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Plastic Detectives Are Watching Us: Citizen Science Towards Alternative Single-Use-Plastic-Related Behaviour

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Abstract: The alarming increase in single-use plastic (SUP) consumption, exacerbated by the COVID-19 pandemic and its detrimental effects on environmental and public health, underscores the urgent need for the public to adopt more environmentally responsible behaviours. This study presents citizen science (CS) initiatives undertaken two years after the onset of the pandemic as an effective means to engage and mobilise citizens in reducing plastic consumption. It combines an inventory of CS actions targeting SUP with a self-designed and implemented CS project. Unlike the predominantly technical focus of existing initiatives, our 'Plastic Detective' project was designed to collect behavioural data related to SUP use. The majority of completed and ongoing CS projects addressing SUPs focused on beach clean-ups, which primarily involved reporting the distribution and composition of plastic litter. However, no initiatives were found to address consumer behaviour. CS activities were predominantly initiated in a bottom-up manner, largely coordinated by non-governmental organisations (NGOs), and were mostly confined to the Northern Hemisphere. In our project, volunteers were asked to observe, sample and categorise behaviours in their surroundings using a model that distinguished between SUP use and the adoption of alternative materials or practices. Additionally, participants' perceptions of SUP were assessed through pre- and post-surveys. Our findings reveal that young people, in particular, are eager to participate in CS initiatives. Regardless of age, gender or location, all respondents—despite acknowledging the need to reduce SUP consumption—identified producers as the key group responsible for addressing plastic pollution. We conclude that CS can act as an effective knowledge broker between research and non-research communities, fostering behavioural change towards more sustainable practices. Moreover, CS initiatives can play a vital role in popularising scientific findings and influencing policy-making processes to promote environmentally friendly alternatives to SUPs.

Keywords: citizen science; single-use plastics; circular economy; consumer behaviour; stakeholders; waste management

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Academic Editor: Michele John

Received: 20 November 2024
Revised: 19 December 2024
Accepted: 27 December 2024
Published: 2 January 2025

Citation: Krawczyk, A.; Salas, B.O.; Grodzińska-Jurczak, M. Plastic Detectives Are Watching Us: Citizen Science Towards Alternative Single-Use-Plastic-Related Behaviour. *Recycling* **2025**, *10*, 4. https://doi.org/10.3390/recycling10010004

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1. Introduction

1.1. Plastic Threat to the Environment and Public Health

The global rise in the use of single-use plastic (SUP) products in recent decades has resulted in significant environmental and public health costs [1,2]. The consequences of SUP consumption and disposal are particularly severe when plastics fragment into microplastics, impacting all ecosystems, including marine, freshwater and terrestrial environments, with an unequal distribution and accumulated plastic burden [3]. The contamination of

marine environments originates on land, with rivers acting as vectors for the transfer of these materials from terrestrial to marine environments. Estimates suggest that between 0.41×10^6 and 4×10^6 tons of debris are transported from land to the ocean annually [4,5], underscoring the value of citizen science (CS) projects that collect data from sources other than oceans and beaches. This is a crucial issue, as plastic pollution contributes to the destruction of fauna in terrestrial and aquatic habitats [6,7], water pollution, and greenhouse gas emissions [8], and has many other negative impacts. Chemicals and microorganisms adhere to microplastic particles, potentially contributing to the spread of various diseases [9–11]. In particular, they have been observed to form a biofilm on the surface of microplastic particles, and the resulting 'plastisphere' may contribute to antibiotic resistance [12].

In the case of animals and the public, the consequences of SUP-related consumption and disposal are manifold and pervasive, especially when SUPs fragment into microplastics—particulates 5 mm or less in diameter. Microplastic particulates infiltrate the atmosphere [3], contaminate water bodies [13,14] and harm flora and fauna in terrestrial and aquatic ecosystems [6,7]. They eventually enter the human food system [11,15,16]. The release of plastic waste into the environment is primarily attributed to improper waste management [17], with multiple sources, including tire abrasion [18], textiles [19], cosmetics and paint. As microplastics, they can enter the human body through inhalation, ingestion and/or dermal contact, where they may interact with physiological fluids and tissues. Despite the detection of microplastics throughout the human body, including in human blood [20], placental tissues [21], breast milk [22] and penile tissues [23], the effects of these particles on human health remain poorly understood. However, emerging research suggests that the impacts of plastic compounds on the human body may not be entirely benign. In fact, the majority of studies have reported negative effects on human health when these compounds come into contact with the human body [24].

The accumulation of plastic debris of any size begins inland, particularly in regions exhibiting a pronounced anthropogenic impact [25], underscoring the significance of data collection at the household and community levels [26]. This is particularly pertinent in the context of the COVID pandemic and the subsequent escalation.

1.2. Plastic from Consumption and Legislative Perspectives

In contrast to the prevailing linear production processes associated with the 'take–make–waste' paradigm, the circular economy model adopts a holistic approach that encompasses the entire life cycle of a product—such as plastic—from the initial stage of raw material extraction through the subsequent phases of design, production and distribution, to the ultimate stages of recycling and waste management [27,28].

Consumers play a pivotal role in the success of a circular economy. They can facilitate the transition by adopting sustainable consumption behaviours and extending the lifespan of products [29,30]. Consequently, the growing preference for conscious plastic consumption, particularly in wealthier Western regions, is to prolong lifespans by influencing consumer behaviour and establishing specific obligations for producers and traders [31,32].

In contrast, the United States lacks a federal prohibition on SUPs. Nevertheless, various initiatives have been implemented at both the city (271 local governments) and state levels (e.g., Connecticut, California, Delaware, Hawaii, Maine, New York, Oregon and Vermont) [33]. However, these ordinances only cover 9.7% of the country's population [34]. Canada has recently enacted legislation, designated as the 'SUP Prohibition Regulations', with the objective of achieving its zero-plastic-waste target by 2030 [35]. The implementation of this regulation is occurring in a phased manner, and thus the items under scrutiny remain available for purchase and use by consumers at the time of analysis.

1.3. Citizen Science—Overview

The paradigm of science and the academy has been evolving. Depending on the discipline, scientific research increasingly involves participation from non-scientists, often referred to as amateurs or volunteers. This marks a new era of public engagement in science, redefining the relationship between scientists and volunteers. These volunteers, while not necessarily experts in the research field, are typically educated individuals with a keen interest in the studies. Their involvement stems from various motivations related to science and society, leading to a transformation in the dynamic between scientists and non-scientists [36–40].

CS is broadly defined as 'engagement of the public in research activity, either through intellectual effort or the provision of other resources' [41,42]. Citizen scientists not only contribute to scientific outcomes [26,43] but also co-create new knowledge alongside academics, integrating local, lay or indigenous knowledge [44].

