CITIZEN SCIENCE AND DATA INTEGRATION FOR UNDERSTANDING MARINE LITTER

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Abstract: Protecting the ocean is essential for the sustainability of the planet. Oceans provide food and livelihood for human populations, host vast biodiversity and ecosystems and provide climate regulatory services. However, due to the vastness of the oceans, monitoring ocean pollution and health is logistically challenging and expensive. This is particularly true for plastics. In the last 50 years, global production of plastics has increased more than 22-fold, and only an estimated 9% of plastics produced have been recycled[1]; Moreover, there is a lack of information on the volume of plastic that is currently in the ocean, where that plastic accumulates, and the process of how plastic breaks down into microplastic as well as a lack of information on how plastic affects ecosystem or human health. Answering these questions requires new ways of collecting and analyzing data. Citizen science and complementary activities, like targeted beach clean-ups, not only provide a cost effective mechanism for collecting data, but also provide an opportunity to increase awareness and action on issues relating to marine litter. A consortium of partners including UN Environment and the Wilson Center are partnering on Earth Challenge 2020[2], the largest globally coordinated citizen science campaign to date, to bring people together to better understand marine litter.

Key words: data, citizen science, plastic, oceans, SDG 14

1. Introduction

The rise in global plastic production has resulted in an estimated 5-13 million tons of plastic from land-based sources ending up in marine environments[3]. This presents an increasing threat to ocean health and biodiversity, as well as a threat to fostering a sustainable blue economy through sustainable tourism and fisheries. Addressing marine litter issues will require a holistic approach which identifies opportunities to reduce plastic use and plastic waste, particularly single use plastics and plastics containing toxins. Further, there is a need for improvements in solid waste collection and management; better treatment of wastewater; and, cleaning-up the volume of plastic which has already entered the ocean.

[1] Geyer, R., Jambeck, J. R., & Law, K. L. (2017). Production, use, and fate of all plastics ever made. Science Advances 3(7), e1700782.
[2] Earth Day Network, website https://www.earthday.org/campaigns/earthchallenge2020/
[3] Jambeck, J., Geyer, R., Wilcox, C., Siegler, T., Perryman, M., Andrady, A. Narayan, R. and Law, K. (2015). Plastic waste inputs from land into the ocean, Science: 347 (6223), 768-771.

Addressing the plastic flow pathways and plastic accumulation in oceans depends on building awareness through citizen engagement and promoting behavior change. Citizen science campaigns have the potential to accomplish both of these tasks.[4] Citizens are in the best position to collect and utilize data within their local communities.[5] However, for citizen generated data to provide local and global advocacy benefits, it must be packaged in a way that is easy to understand and is consistent across time and location. Additionally, to garner action on marine litter, citizens need to not only understand the current volume or flow of plastics into marine environments, but also how to take action in their own community to reduce the flow of plastics into the ocean and to target beach and ocean cleanups to the most affected litter accumulation spots.

The importance of tackling marine litter has been globally recognized in the context of the Sustainable Development Goals (SDGs). Specifically, target 14.1 states "by 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution".[6] UN Environment is developing a methodology for national monitoring of marine litter which includes identification of the primary sources of plastics entering the environment, plastic flow pathways, and accumulations zones. The methodology is directly linked to monitoring of the SDG target 14.1. This methodology will assess plastic production data, estimating leakages from waste systems, quantifying plastic flows through waterways, and identifying plastic accumulation zones. This methodology will use citizen science data as a primary source of information for measuring plastic accumulation on beaches and coastal waters and will use this data to estimate plastic leakage and flow based on data modelling. In terms of monitoring the concentration of marine plastics the methodology includes four themes, (1) plastic debris washed/deposited on beaches or shorelines (beach litter), (2) floating plastic debris and plastic debris in the water column, (3) plastic debris on the seafloor/seabed and (4) plastic ingested by biota (note the methodology is underdevelopment but is described in the official workplan for the SDG process)[7].

2. Citizen science and marine litter

There are already a number of citizen science efforts to collect data on marine litter such as the Australian Marine Debris Initiative (AMDI), the Civic Laboratory for Environmental Action Research (CLEAR), OpenLitterMap, Litterati, Marine Debris Tracker, Marine Litter Watch, Dive Against Debris, the Adventure Scientists Global Microplastics Initiative, Guts for Science, and many others. These programs bring together citizen scientists, communities, organizations and other stakeholders to collect data on the extent of the problem, track the

