Chapter 8
Engaging Volunteers as Experts in Data-Driven Research Projects and a Circular Economy: The Case of PlastOPol

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Abstract Beached plastic litter is a global concern and is also an important source of data for research to improve our understanding of the extent and the main sources of the problem. Digital tools can help both in making the data registration process easier for *citizen scientists* and in processing the information and displaying it visually to decision makers. However, we argue that it is also vital to include the local ecological knowledge of both volunteers and semi-professional beach-cleaners. In this chapter, we summarise the main challenges in modelling plastic behaviour in the seas together with some of the best tools available to date. We then highlight how volunteers can contribute to testing and refining the tools. We exemplify this point through the case of the PlastOPol project and derive implications for mitigation and prevention measures.

Keywords Local ecological knowledge · Marine plastic pollution · Spatio-temporal models · Litter · Debris

Background

8.1 The Issue of Marine Litter

Marine litter is defined as any persistent manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment and is listed amongst the major perceived threats to biodiversity (Gall and Thompson 2015). Plastic dominates the litter items on a global scale with scientific studies

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estimating that a staggering 8–13 million tonnes of plastic pollution which enters the oceans annually from land as a result of waste mismanagement (Jambeck et al. 2015). Plastic debris is of particular concern due to its abundance, and its persistence in the environment, which makes it a ubiquitous category of marine debris. One of the key indicators of abundance, composition, and trends of litter in the marine environment is the amount found on beaches as these act as a key pathway for litter to enter in the oceans due to mismanagement (Haarr et al. 2020).

In 2010, the European Union's Marine Strategy Framework Directive recommended the goal of measurable reductions in marine litter in the European region by 2020. Similarly, the OSPAR Commission has set down objectives for the reductions in, and monitoring of, marine litter in the North East Atlantic region (Ospar Commission 2014). In order to reach the targets set by the OSPAR and EU's Marine Strategy framework, coordinated efforts are essential from preventive waste management to mitigative measures for waste removal in the region. Citizen and volunteer-driven beach cleanups are considered an effective mitigation strategy for both raising awareness about the problem and for removing, and thereby reducing, the number and quantity of litter items entering the ocean ecosystem. However, robust time series of quantitative and representative beach litter data are generally not available, in large part due to the high cost and logistical challenges associated with collecting such data (Haarr et al. 2020).

8.2 Challenges in Harmonising Data from Citizen Science

Volunteer beach-cleaners often record their findings on apps or Web portals. Some of these apps and portals include Pelletwatch; Debris Tracker; Clean Swell; Shoreline Cleanup; Birds and Debris. The challenges of relying on beach cleanup data include issues of accessibility that limit geographical coverage, the difficulty in characterising and classifying the litter in its various states of decomposition and the extra time it takes for volunteers to record their information.

As prevention of plastic pollution entering the marine environment is still the most effective way of tackling the problem, source identification is also a main concern (Falk-Andersson et al. 2020). Technological tools to record and simulate plastic flows can assist in dealing with these challenges. Identifying sources of marine plastic pollution is the focus of research projects around the world; however, to this day, they are still in their infancy and their accuracy and level of detail are disputable. Indeed, models are a simplification of a real phenomenon that allow thinking about the phenomenon in question. Models help identify patterns, and better understand the implications of the phenomenon. Spatio-temporal models such as those simulating plastic flow patterns in water systems can be based on physical parameters and/or on existing data from real floating objects.

Three main challenges arise in the attempt to model plastic behaviour at sea.

Firstly, the complexity of the hydrological system and underwater topography is very high. Weather is changeable and will influence drifts and currents, wave height and direction, not to mention influx of fresh and brackish water from rivers and streams. Larger scale ocean circulation systems are better understood; however, there can be variation from models due to changes in water density from inputs of freshwater from melting ice as a consequence of climate change. Moreover, the behaviour of litter may be strongly influenced by the topography of the continental shelf, which is not always mapped accurately. There are many knowledge gaps in our understanding of the conditions in which litter objects float, sink and get beached, and potentially re-enter the marine environment. The practical challenges of carrying out research in marine environments make data collection and precise mapping very costly. In principle, it is possible to build models without reference to physical parameters, by using machine learning on particular datasets. However, this kind of approach requires very large datasets to train the models and identify an adequate pattern in the data. If data are lacking or biased (Mehrabi et al. 2021), this will be reflected and even exacerbated in the model, and its accuracy and usefulness will be undermined.