Scientists' understanding of CS, in turn, relates to its ambiguity and multifunctionality [45]: (1) as an avenue for democratisation, participation, equity and social justice in the overall scientific discourse and the creation of scientific agendas [46] and/or (2) as community engagement in scientific activity (i.e., a kind of partnership between scientists and amateurs, for example, to collect and analyse data) [47–51]. Historically, CS was most prevalent in the natural sciences and local history [44]. However, recent advancements in technology have facilitated data collection and sharing, leading to an exponential increase in CS initiatives. Over the past three decades, numerous CS initiatives have emerged, with the majority focusing on biology, conservation, ecology (where CS is used as a methodology for data collection) and geographic information systems (GIS) or VGI (using publicly collected geographic data). Notable examples include iNaturalist, Jelly Watch, Natur Watch, eBird, Coral Watch, Safecast, Citclops and Eye on Water [51–53]. Similar growth has been observed in social sciences and epidemiology, especially in addressing environmental and health-related issues [54].

Despite the growth of CS, doubts persist regarding the scientific quality of volunteer-contributed data [55]. While citizen scientists often remain uncredited in publications, studies show minimal differences in data quality between trained scientists and volunteers [44,56]. Occasional errors in volunteer-collected data can usually be mitigated through more 'direct citizen science' approaches [57].

CS has become integral to modern research, blending methodologies and results into a new paradigm. Digital platforms have further amplified its potential, enabling cost-effective data collection and quality assurance through standardised protocols, methods and training [44,58–62]. Beyond scientific outcomes, CS fosters social innovation and public awareness, empowering individuals to act sustainably in relation to the environment and their own health. However, these initiatives remain more common in developed countries, where fewer structural barriers exist compared to poorer regions [63].

1.4. Citizen Science Engagement in Addressing the Plastic Threat

CS has proven effective in raising awareness and understanding of environmental issues [64–67], including SUPs [30]. In the context of the COVID-19 health crisis, the appeal of plastic, and SUP in particular, was evident in the notable decline in research output in 2022 compared to previous years [68]. During the pandemic, the perception of SUPs as a safer, health-conscious alternative led to a notable surge in its use [43,69,70]. Similarly, the ongoing conflict between Russia and Ukraine has highlighted the usefulness of plastic as a reliable and secure material in the context of humanitarian assistance, particularly as part of internationally coordinated aid operations [71]. However, consumers' assumption that plastic is the most convenient and irreplaceable packaging material is somewhat misguided.

Despite an awareness of the detrimental effects of plastic usage on human health and well-being, consumers tend to engage in environmentally unsustainable behaviours when immediate threats to life and health are present. Moreover, they are largely left to educate themselves. Many rely on online resources for information, but these sources frequently contain misinformation [72,73]. With plastic pollution projected to double by 2040, timely and effective solutions are urgently needed.

One promising approach is leveraging CS to enhance public awareness of the environmental and health challenges posed by SUPs. This paper examines the role of CS in addressing current environmental issues, with a particular focus on the climate impact of SUPs. We also explore the potential of CS to influence behaviour towards SUPs, drawing insights from our self-designed 'Plastic Detective' project. These topics are discussed within the context of the COVID-19 pandemic, which has significantly increased SUP consumption.

2. Results

2.1. Citizen Science Project Inventory

Metadata associated with the CS projects indicated in this paper are stored in the Jagiellonian University and Rodbuk repositories (https://doi.org/10.57903/UJ/LORK2I). The figures below summarise the results of the CS project inventory. The majority of projects focus on pollution or littering from SUPs in or near water bodies, primarily targeting oceans, ocean shorelines, rivers and lakes (Figure 1).

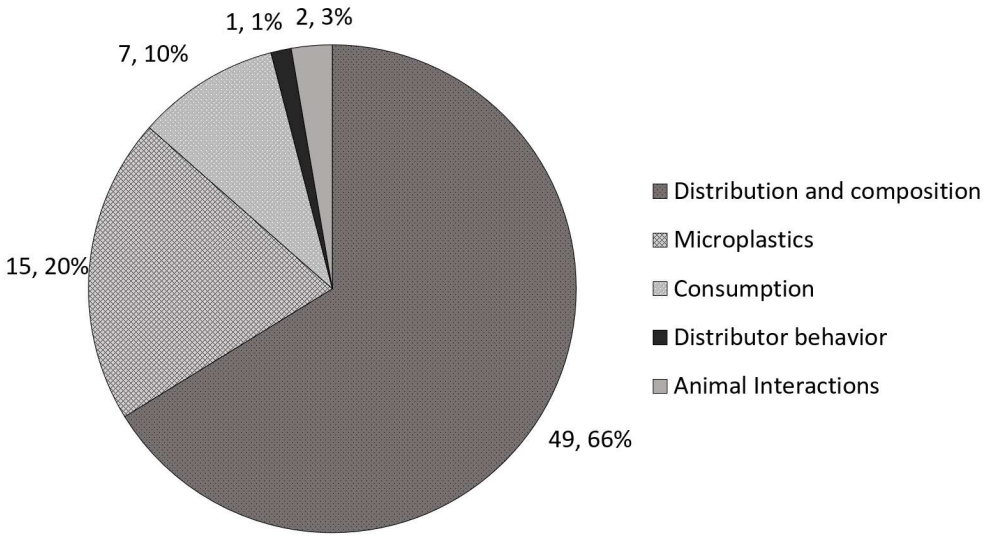


Figure 1. Focus area of the project; with categories presented as absolute numbers and percentages; separated by semicolons.

The remaining projects not directly associated with water bodies can be divided into two categories. The first category includes projects relating to plastic use or litter in specific locations, such as homes, schools or shops. The second category comprises projects focusing on broader community or city-wide initiatives (Figure 2).

A significant proportion of the projects have a global scope, making them accessible to citizen scientists regardless of their geographic location. Other projects have a regional focus, with some open to all countries in Europe, a few limited to specific European countries and others targeting countries in Asia or Africa. The projects that were not global were distributed across continents in roughly equal proportions in Europe and North America, followed by Asia and other continents. Africa, South America and Australia had the least representation (Figure 3). The vast majority of these projects were executed in

the Global North, with the Global South seeing the highest number of initiatives in Asia (Figure 3).