[4] Phillips, T., Ballard, H., Lewenstein, B.,, and Bonney, R. (2019). Engagement in science through citizen science: Moving beyond data collection. Science Education, 103, 3, 665-690.
[5] UN Environment Science-Policy-Business Forum (2019). The Case for a Digital Ecosystem for the Environment, discussion paper, UN Environment. https://un-spbf.org/wp-content/uploads/2019/03/Digital-Ecosystem-final.pdf
[6]United Nations, Global indicator framework adopted by the General Assembly (A/RES/71/313) including annual refinements contained in E/CN.3/2018/2 (Annex II) and E/CN.3/2019/2 (Annex II). (2019). https://unstats.un.org/sdgs/indicators/Global%20Indicator%20Framework%20after%202019%20refinement_Eng.pdf
[7] UN Environment, SDG workplan submission, SDG 14.1.1. Last updated July 2018. https://uneplive.unep.org/media/docs/projects/14_1_1_work_plan.pdf

source of the litter, understand how it is released into the environment, track and promote litter removal from our coastal areas and waters, influence policy and promote behavior change. Notably, different citizen science programmes have different purposes and assess different aspects of the plastic value chain (beach litter, floating, suspended or sea floor litter in coastal areas, plastics ingested by biota, microplastic concentration or information on waste management). For instance, Marine Litter DroNET uses drone technology, machine learning and citizen science to recognize plastics and hotspots. Citizen scientists also help train algorithms by tagging plastics in drone gathered images. The greatest prevalence of citizen science data is from land-based sampling, such as beach clean-ups, as land based sampling is easiest to carry out[8]. The efforts to collect citizen science data from beaches and nearshore locations range from beach clean-up events which involve broad community participation, to clean-up specific sites, to trained data collectors using designed surveys at a site selected for statistical purposes.

Data collected through these citizen science initiatives follows specific protocols and data collection procedures and can provide a valuable source of information for understanding plastic debris. However, these initiatives use diverse methods to identify the status of marine pollution, which makes it difficult to integrate the data available in a consistent way in order to measure the true scale of the problem. It is necessary to harmonize these approaches to gather comparable data for spatial and temporal analysis. Harmonizing and integrated data from citizen science initiatives can provide information for estimating debris baselines, volume, impacts and changes[9]. Additionally, this information can serve as an input and validation data for global models of plastic concentration and flows, including modelling the movement of plastics through ocean currents.

2.1. Definitions, harmonization and data collection

Monitoring marine litter is important for understanding how marine litter impacts the natural environment, for informing national policy and for building consumer awareness of issues related to the use of certain plastics. To accomplish these objectives requires data which is comparable across time and location and which, through data processing, can supply policy-relevant indicators. In some cases, understanding the particular sources of marine plastics can be accomplished by conducting brand audits which assess the prevalence of different types of plastic products. The Break Free From Plastics[10] tool provides an example of a citizen science initiative which can provide additional information for identifying the relative contributions of different economic actors to marine litter.

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[8] Hardesty, B., Wilcox, C., Schuyler, Q., Lawson, T. and Opie, K. (2017) Developing a baseline estimate of amounts, types, Developing a baseline estimate of amounts, types, sources and distribution of coastal litter – an analysis of US marine debris data. CSIRO. https://research.csiro.au/marinedebris/wp-content/uploads/sites/133/2018/02/CSIRO_Analysis-US-marin-debris-data_OCNOAA-Report_23Oct2017.pdf

[9] Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (2019) *"Guidelines for the Monitoring and Assessment of Plastic Litter in the Ocean"*, GESAMP Reports and Studies #99. https://environmentlive.unep.org/media/docs/marine_plastics/une_science_dvision_gesamp_reports.pdf

[10] Break Free From Plastics Brand Audit Toolkit, https://www.breakfreefromplastic.org/brandaudittoolkit/

At the international level, the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP), was tasked with developing an internationally comparable methodology for monitoring marine litter.[11] The GESAMP methodology details the value of citizen science initiatives for contributing incidental observations or sampling of specific items, as well as the value of providing regular data which can be used to estimate data on litter density and quantities.[12] However, when definitions and methodologies are not followed consistently, this can lead to misleading or conflicting conclusions. For example, one study of marine litter data sources in the United States found little correlation between the estimated pattern of debris loading when comparing data following the National Oceanic and Atmospheric Administration and the Commonwealth Scientific and Industrial Research Organisation (CSIRO) methodology.[13] This was partially due to differences in the way that sites were identified and the exclusion of smaller items in one of the methodologies. Moving forward there is a need to bring members of the citizen science community together to promote open data, the use of standard definitions and data collection methods, to promote and to identify ways to harmonize existing data collections. The Earth Challenge 2020 provides an example of a research initiative to bring citizen scientists, researchers and policy makers together to analyze how existing citizen science data can be pooled together for better analysis and to promote harmonized, open data collection and sharing.