The second challenge is related to the complexity of plastic as a material. As highlighted in Chaps. 1 and 3, the way in which plastic particles flow is dependent on their size, weight, density, and shape, which in turn is dependent on the particular composition of the plastic polymer (Steer and Thompson 2020). Their size changes over time according to their decomposition rate, which itself is dependent on the polymer type and exposure to weathering. When modelling their flow patterns, we distinguish macroplastics (over 5 mm) from microplastics (5 mm or less; Steer and Thompson 2020). The porosity of plastic particles makes them prone to colonisation by viral and bacterial communities, creating a biofilm or plastisphere (Amaral-Zettler et al. 2020). These pathogens, together with pollutants such as heavy metals (see Chap. 11) act as *hitch-hikers* (Brennecke et al. 2016; Kirstein et al. 2016) and affect the particles' mass and density and by extension their buoyancy (Khalid et al. 2021). Attempts have been made at modelling the spread of microplastic (e.g. Huserbråten et al. 2022) based on the previous efforts to model the spread of salmon lice around fish farms in Norwegian fjord systems. These models are called particle dispersion models and work by standardising particles to a single size, shape, and weight, close to the ones of salmon lice, and by simulating a known current system. The particles are then shown to follow the currents and disperse into the sea. There are many issues with this type of model, one of which is the lack of verification, or ground-truthing and, as previously mentioned, the diversity of shapes and composition of plastic particles.

The third challenge consists in an overall lack of data. Despite the many apps and Web portals available worldwide for registering images and information about the litter found, this is most often restricted to beached litter. There are exception to this as some projects have focused on plastic accumulating in remote areas (de Vries et al. 2021). Other projects have attempted to map litter on the ocean floor (Buhl-Mortensen and Buhl-Mortensen 2017), and georeferenced images and videos exist and can be requested for analysis. However, to build comprehensive knowledge of how plastics behave at sea, making their way through the water column, carried by currents, nutrient upwelling, and eventually ending up on shorelines or at the bottom of the sea, would require tagged objects that continually send signals on their journey. This is technologically challenging and costly, not to mention that it is ethically questionable to add even more plastic into already saturated oceans (Huserbråten et al. 2022). Drifter programmes exist, such as NOAA's global drifter programme, and were used in the PlastOPol project to try and make sense of flow patterns; however, it is far from enough to gain an understanding of such a complex environment.

The challenges mentioned above point to the need to include other sources of information than raw data and models. It can be useful to include knowledge from people familiar with an environment and with the litter. Volunteers working with the beach and ocean cleanup programmes develop knowledge about the characterisation, flow patterns and even the origin of the litter. This knowledge is often not picked up in the apps or portals they use to record their findings (Falk-Andersson et al. 2020). This type of knowledge can be compared with the concept of local ecological knowledge (LEK) defined in Chap. 14. There is a worldwide recognition that LEK is being lost or under-recorded (Zukowski et al. 2011). Similarly, citizen science data are often not used to their full potential, sometimes because of a lack of contact between researchers and the volunteer community (Falk-Andersson et al. 2020). We argue that the knowledge built-up by volunteer beach-cleaners is comparable to local ecological knowledge, and that volunteers should be included as experts in research and development projects involving marine litter.

This chapter will address the following research questions:

R.Q.1. How can we best utilise volunteers' efforts and harmonise the knowledge collected by them during the beach cleanup projects?

R.Q.2. What tools can be used to effectively engage the volunteers and collect valuable information for developing evidence-based mitigation strategies for marine litter?

Here, we illustrate the use of the digital tool for mapping marine litter across the case area of Møre and Romsdal including Ålesund, Norway. The case study presents the need for digital tools and its applications to harmonise volunteers' data and its potential applications in scientific studies. In Sect. 8.3, we will start by defining the theoretical framework and the concept of local ecological knowledge and citizen science. In Sect. 8.4, methods, we will present the PlastOPol project and the digital tool developed. We will also outline the profile of some typical volunteers around the coasts of Norway. The findings from the project and the tools will be elaborated in Sect. 8.5. Finally, the limitations and way ahead in utilising citizen science in managing marine litter will be discussed in Sect. 8.5.3 and limitations in Sect. 8.5.4.