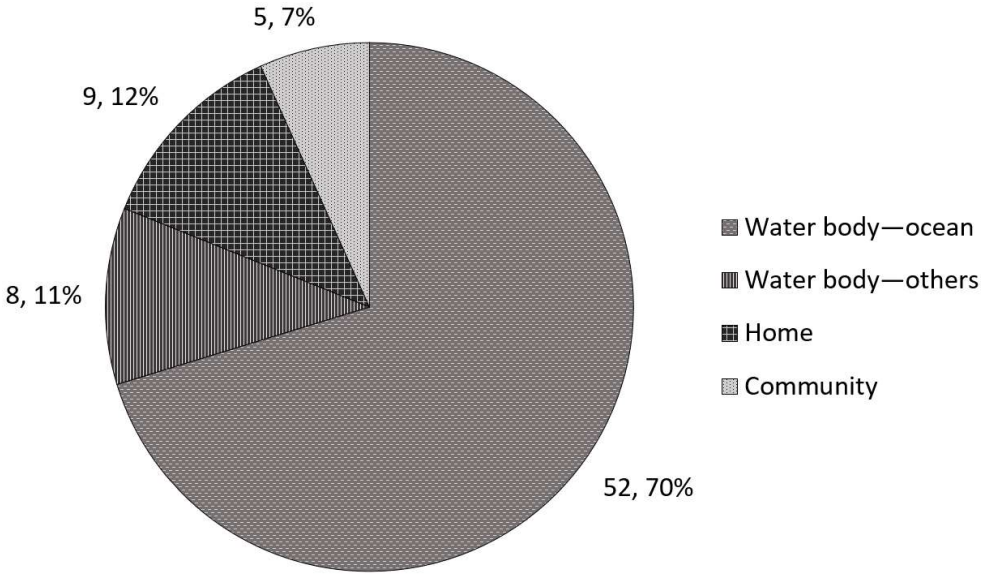


Figure 2. Sample location; with categories presented as absolute numbers and percentages; separated by semicolons.

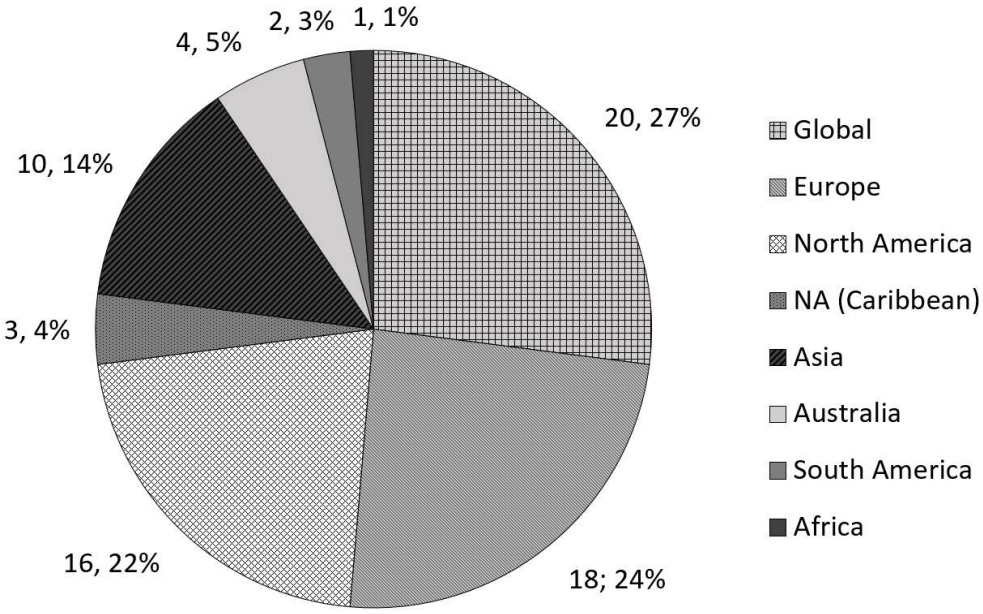


Figure 3. Distribution of the projects; with categories presented as absolute numbers and percentages; separated by semicolons.

In general, CS projects related to plastics are spearheaded by diverse entities, including non-profit organisations, academic institutions, government bodies, private enterprises and combinations of these entities. The data indicate that non-profit organisations (e.g., charities, museums, foundations and funds) were the most involved, followed by academic institutions and government entities. Private companies participated in only 7% of all projects. Collaborative efforts between multiple entities were common, with academia and non-profit NGOs forming the most frequent partnerships (6%). Other combinations, which accounted for $\leq$1% of all projects, included partnerships between academia and government entities; government entities and private companies; academia, government entities and non-profit NGOs; academia, non-profit NGOs and private companies; govern-

ment entities and non-profit NGOs; and government entities, non-profit NGOs and private companies (Figure 4).

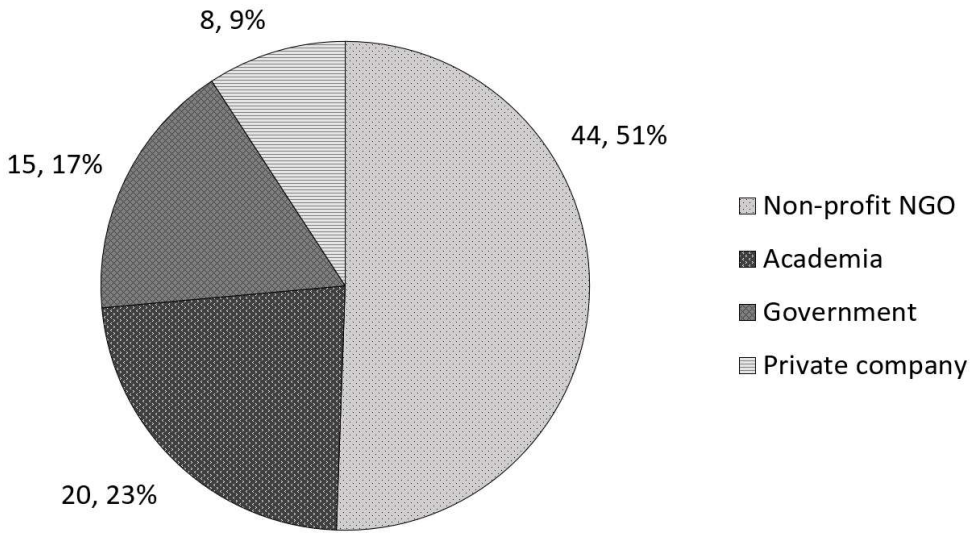


Figure 4. Types of CS project organisers; with categories presented as absolute numbers and percentages; separated by semicolons.

Nearly half of the projects employed an internal method for data or sample collection, which was accessible to the public upon registration. These methods included paper questionnaires/surveys, Google Forms or Microsoft Forms. However, the most common approach to open data collection involved mobile applications, followed by the use of forms provided by a previously referenced CS project platform. Some projects also developed dedicated webpages for data collection, while 6% offered both a mobile app and a webpage. The most unique method of data and sample collection was through the postal service, which was used by a single project (Figure 5).