2.2. Earth Challenge 2020 and other Citizen Science Initiatives

April 22, 2020 marks the 50th anniversary of Earth Day. In recognition of this milestone Earth Day Network, the U.S. Department of State, the Woodrow Wilson International Center for Scholars, and other partners are launching Earth Challenge 2020 (EC2020) as the world's largest globally coordinated citizen science campaign. Earth Challenge 2020 has two goals. First, the EC2020 seeks to increase the amount of open and interoperable citizen science data to help answer more complex, global questions than any dataset could address alone. To enable new data collection, mobile application with numerous data collection widgets and a software development kit will be built. To facilitate data integration, a metadata catalogue and API-enabled platform for data integration, analysis, and visualization will be created. Second, EC2020 seeks to equip and empower people around the world to understand and act on citizen science data to build safer, healthier communities. It will offer access to open data, and also educational resources and a "What you can do" toolkit identifying opportunities for individual and policy-oriented interventions.

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[11] Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (2019) *"Guidelines for the Monitoring and Assessment of Plastic Litter in the Ocean"*, GESAMP Reports and Studies #99. https://environmentlive.unep.org/media/docs/marine_plastics/une_science_dvision_gesamp_reports.pdf

[12] ibid

[13] Hardesty, B., Wilcox, C., Schuyler, Q., Lawson, T. and Opie, K. (2017) Developing a baseline estimate of amounts, types, Developing a baseline estimate of amounts, types, sources and distribution of coastal litter – an analysis of US marine debris data. CSIRO. https://research.csiro.au/marinedebris/wp-content/uploads/sites/133/2018/02/CSIRO_Analysis-US-marin-debris-data_OCNOAA-Report_23Oct2017.pdf

In 2018, the Earth Challenge 2020 team launched a global crowdsourcing call for people to identify the most important research questions in environmental and human health. Hundreds of responses from all seven continents were distilled into 6 research questions, including *"What is the extent of plastics pollution?"* These research questions will serve as focal points for developing including technologies for data collection and integration as well as education and outreach materials. For each of the six research questions, teams of researchers, educators, and other experts will help design the specific protocols for data collection (e.g., through the mobile application), data integration (e.g., by identifying relevant sources of data), and the development of educational and outreach materials. Research teams will also help map the contributions of Earth Challenge 2020 to the SDGs.

Members of the Earth Challenge 2020 plastics research team has already helped shape the project in a number of ways. In early 2019, UN Environment convened a workshop of global experts to help inform the methodology of 14.1. These experts helped illustrate the need for integrated citizen science data on plastics pollution, and also the need for data collection through the app on a more upstream topic, like household waste or municipal waste. Additionally, research teams also helped identify and secure four data sets for a data integration hackathon held in partnership with DataKind DC. Results of this hackathon will be made available through ArcGIS software in July 2019.

Ultimately, the aim of Earth Challenge 2020 is to create an infrastructure of coordinated citizen science technologies and communities. While the six research questions are initial opportunities for coordination, the interoperable infrastructure built from EC2020 will ultimately be valuable for advancing citizen science in a range of areas impacting environmental and human health.

2.3. Citizen action

In addition to involving volunteers in data collection, citizen science brings numerous opportunities for educating people on the specifics of a given problem and working towards a solution. Citizen science campaigns, such as the Earth Challenge 2020, can work with teachers to create lesson plans for bringing the project into classrooms worldwide. These lesson plans may cover a variety of informative topics, including the science behind plastics pollution, information on the factors that cause waste to spread throughout the environment, information on which types of plastic products are particularly likely to end up in the environment, and empowering students to analyze the citizen science data collected and integrated through Earth Challenge 2020 including data from existing citizen science initiatives.

In addition, citizen science can help mobilize citizen action and provide policy-relevant information by engaging volunteers and communities with the process of knowledge production. The EC2020 will include the production of a "What you can do" toolkit which will provide information on individual and policy-oriented interventions translated into six UN languages and customized to geography and research domain. Opportunities for individual action may include recycling, with additional data and information used to stimulate action to reduce plastics use, especially single use. Other opportunities may include participation in

beach cleanups, though these only address plastic pollution at the location of final accumulation.