8.3 Theoretical Framework

8.3.1 Local Ecological Knowledge

Engaging volunteer beach-cleaners in research projects should be carried out thoughtfully. Literature about LEK highlights it as very valuable and important, especially in the context of natural resource management, for example, fishing and other forms of harvesting (Ruddle 2000). In this context, Ruddle describes it as sophisticated, empirical, risk-based, still-evolving knowledge arranged against a set of principles and institutions that might be different to the mainstream ones (2000). It can be argued that beach-cleaning, as a form of nature conservation, mitigating impacts on wildlife and natural resources, also falls in that category.

LEK and citizen science have been linked in the context of climate change research by Reyes-García et al. (2020). The point that Ruddle makes is the urgent need to capture precious local knowledge, whilst at the same time, showing respect for the knowledge-bearers and avoiding stapling our 'utilitarian' values and merely extracting data and information out of them. In order to achieve this, it is essential to understand the values and motivations of the volunteers, and we argue, what their working conditions are, in order to best approach this exchange.

8.3.2 Citizen Science

The term citizen science is used to refer to scientific projects that involve non-professional scientists in the scientific enquiry (Silvertown 2009). In research projects, non-academic stakeholders tend to be regarded merely as sources of data, either passive or active, following the recent term 'crowdsourcing' (Wiggins and Crowston 2011). Some research projects involving civil society, also called 'citizen science projects', are moving away from this trend, following Schrögel and Kolleck's model (2019) and enabling participants to contribute more meaningfully to research and policy development and learn from the process (e.g. Oturai et al. 2022). There are many benefits in using citizen science data including a wider geographical span covered, lower financial costs, and carbon emissions from using local volunteers, increased environmental awareness of volunteers (Rayon-Viña et al. 2019). In the case of marine litter including abandoned, lost, and otherwise discarded fishing ear (ALDFG), volunteer beach-cleaners often register their findings using apps or Web portals, hoping their efforts will inform policy development to mitigate marine plastic pollution. Studies have shown that citizen science project-based data had as high standards as data collected using more classical scientific methods (Falk-Andersson et al. 2020). As an added benefit, research has shown transformational change in the volunteers taking part following increased awareness, understanding of the mechanisms of plastic pollution and of its drivers and impacts (Wyles et al. 2017; Rayon-Viña et al. 2019).

So how should we engage with these volunteers and benefit from their invaluable knowledge, whilst giving something back? How can research projects on marine plastic and ALDFG effectively drive a positive change? These questions, and the ambition of modelling plastics flow patterns, were the springboard for the PlastOPol research project.

8.4 Methods: The Case of the PlastOPol Research Project

Through the PlastOPol project, two tools were developed, one aimed at volunteers, and one at local policy-makers.

The first tool is a spatio-temporal visualisation of the litter collected between 2013 and 2021 in the region of Møre and Romsdal and a prediction model for 2022. The data are represented in the form of circles of different sizes and different shades of red according to the weight recorded in the Ryddenorge portal (Bli med | Aksjoner—Rydde (ryddenorge.no) as seen in Fig. 8.1. The objective is to create an at-a-glance impression of where the hotspots are in the region to support decision-makers on in identifying areas to allocate resources for waste management and cleaning activities. The visualisation also offers the possibility to filter only litter from fisheries.

The second tool consists in a model that detects litter objects in photos, which is itself embedded in an app that can also work offline. This constitutes a feat of technology as it requires compressing very large infrastructures into portable devices