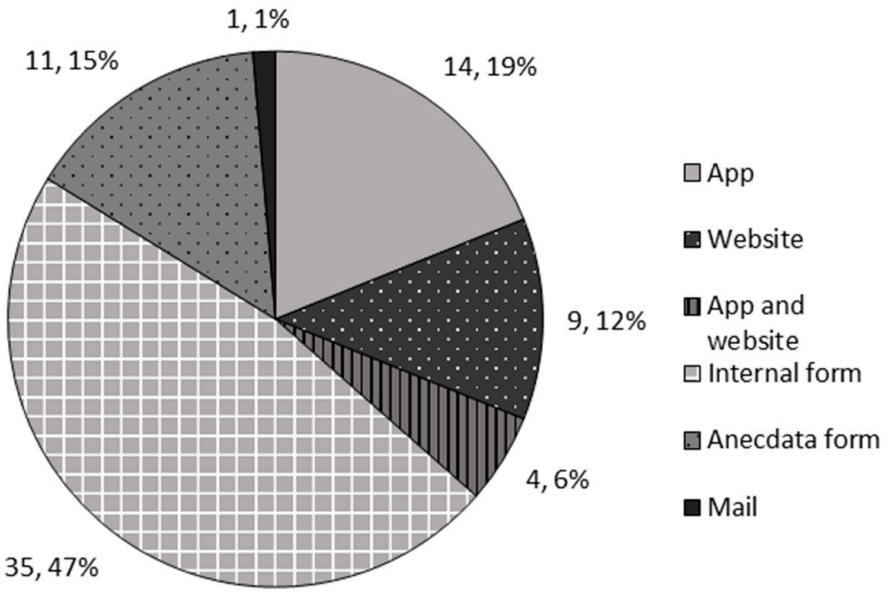


Figure 5. Methods of data collection within the projects, with categories presented as absolute numbers and percentages separated by semicolons.

The majority of the investigated projects (66%) focused on the quantity, distribution and composition of plastic litter. Most of these projects adopted a beach clean-up methodology, which followed a similar structure across initiatives. Participants were tasked with

collecting plastic waste, recording key details of what was collected (e.g., location, type of plastic and images), sharing the collected data and disposing of the plastic appropriately. The objective was to clean up litter while simultaneously raising public awareness about the scale of the plastic problem.

The second most common area of focus was microplastics (20%), with projects similarly structured to those addressing plastic litter. These initiatives emphasized the collection and documentation of data on the quantity and distribution of microplastics. A total of 9% of the projects were concerned with the consumption of SUPs, with the overarching objective of enhancing awareness about plastic usage, both at home and in educational settings. Two projects (3%) focused on animal interactions, seeking to document instances of wild animals interacting with plastics, primarily in marine environments. Finally, one project (1%) asked citizen scientists to document examples of plastic packaging in retail settings to identify sources introducing plastic packaging into the supply chain of sold products.

2.2. The Plastic Detective Project

The website for the 'Plastic Detective' project received 260 visits, with 177 respondents completing a survey, yielding a notably high response rate of 68%. Valid survey entries were collected from the following countries: the USA (93 entries), Poland (59 entries), Italy (17 entries), Germany (12 entries), France (11 entries), Canada (10 entries), The Netherlands (2 entries), Belgium (1 entry) and Spain (1 entry).

The gender distribution of participants was skewed towards women, who accounted for 57.6% of respondents, compared to 41% men, 0.5% non-binary individuals and 1% who chose not to disclose their gender. The most represented age group was 25–34 years (29.5%), followed 18–24 years (24.8%), 44–54 years (18.1%), 35–44 years (11.0%), 55–64 years (10.0%), 65–74 years (5.2%) and those aged 75 and above (1.4%). With regard to waste segregation practices, plastic was the most frequently segregated category (N = 147 instances), followed by paper (N = 132), glass (N = 121), metals (N = 91) and organic matter (N = 88).

Participants in the 'Plastic Detective' project were asked to evaluate their perceptions of the feasibility of living without SUPs before and after participating in the project. No statistically significant difference was observed in perceptions across all participants (p = 0.087; Figure 6). The analysis only included participants who completed both the pre- and post-participation surveys (N = 64).

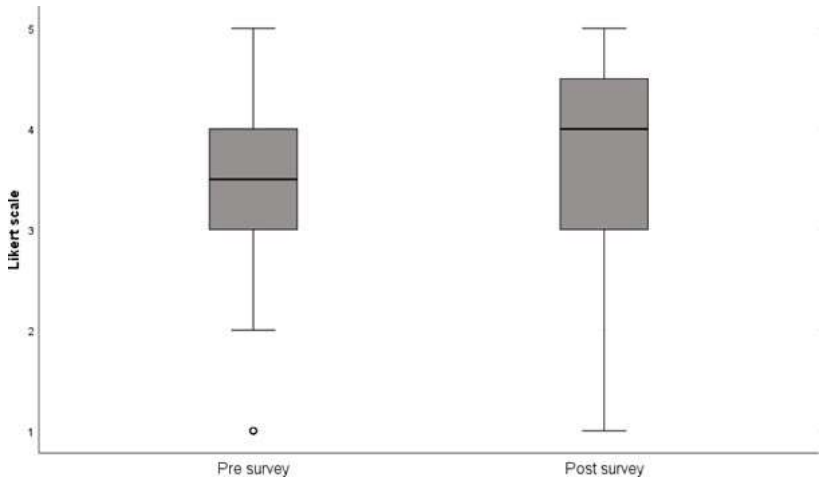


Figure 6. Distribution of participants' responses to the question 'How realistic is it to live without single-use plastics?' in the Pre-survey and Post-surveys from all of the regions. The y-axis values are the possible responses on a 5-point Likert scale ranging from 1 (not realistic at all) to 5 (extremely realistic).

Participants were then asked to provide a rationale for their responses regarding the feasibility of living without SUPs. In the pre-participation survey (Table 1), the most frequently cited reasons for selecting either response one or two were the widespread availability, convenience and low cost of SUPs. For those who selected the third option, the hygienic benefits of SUPs in the medical and food industries were emphasised, along with their extensive availability, the challenges of avoiding them in certain contexts and the difficulty of changing consumer behaviour. Participants who answered four or five highlighted the availability of reusable alternatives, as well as the necessity of changing consumer behaviour. Additionally, some referenced the historical absence of plastics, suggesting that a return to a pre-plastic lifestyle is feasible.

Table 1. Frequency of pre-participation survey responses regarding answers to the question 'How realistic is it to live without single-use plastics?' A score of 1 indicates not realistic at all, while a score of 5 indicates very realistic.