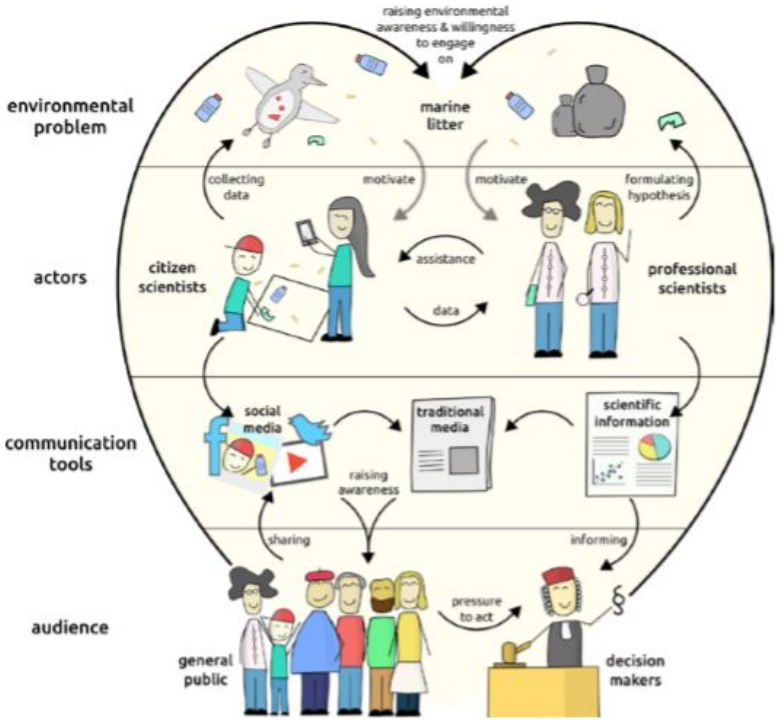

Figure reproduced from: Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection, *"Guidelines for the Monitoring and Assessment of Plastic Litter in the Ocean"*, GESAMP Reports and Studies #99, 123p, 2019. Figure authors: Tim Kiessling and Martin Thiel (Creative Commons BY-NC 4.0 licence).

3. Timeline and scaling

For work on SDG 14.1.1., methodological development and initial pilot testing will take place in the second and third quarters of 2019, the pilot project includes local testing in Kenya and Seychelles during 2019 and seven additional countries in Asia and Africa in 2020. Current efforts to bring the citizen science community on board are also underway, and will be amplified through Earth Challenge 2020 and working groups such as the WeObserve SDGs and Citizen Observatories Community of Practice funded by the European Commission and Citizen Science Global Partnership SDGs and Citizen Science Maximization Group.

A full working methodology for measuring SDG 14.1.1 will be developed by October[14]. This work builds upon the GESAMP methodologies, the experiences of CSIRO, and the results of other activities like the Earth Challenge 2020 and the DataKind hackathon. Earth Challenge 2020 will include focused data collection on a global scale throughout 2020, and will also

[14] UN Environment, Global Manual on Ocean Statistics: Towards a Definition of Indicator Methodologies (forthcoming), UN Environment, draft version available at: https://uneplive.unep.org/media/docs/statistics/egm/global_manual_on_ocean_statistics_towards_a_definition_of_indicator_methodologies.pdf

enable longer-term citizen science data collection and integration. The methods will then be scaled to a greater number of countries across all regions in 2020 with continued expansion.

4. Conclusions

The SDGs identify 169 targets that are necessary for achieving development[15] - these targets represent the issues that are essential for achieving an inclusive and sustainable future and provide a framework for holistic development across social, environmental, economic and political spheres. However, without data and science which can be used to analyze development targets, it is not possible to target interventions, investment or engage with local and national policy-makers.

Data from citizen science provides a cost effective resource which can be combined with other sources of data to better measure our planet. Numerous initiatives are already mapping citizen science to the SDGs, including at the goal, target and indicator level. Many of these are undertaken by researchers working collaboratively, such as a community of practice fostered by the WeObserve project (WeObserve SDGs CoP), and through SDGs, Citizen Science Maximization Working Group of the Citizen Science Global Partnership, and through a CODATA-WDS Task Force on Citizen Science and the SDGs.

Citizen science data could be better brought into the scope of official SDG monitoring through: (1) building recognition of the value of citizen science data with the producers of official statistics (national statistical offices, other government stakeholders and SDG custodian entities; (2) encouraging citizen science organizations to openly share data and metadata and to publish information related to data validation procedures; (3) promoting the use of harmonized definitions, formats and methodologies across citizen science and earth observation communities; and (4) working to bring citizen science data into an accessible repository. There is expansive opportunity for combining citizen science data with Earth Observations (EOs) to support cross-validation.

The efforts on measuring SDG 14.1.1 on marine litter are still a work in progress, but can provide an example of how to bring together citizen data with other types of information for official SDG monitoring and to generate actionable results. Citizen data provides an additional opportunity to engage with citizens to take action to improve their natural environment. For marine litter, beach cleanups serve a valuable purpose, and additional education and engagement could also be used to encourage citizens to make different consumption decisions and to rethink how waste is generated. The Earth Challenge 2020 provides an example of such an initiative which could be used to stimulate long-term engagement between citizen scientists, data scientists and national statistical systems to galvanize action.

5. Acknowledgements and partners

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[15] United Nations. (2015) Transforming our world: the 2030 Agenda for Sustainable Development, A/Res/70/1.

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