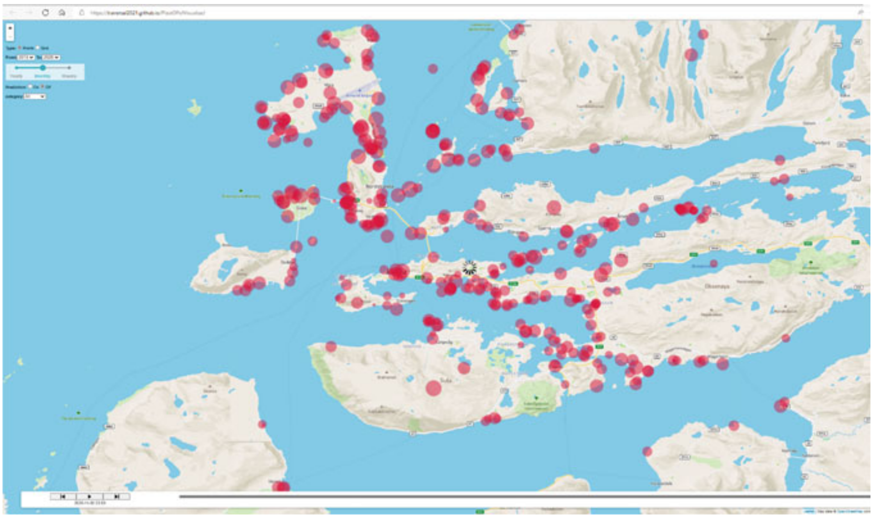

Fig. 8.1 Interactive visualisation platform displaying the marine litter collected by volunteers in Møre and Romsdal cumulatively between 2013 and 2021 as recorded on Rydde, developed as part of the PlastOPol project

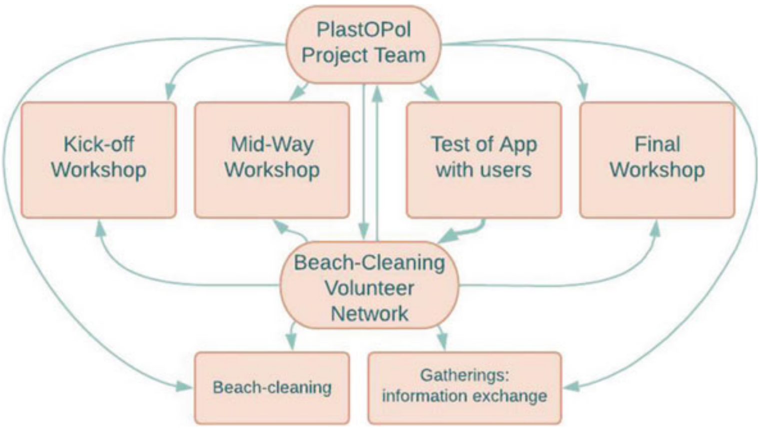

Fig. 8.2 Model conceptualising the collaboration between the PlastOPol project team and the beach-cleaning volunteer network

(Córdova et al. 2022). The implications are that such a model can be used in remotely operated devices such as drones or underwater cameras or by volunteers on their mobile phones.

For this tool to be useful to its users, it was important to understand their needs and working conditions. This was achieved through observation, by including the volunteer networks as reference group in the project and to all three workshops, by joining some of the network's own activities, and by testing the tools with the volunteers out in the field. In addition, their experience of marine litter hotspots was used to calibrate and validate the prediction model, and the app was tested in the field with the volunteers on several occasions and problems fixed along the way. A diagram to illustrate the collaboration with the volunteers is presented in Fig. 8.2.

The results of these tests and observation are explained in the next section, where we define a profile of coastal cleanup volunteers and discuss the implications for involving them in research projects and ultimately, in preventive measures.

8.5 Results

8.5.1 Towards Building a Profile of Coastal Cleanup Volunteers in Mid and Northern Norway

We go beyond the *enviro-leisure activism* model used by Power (2022), and instead, build on the concepts of civic ecology and environmental stewardship proposed by Jorgensen et al. (2021). We present a profile of organised, dedicated and well-trained volunteers on the West coast of Norway (see Chap. 4), as these form a particularly large community. Indeed, these volunteers form networks or communities with various degrees of organisation. In some cases, they receive payment for their work from the Environmental Agency or the Norwegian Retailer's Environment Fund (in Norwegian: Handelens Miljøfond), in which case we refer to them henceforth as semi-professional.