Category	1	2	3	4	5	Total
Available reusable alternatives	0	1	6	13	12	32
Sanitary properties	2	1	9	8	0	20
Wide availability	4	6	8	1	0	19
Convenience	4	6	3	4	0	17
Difficult to change	0	2	7	3	0	12
Low cost	1	4	6	1	0	12
Consumer behaviour change	0	0	0	2	7	9
Ineffective alternatives	2	2	3	1	0	8
Pre-plastic lifestyle	0	0	1	0	6	7
Lack of industry interest	1	0	4	0	1	6
Lack of reusable alternatives	2	0	4	0	0	6
Lack of legislation	0	1	4	0	0	5
Environmentalism	0	0	1	2	2	5
Lack of awareness	0	1	2	0	0	3
Political hurdles	0	0	2	0	1	3
Increasing awareness	0	0	0	2	0	2
Existing legislation	0	0	0	2	0	2
Ineffective recycling measures	0	0	0	1	0	1
Ineffective reduction measures	0	0	1	0	0	1
Consumerism	0	1	0	0	0	1

The rationale behind the responses to the question 'To what extent is it feasible to live without SUPs?' from the post-survey are outlined in Table 2. Participants who selected the first or second option cited the widespread accessibility, ease of use and affordability of SUPs, along with the prevailing societal inclination towards consumerism, as key factors influencing their decision. For those who chose the third option, the most frequently cited reason was the difficulty associated with transitioning from single-use to reusable items. Participants who answered four or five highlighted the availability of reusable alternatives, the need for changes in consumer behaviour and increased awareness of the issues related to SUP usage as significant factors.

Table 2. Frequency of post-participation survey answers regarding the reasoning behind the answer to the question 'How realistic is it to live without single-use plastics?', where 1 is not realistic at all and 5 is very realistic.

Category	1	2	3	4	5	Total
Available reusable alternatives	0	1	2	4	4	11
Consumer behaviour change	0	0	1	3	4	8
Increasing awareness	0	0	2	4	0	6
Difficult to change	1	0	3	0	0	4
Convenience	1	0	0	2	1	4
Low cost	0	1	2	0	0	3
Sanitary properties	0	1	2	0	0	3
Wide availability	0	1	2	0	0	3
Environmentalism	0	0	0	3	0	3
Ineffective alternatives	0	0	2	0	0	2
Consumerism	0	1	0	1	0	2
Lack of legislation	0	0	0	0	2	2
Pre-plastic lifestyle	0	0	0	0	1	1
Lack of necessity	0	0	0	0	1	1
Lack of industry interest	0	0	1	0	0	1
Existing legislation	0	0	0	1	0	1

The respondents were asked to rank the following groups to assess their perceived importance in the fight against SUPs. In the pre-participation survey, producers were identified as the most important group, followed by politicians, consumers, scientists, recyclers and journalists. This ranking was maintained in the post-participation survey (see Table 3 and Figure 7). A comparison of the pre- and post-participation survey responses showed no statistically significant differences across all stakeholder groups (producers: $p = 0.493$, scientists: $p = 0.116$, consumers: $p = 0.291$, recyclers: $p = 0.136$, journalists: $p = 0.568$, politicians: $p = 0.814$).

Table 3. Mean values and significance based on stakeholder and survey group (pre- or post-participation survey) differences.

Stakeholder	Negative Ranks			Positive Ranks			Ties	Z	*p*
	N	MR	SR	N	MR	SR			
Producers	14	11.43	160.0	9	12.89	116.0	37	–0.685 [a]	0.493
Scientists	15	13.87	208.0	19	20.37	387.0	26	–1.571 [b]	0.116
Consumers	10	9.55	95.5	12	13.13	157.5	38	–1.056 [b]	0.291
Recyclers	17	14.71	250.0	10	12.80	128.0	33	1.493 [a]	0.136
Journalists	9	13.33	120.0	14	11.14	156.0	37	–0.571 [b]	0.568
Politicians	10	15.80	158.0	14	10.14	142.0	26	–0.236 [a]	0.814

Note: MR = mean ranks; SR = sum of ranks; Z = Wilcoxon signed-rank statistic; *p* denotes statistical significance; a. based on positive ranks; b. based on negative ranks.

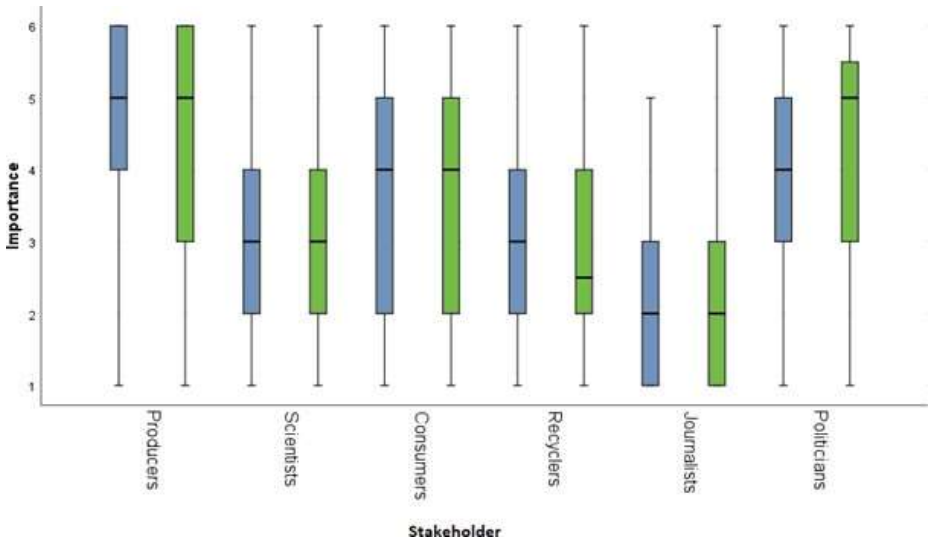


Figure 7. Distribution of participants' responses to the question 'Please rank the following groups by importance in the fight against single-use plastics' in the pre-participation (green) and post-participation (blue) surveys. The *y*-axis values denote the rankings of stakeholders by importance, ranging from 1 (least important) to 6 (most important).

3. Methods

3.1. Citizen Science Project Inventory

The CS inventory compiled past and ongoing CS projects related to plastics through a Google internet search conducted in September 2022 using the predefined keywords 'citizen science', 'participatory science', 'community science' and combinations of the term 'single-use plastic' with one of the previous terms. From this search, the following CS project platforms were identified and utilised: eu-citizen.science (https://eu-citizen.science/, accessed on 12 September 2022), SciStarter (https://scistarter.org/, accessed on 12 September 2022), AnecData (https://www.anecdata.org/, accessed on 12 September 2022), Zooniverse (https://www.zooniverse.org/, accessed on 12 September 2022), and the European Commission's 'Citizen Science—Citizens' Data' collection (https://data.jrc.ec.europa.eu/, accessed on 12 September 2022). Only projects with a primary focus on plastic, which provided a sufficient and clear description of their methodology and objectives and were advertised and presented in English, were included. In total, 74 plastic-related CS projects (49 active and 25 completed) were identified (Appendix A) and categorised by the location of interest, organising and funding, focus, data collection method and scope and distribution.

3.2. The Plastic Detective Project

The objective of the 'Plastic Detective' project was to gain insights into citizens' consumption of SUPs. To achieve this, volunteers committed to environmental stewardship and willing to engage in the project were recruited. Calls to action were posted on various CS platforms, including SciStarter, Anecdata and eu-citizen.science, and were shared on dedicated Facebook and Twitter groups. The groups were identified through keywords such as 'sustainable', 'plastic-free', 'zero-waste' and 'plastic'. Snowball sampling [74] was also used an to identify relevant Twitter accounts with large followings, which were then contacted directly and asked to promote the project.

