their contributions; and
- legal and ethical obligations must be met, such as complying with regional information-sharing laws and customs.

It is worthwhile for the data aggregating body to begin working with citizen science, Indigenous, and broader communities early in the process of SDG reporting for plastic debris density. Wherever possible, efforts should be cooperative, and build upon existing citizen science efforts rather than replicating them.

Partnerships to advance SDGs and citizen science requires an investment of time and resources. This can be developed gradually and iteratively over time, as several global citizen science projects exemplify (e.g., Global Mosquito Alert, Tyson et al. 2018, Južnič-Zonta et al. 2022). Public awareness of SDGs would grow with such collaborations and holds promise to increase people's awareness of the plastics problem and inspire them to be a part of the solution on local, national, and international levels, beyond beach clean-ups (Fraisl et al. 2020; Fritz et al. 2019). Cooperatively working with groups currently implementing FAIR and CARE principles, or the PPSR Core standards could guide how to support diverse stakeholder groups with submitting plastics data for SDG reporting.

CONCLUSIONS

The SDGs provide a global process that encourages countries to measure plastic pollution within their marine environment. The SDG Indicator on plastic debris density focuses on four habitats, where we have provided an overview of beach plastic density and the three criteria for data to enable inclusion.

Many citizen science projects already collect data fit for this purpose; projects could compare their data with these criteria and consider minor adaptations to ensure compatibility. The ability to combine datasets to calculate beach debris density would not only expand the ability to report on SDGs, but also provide further evidence to manage plastic pollution. We have also described the complex process by which the UNEP requests, from countries, data relevant to the SDGs, and we have highlighted the role of the data aggregating body, which is responsible for identifying databases and engaging with stakeholders within a country. Engagement between the data aggregating body and stakeholders collecting debris data within a country provides a forum for the citizen science community to engage directly in discussions concerning plastic pollution. We encourage the citizen science community to highlight the value of data collected from projects and define expectations with sharing citizen science data to ensure co-benefits. Partnerships between government and the citizen science community hold promise in advancing the SDGs, leading to long-term change.

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COMPETING INTERESTS

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AUTHOR CONTRIBUTIONS

JG: conceptualisation, formal analysis, writing, visualisation, project administration. JLO: formal analysis, writing, visualisation. HT: conceptualisation, writing. TP: conceptualisation, formal analysis, writing. BM: conceptualisation, writing, project administration, funding acquisition.

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