Through their networks and communities, volunteers gather and provide each other with moral, logistical, and other practical support, and, most importantly, share information. Such information includes what types of litter are most commonly found, what areas need attention, what sort of waste collection arrangements exist, or what the potential origin of the litter might be. Hypotheses about the sources of the litter are often supported by local knowledge and evidence such as labels with a company name or other signature, particular types of ropes used by the fishing or aquaculture industries, polystyrene boxes for frozen fish, etc.

In addition to being knowledgeable about the nature of the litter they collect, volunteers often develop an understanding of physical parameters in the areas they clean, such as microclimatic conditions, currents, topography, and tides. To the point that they may be able to predict what a storm will bring (Neis 1992). Indeed, strong weather events such as storms, hurricanes, floods, and tsunamis (Pelamatti et al. 2019; Murray et al. 2018) have been documented to contribute to a surge in marine litter, particularly of large items.

Volunteers are, by definition, highly motivated as they conduct activities without or with little monetary reward. They often brave harsh weather and prioritise beach-cleaning over other more hedonistic activities. Semi-professional beach-cleaners often start as volunteers, before becoming so engaged and committed to their patches and surroundings that they turn to sources of funding to be able to dedicate more time to the activity. They are often motivated by ideals, which could be simply: having a clean beach to enjoy, or more abstractly: removing plastics from an environment to protect local wildlife or to make a better world for their children and future generations. In many cases, they will develop relational values (Chan et al. 2018) with one or several places they visit repeatedly, whether consciously or not, and grow to care more and more about the changes in that area.

Another characteristic of the West coast of Norway is the number of small islands and remote island communities. In these cases, volunteer beach-cleaners are often strongly embedded in their local societies. They will be aware of plastic leakages reported to the authorities and will help mitigate any impact. Anonymity may be the preferred course of action to follow GDPR regulations and prevent possible conflicts of interest when reporting.

8.5.2 Benefits of Using Digital Tools and Engaging Actively with Volunteer Communities

Our interactions with the volunteer networks and participation in the cleanup activities revealed that improved digital tools can facilitate the work of volunteers, by streamlining or even automating the registration process. Indeed, frustration over clunky Web portals or malfunctioning apps, or worse, paper forms that get wet or fly away in the storm, may discourage the volunteers from submitting their data.

The collaboration experience was extremely positive, and the impression is that the volunteers cannot only help test the tools but also act as champions for their adoption by the community if they think it adds value to their work. In the case of PlastOPol, basic bugs were detected in the app when used in the field as well as the need for shorter pathways to the recording of the information so as to avoid unnecessary time spent on a phone rather than picking up litter. As the app is still being piloted and improved, we are unable at this stage to provide numbers of volunteers who have adopted it. In the cases where research is carried out at a more policy-oriented/ innovation level, the volunteers can bring insights on why, where, and in what way waste management is lacking, what incentive orders are needed from the government or what policy should be put in place.

Implications for Research: Working Towards a Practice-Enlightened Tool Development

Academics may tend to pursue what they consider ‘interesting questions’, advance knowledge about how or why a certain phenomenon occurs. In the field of data science, they might, to use an old cliché, develop an entire system from ‘the comfort of their armchair’. These systems and models therefore often do not consider the ways in which an activity is practised or what the needs are for the activity to be carried out successfully and more efficiently. To give a concrete example: a scientist may not be aware of the bias embedded in the data they are looking at; e.g. that the locations reflect where the volunteers go repeatedly for various reasons and are not necessarily representative of the true distribution of marine litter. It is, therefore, essential to understand the activity that a tool is meant to support and even engage in it to experience the different stages at which the tool might come in useful or be redundant. A subtle balance has to be struck amongst the interests of all partakers in the project. Science and technology should be developed but scientists should be challenged to incorporate their end-users in the design (Demirel 2020). In other words, a translator or interpreter should act as a pivot in order to find a common language and interest for the sake of the project’s success.

On the other hand, volunteers will often commit their time and travel distances to attend workshops and seminars on the topic they feel passionate about if they think that a positive outcome is likely. Not delivering and inviting them as a mere box-ticking exercise should be discouraged not only on ethical grounds but also to avoid participation fatigue. A respectful communication should be established, where the volunteers feel that their knowledge is valued, and that their inputs are truly incorporated in the research and tool development.