We provided each volunteer with a detailed description of the 'Plastic Detective' requirements and regulations. Volunteers were then tasked with monitoring the usage of SUP items by individuals in their respective communities (see Appendix A). They were

asked to select individuals—such as family members, colleagues, partners or friends—to observe and categorise the types and quantities of plastics consumed daily.

Data were collected via an online survey using the ArcGIS CS tool 'Survey123', which remained open for 140 days, from 2 December 2022 through 21 April 2023. Of particular interest were the quantities and types of SUP items (e.g., PET bottles and plastic shopping bags), as well specific instances of their use. Plastic Detectives were free to observe as many individuals as they were willing to monitor. No sensitive or personally identifiable data were collected.

The items selected for analysis were chosen due to their high availability, frequent use, inclusion in the EU Directive 2019/904 on reducing the impact of certain plastic products on the environment and their relevance according to previous studies on SUP item consumption. These items included plastic SUP bags [75], bottles [76–78], straws [79], cups [80], cutlery and containers [80–82]. Sanitary items, such as gloves, protective masks and shaving razors, which are not covered by the directive, were also included in the survey.

The 'Plastic Detective' survey consisted of three sections: (i) a pre-participation survey, (ii) the CS questionnaire and (iii) a post-participation survey (see Supplementary Materials). Before deployment, pilot testing was conducted with participants whose profiles were similar to those of the target respondents. The majority of the statements were clear, with only a few requiring linguistic modification. The pre- and post-participation surveys each took approximately five minutes to complete, while the main CS questionnaire required 10 min on average.

The pre- and post-participation surveys comprised three demographic questions (age, country of residence and gender), a ranking of SUP stakeholders by importance (producers, politicians, consumers, scientists, recyclers and journalists) and an assessment of the feasibility of living without SUPs, presented as both a Likert item and an open-ended question.

The CS questionnaire could be completed multiple times, allowing for data to be collected on multiple observed individuals. Respondents were asked to provide demographic details about the observed person (age, country of residence, gender and household size). No sensitive data were gathered, and the procedure ensured that individuals observed could not be identified. The questionnaire consisted of 12 closed questions on the use of specific SUP items, their alternatives or associated behaviours. An 'Other' option was provided to allow participants to share additional thoughts or observations.

In summary, the questionnaire analysed four categories of SUP-related behaviours: (1) use of SUP items, (2) use of single-use non-plastic items, (3) use of multiple-use items and (4) non-use of the item (alternative behaviour).

Our principles are rooted in working 'lege artis', upholding strict honesty regarding both our own contributions and those of others. Scientists involved in the project maintain regular contact, sharing knowledge and experiences to support one another. The performance of all tasks is carried out with a strong sense of responsibility.

Respondents were not asked to disclose their identities, and the information collected was associated with pseudonyms rather than their real names. There were no foreseeable risks to participants in the study. Participation was entirely voluntary, with no penalties for opting out. Respondents were not obligated to answer any questions they preferred to skip and could withdraw from the study at any time for any reason.

4. Data Analysis

A Wilcoxon signed-rank test for paired samples was conducted to analyse discrepancies between pre- and post-participation survey responses. Rankings of SUP stakeholders

were assigned values between six (highest importance) and one (lowest importance), creating an index. Median differences in stakeholder rankings were then analysed.

For the CS data, responses were independently analysed based on the number of respondents per question. The mean values for each target were evaluated using demographic variables as defining factors in the model. Each item in the survey was assigned a SUP consumption score on a scale of 1 to 4. A score of 1 indicated that the item under observation was not used by the target, while a score of 4 indicated that the target used a SUP item. Items falling into the other two ordinal categories were assigned scores of 2 and 3, respectively. A lower score indicated a greater distance from the use of SUP items and a closer proximity to a behaviour conducive to a circular economy (i.e., lower consumption levels). The Kruskal–Wallis test was used to analyse consumption scores across age and gender groups. All analyses and visualisations were performed using the statistical software package SPSS Statistics 21.

5. Discussion

5.1. Have CS Activities Responded to the Increased Plastic Threat During the COVID-19 Pandemic?

Although public awareness of the environmental threat posed by plastic to the natural environment and public health was relatively high before the COVID-19 pandemic, its consumption, especially of SUPs, increased dramatically during the early stages of the pandemic. Not surprisingly, health safety issues took precedence over environmental issues, such as the climate crisis, much of which is exacerbated by plastic production [29,83]. A return to eco-friendly attitudes will take time, and there remains a wide variation in the decline of plastic consumption, depending on geographic, socioeconomic and cultural circumstances [84].

The CS projects presented here are dated late 2022, nearly two years after the initial pandemic outbreak in Huan, China [85]. Due to lockdown restrictions, public activities were limited, resulting in a significant increase in the number of projects initiated. However, these projects were not evenly distributed thematically, geographically or institutionally. Our inventory may not offer a complete picture of CS on SUPs, as some projects were not reported in the scientific literature or were not published in English. Others may have been withheld due to controversial links to plastic commercialisation or social outcomes during the pandemic [37], while some were still in the process of time-consuming fundraising efforts.

The majority of CS projects in our inventory focused on the distribution and composition of SUPs, which aligns with findings from previous studies that have used CS-collected data [86,87]. Microplastics were the second most common focus, as they have been identified as a threat to aquatic and terrestrial ecosystems [25,88,89].

While understanding consumer behaviour towards plastic is crucial for gaining insights into consumer choices, it remains largely underaddressed by legislation, policy and research. The latter remains practically unexplored [90], and despite varying national, administrative and cultural circumstances, legislative strategies for minimising SUP usage have achieved only moderate effectiveness, mostly focusing on technical and logistic solutions.

The validity of collecting primary data from individual consumers (e.g., through surveys) is often questioned due to concerns about the accuracy of the information provided [91]. Therefore, employing CSs as objective data collectors, rather than relying on direct respondents, is a valuable approach.

One of the principal advantages of CS-based research methodologies is that they provide access to previously inaccessible information. As a result, many of the CS projects

examined in this study are of a significant scale, spanning global, regional and national levels, capitalising on the cost-effective nature of the approach [92]. Europe and the United States are at the forefront of CS, as evidenced by the findings of Figueiredo et al. [91] and Gura [60]. Notably, the US also has the highest number of identified plastic-related CS projects. Although there are CS projects based in some Asian countries, more projects gather data from these countries, aligning with the official statement of the ASEAN (Association of Southeast Asian Nations), which claims that its member states are among the world's largest sources of plastic pollution [93]. Given the global reach of the inventoried projects, we limited our assessment to the availability and use of SUP products, excluding waste management systems, which vary across the inventoried countries.