Science and Digital Tool Development for Transformational Change

Information and communication technology (ICT) and research projects in general can bring something to the political agenda. They can provide a platform for the expert knowledge of volunteers to have a voice, to inform, and contribute to data collection and decision-making. Spatio-temporal visualisation models have the potential to summarise years of scattered efforts into powerful images and provoke reactions. Longitudinal studies using digital tools will generate robust datasets that can be used for image or pattern recognition that would further aid in predictions of sources, abundance, characterisation, and transport of typical litter items. These tools can then assist local and regional policy-making on marine litter prevention.

8.5.3 Using Citizen Science for Preventive Strategy Making

As previously established, preventive strategies are more holistic and effective in battling the marine litter problem than mitigation measures. Indeed, the following debates regarding the collection and removal of marine litter including ALDFG have arisen, to which volunteer and semi-professional beach-cleaners can provide valuable insights through their practical experience in the field.

> As plastics that have been exposed to weathering for years become brittle to the touch or handling, to what point should we strive to extract plastics from a given environment?

This question has attracted attention at national level in Norway and points to the difficulty of handling microplastics and our lack of understanding of the overall effects of leaving plastic in the environment, when compared to handling it for removal. There is no simple answer to this question, and there is widespread scepticism about the benefit of large-scale cleanup operations including complete habitat overturn to remove *macrolitter* from the soil or ocean floors (Buhl-Mortensen and Buhl-Mortensen 2018). However, some industry-led stakeholders may think otherwise and be of the opinion that it is a good idea to involve large machinery and extract entire layers or soil and sediment, even to the detriment of invertebrates and other members of the local fauna and flora.

A second question that divides the community is:

> What is the mass of various plastic polymers collected from the beach clean-up programmes? And how can recordings of beach clean-up be more effective for generating evidence for effective policy making?

The volunteer-based beach cleanup programmes conducted by authorised agencies in Norway typically follow OSPAR regulations to document the retrieved litter items (HN Rent 2021). Although OSPAR guidelines provide a uniform framework for classifying the retrieved items, it only allows users to record the findings based on the size and number of the collected litter. Such a classification approach misses recording the other essential details, such as the quality of the retrieved litter its mass. The lack of mass-based data on collected litter is highlighted as one of the significant limitations in developing a holistic understanding of the mass flows of plastic items across their life cycles (Deshpande et al. 2019). The product mass flows across their life cycle stages are vital for developing preventive strategies for sustainable and circular management of end-of-life products.

The inclusion of these qualitative and quantitative dimension in volunteer recordings may lead to building critical knowledge base for preventive strategies such as polluter pays, extended producer responsibility, or developing sustainable strategies for circular economy in the region.

8.5.4 Limitations

Although volunteers expressed high hopes about the technological achievements of the project, a few issues remain to be addressed. Indeed, to avoid duplication, the current national database and the PlastOPol app should be merged or at least made to communicate with existing national reporting systems; the app should be more user-friendly to really make the registration process easier, and the object detection model's accuracy should be improved through repeated use of the app. This is a work in progress and we still hope to make the tools publicly available and free.

Secondly, although technology can bring publicity to an issue and even push it to the political agenda, there are currently no legal tools to deal with the problem of marine plastic pollution and assign budget and staff at municipality level. This therefore remains, to this day, an idealist issue, and volunteers and school children will continue to bear the brunt of the cleanup process.

8.6 Conclusion

When envisioning research projects and a circular economy, the volunteers will be a keystone agent on several fronts. Their knowledge of the litter hotspots can allow informed remediation efforts enabling material to be reintegrated into the value chain. Meanwhile, local knowledge of volunteers can help identify potential sources of plastic leakage into the environment and thereby inform preventive measures. One could imagine creating a bridge between the different stakeholders to not only recover lost items, but most importantly to avoid the plastic from being discarded in the first place. Indeed, the different local businesses could be connected, and new loops created based on the information gathered by the volunteers.

With their knowledge of local stakeholders and flow patterns of the litter, they could, if engaged honestly, play a crucial part in pointing at all the disjointed ends of the current non-circular system, highlighting areas and stakeholders where there is potential for collaboration and reporting non-compliance to the law. A great incentive for them will be to see a reduction in the amount of litter in the environment they know so well.

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