5.2. Does CS Matter? Effects of CS on Perceptions of Plastic

In contrast to the technical nature of most CS initiatives focused on plastic, our project, 'Plastic Detective', was designed to collect behavioural data on SUP items. Through this, we aimed to explore the potential for changing public behaviour towards SUPs.

The participants in the 'Plastic Detective' project were predominantly young, aged 18–24 and 25–35 years, with women being more active than men. This is consistent with previous studies on environmental activism, including CS [40]. The 'Plastic Detective' project, which specifically examined the use of plastic grocery bags, indicated that social pressure is a significant factor in encouraging the transition from plastic to reusable cloth grocery bags [94]. The study suggested that individuals are more likely to adopt cloth bags if they see others in their social circle using them. Additionally, the implementation of legislative measures, such as charging for plastic bags, has been shown to increase the use of reusable bags [95,96]. This finding could be extrapolated to other commonly used SUP items, such as straws [79], take-out containers, cutlery [97] and cups [80], and supports the effectiveness and importance of legislative action in reducing SUP usage.

A lack of usage of a particular item, as evidenced in the 'Plastic Detective' survey, will result in a reduction in its consumption score. This could explain the lower values for items like straws, which some researchers have identified as relatively easy to stop using or boycott [79,98]. However, if a participant does not directly observe the use of an item, they may perceive it as not being used (non-response bias). Consequently, the consumption scores for both the item and the participants may not accurately reflect the actual frequency of use.

The importance of legislation limiting access to SUPs is supported by the literature [95,96,98–100] and is a widely accepted in society [79,101,102]. Despite the EU SUP Directive's emphasis on banning or limiting SUPs through the introduction of single-use alternatives (e.g., eco-containers made of paper), it does not explicitly endorse the use of reusable items. However, the objective of a circular economy approach is to focus on product design and waste prevention. In contrast, Harris et al. [102] found no significant reduction in packaging debris on shorelines following the introduction of an extended producer responsibility policy, which indirectly limits access to SUPs by shifting the waste management responsibility to producers. This policy incentivises waste reduction, for example, through improved product design. However, plastics remain the most segregated category of recycling, suggesting that SUPs may be reincorporated into the economy.

The findings of the 'Plastic Detective' project are based on the observations of citizen scientists, whose accuracy and rigour in data collection are generally comparable to those of professional academics [103]. However, for studies requiring a high degree of scientific rigour or technical expertise, the quality of the results may be compromised [104,105]. The limitations of the 'Plastic Detective' project are related to the small number of observations, which can be attributed to a moderate response rate to our call for participation. Therefore,

the results may not fully represent the activities of citizen scientists in relation to plastic or the demographic and behavioural characteristics of each region. Nevertheless, the findings offer a preliminary observational inventory that provides insights into the threat of plastics and lays the foundation for future collaborations between academics, citizen scientists and policymakers. Without active public involvement in addressing environmental risks, such as climate change and plastic pollution, it is unlikely that these issues can be effectively resolved [83,106]. To facilitate this process, further research is recommended, employing a larger and more representative sample size and utilising an improved structure and dissemination method.

The participants' perceptions of the feasibility of living without SUPs remained consistent between the pre- and post-participation surveys in the project. Although CS has been shown to enhance participants' knowledge, awareness and understanding [64–67], it has also been found to have little impact on behavioural changes [65]. This may be because the quantification and realization of the degree of SUP use by those around them were insufficient to effect a change in their perceptions. Alternately, this could be attributed to the participants' already high environmental awareness, as their participation in the CS project suggests a pre-existing interest in the issue. It may also reflect a maintenance of their stance, regardless of the project's impact, leading to a response shift bias [107–109].

In both the pre- and post-participation surveys, the most frequently cited reasons for why it is realistic to live without SUPs were the availability of reusable alternatives and the support of the literature [110–113]. This idea is further elaborated by Heidbreder et al. [79], who found that ethical consumers not only refuse to purchase products or brands that they deem inappropriate but also engage in 'buycotts' (i.e., promoting and praising alternative products or brands). The notion that consumer behavioural change is a key factor in living without SUPs places the onus of transitioning to a circular economy on consumers. This is corroborated by Cowan et al. [101], who identified consumer behaviour and purchasing patterns as primary contributors to plastic pollution. Respondents also cited consumer behaviour as a reason why a SUP-free lifestyle is not a realistic option. The majority of responses indicated that it is a challenging transition, with the convenience and low cost of SUP items identified as the primary reasons for the difficulty transitioning to reusable items, even when such an option is available. This finding is consistent with the results of Jahani et al. [82], who identified situational influences as a barrier to reducing the use of SUP items. Sanitary concerns are frequently cited as reasons for the middle-ground ratings given by respondents. Indeed, in the wake of the global pandemic, the health benefits of the sterile conditions provided by SUPs have been emphasised by several researchers [29,114,115].

In response to the question of which stakeholders bear responsibility for combatting SUPs, participants identified producers as the most culpable party, not mentioning consumers. This may be due to the fact that the life cycle of an SUP item begins at the point of production. It is the responsibility of politicians, or those who create policy, to regulate the availability of SUP items and alternatives. Banning SUP items would stop their production, thereby removing them from the market and preventing consumer purchases. Consumers are regarded as the third most important group in the fight against plastic, possibly because they are more likely to purchase what is readily available to them. Nonetheless, research indicates that consumers are aware of their role in fighting plastic pollution [80]. The scientific community, recycling industry and members of the press were regarded as the least influential stakeholders, likely due to having direct involvement with SUPs compared to the other key stakeholders. This aligns with findings indicating that consumers emphasise the importance of behavioural change and policy, while industry stakeholders place greater importance on the scientific community [101,116].

6. Conclusions

Plastic products are cheap, useful and convenient in daily life, and thus they have an important impact on consumer choices. However, due to the growing evidence on their toxicity to the environment and public health, alternatives to SUP production and their perception seem to be the most obvious solution [117,118]. CS can play an important role in national discourse aimed at developing solutions to urgent social issues. It is essential for representatives from the scientific, political and civil society sectors to collaborate in an efficient and sustainable manner. Citizens should be involved from the outset and throughout the decision-making process. In this way, CS provides a valuable opportunity to strengthen the connections between society, politics and science, contributing to the sustainable transformation of society [44].

The most promising proposals to minimise SUPs are as follows:

(1) Systemic formal (schools) and non-formal (CS and campaigns) education aimed at promoting environmental awareness and eco-friendly behaviour. This should be combined with economic measures (e.g., taxes and incentives) and a legislative framework to reduce SUP production. Banning SUPs has proven to be less efficient than imposing economic measures (taxes and levies) on consumers. Education programmes should be tailored to specific groups and carefully evaluated for effectiveness, as they vary significantly across regions and countries [117,118].

(2) A complete replacement of SUPs with other products (e.g., paper) is not a sustainable solution, as it merely perpetuates the problem. Mult-use items are much better for the environment, public health and public acceptance [117].

(3) Local municipal management systems, supported by law and clear management strategies (e.g., transparent recycling systems, reasonable prices and continuous monitoring), can increase public awareness and encourage the proper implementation of eco-friendly practices in daily life [118].

(4) A broad communication and information system is necessary to inform the public about the potential threats of single-use product pollution (not just SUPs) and provide recommendations on how to minimise it at individual and local level. This includes incentives for exchanging SUPs for multi-use and/or alternative products, deposit systems and penalties for littering or not recycling [119,120].

(5) Future research should focus more on consumer behaviour and evaluate the impacts of various methods on eco-friendly practices [121]. An emerging area of interest is novel methodologies, such as machine learning, to predict plastic pollution and assess the effectiveness of policy interventions. This research should be based on large datasets, ideally combining multiple levels of data with socioeconomic information [122]. CS could support such predictive models.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/recycling10010004/s1, Supplementary Materials: Surveys & Questionnaire.

Author Contributions: Conceptualization, methodology, software, validation; formal analysis, data curation, writing—original draft preparation: A.K.; B.O.S.; writing—review and editing,; visualization, supervision, project administration, funding acquisition, investigation, resources: M.G.-J. All authors have read and agreed to the published version of the manuscript.

Funding: The publication has been supported by a grant from the National Science Centre, Poland 2020/39/B/HS4/00264.

Data Availability Statement: The original data presented in the study are openly available in the Jagiellonian University and Rodbuk repositories at https://doi.org/10.57903/UJ/LORK2I.

Conflicts of Interest: The authors declare no conflicts of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

Appendix A. Table of Projects

No.	Name of Project	Organizer
1	Dive Against Debris	PADI Aware
2	River Survey	The Ocean Clean Up
3	Ocean Survey	The Ocean Clean Up
4	Marine Debris Tracker	Morgan Stanley, National Geographic Society and the University of Georgia
5	International Coastal Cleanup	Ocean Conservancy
6	Litterati	Litterati
7	Plastic Pirates—Go Europe	European Union
8	2 min beach clean/2 min litter pick up	The 2 Minute Foundation
9	CoastWatch Micro Litter Survey	European Commission
10	International Pellet Watch	Laboratory of Organic Geochemistry, University of Agriculture and Technology
11	Marine LitterWatch	European Environment Agency
12	The Great Nurdle Hunt	Fidra
13	The RIMMEL project	European Commission
14	The Plastic Tide	Zooniverse by The Citizen Science Association
15	Plastic Origins	Surfrider Foundation Europe
16	Ocean Initiatives	Surfrider Foundation Europe
17	Plastic Citizen	University of Hull
18	No Home for Plastic	VOICE
19	Stay at Home—Household Waste Audit	S.C.R.A.P. Gallery
20	#ECOSQUADGOALS	De La Salle University
21	#OpenLitterMap	GeoTech Innovations
22	Clean Sea LIFE	Parco Nazionale dell'Asinara
23	Plastexperiment	Vetenskap and Allmänhet (VA—Public and Science) and the University of Gothenburg
24	Plastic Spotter	Leiden University Citizen Science Lab
25	OSPARITO	Surfrider Foundation Europe
26	Surfing for Science	Universitat de Barcelona, Surfrider Foundation and EarthWatch
27	Pescadores de Plastico	BETA Technological Center (University of Vic, Central University of Catalonia)
28	ePollution	eOceans
29	Tangled in Trash: A Reporting Tool for Wildlife	National Marine Sanctuary Foundation
30	Shorelines Cleanup	San Antonio Bay Partnership
31	Nurdle Patrol	Mission-Aransas National Estuarine Research Reserve
32	BeachWatch—Plastics Brazil	UFABC
33	TIDES—Trash Information and Data for Education and solutions	Ocean Conservancy
34	The Big Microplastic Survey	Just One Ocean and University of Portsmouth
35	AMDI—Australian Marine Debris Initiative	Tangaroa Blue Foundation

No.	Name of Project	Organizer
36	MDMAP—Marine Debris Monitoring and Assessment Project	NOAA
37	Florida Microplastic Awareness Project	University of Florida and IFAS Extension
38	Litter-free Digital Journal	South Carolina Aquarium
39	Plastic Litter Project: Coastal Litter Mapping	University of the Aegean
40	Microplastics Pollution Monitoring Program	Ocean First Institute
41	Programa de Monitoreo de Desperdicios Sólidos	LabCom (Reserva Natural Ciénaga Las Cucharillas run by Caras con Causas)
42	Explosive Shock Tube Data Collection	Center for Coastal Studies
43	Kinh Tế Sinh Thái Việt Nam	Key-Log Economics
44	Maine Microplastic Monitoring	Community Environmental Health Lab—MDI Biological Laboratory
45	Plastic Pollution: Impacts on Wildlife	Cape Eleuthera Institute
46	OIB Beach Garbage Pickup	Ocean Isle Beach Sea Turtle Protection Organization
47	Testing Our Waters	Anthropocene.Design
48	Freshwater Microplastics in Maine	Lakes Environmental Association
49	Airborne Microplastics	INBRE—Northwest College
50	Exploring the Marine Microbiome	MDI Biological Laboratory
51	Eco-Schools Bahamas: Shopping Bag Challenge	Bahamas Reef Environment Educational Foundation (BREEF)
52	Surfers Against Sewage	Surfers Against Sewage
53	Beat the Microbead	Plastic Soup Foundation and UNEP
54	Strengthening and Improving Marine Litter Response in Indonesia	Korean Ministry of Oceans and Fisheries, Korea Marine Environment Management Corporation, Our Sea of East Asia Network (OSEAN), and the Indonesian Waste Platform (IWP)
55	Mesoplastic on the Polish Coast	Institute of Oceanology of the Polish Academy of Sciences and Experiment Science Centre in Gdynia
56	Break Free From Plastic	Greenpeace
57	Quantity and type of coastal debris pollution in Taiwan	IndigoWaters Institute and Institute of Marine Affairs and Resources Management
58	Preventing Plastic Pollution	Interreg France (Channel) England Programme and 18 other orgs
59	Fish Feed Bag	Plastic Free Seas
60	Produce Packaging Project	Plastic Free Seas
61	Citizen science project in Chile	Carla Wichmann and team
62	CounterMEASURE	UNEP
63	Mapping Portsmouth's Plastic	University of Portsmouth
64	MarineQuest	University of North Carolina Wilmington and 2TC
65	Community's Awareness on the Use and Address of Municipal Plastic Waste	The Research Center for Gender, Family, and Environment in Development
66	Microplastic Detective	Ecological Observation and Wetlands Conservation
67	Investigation of Plastic Types in Households and Waste Banks	Nexus Foundation for Environmental Health and Development
68	National Marine Debris	CSIRO
69	Clean Up Australia's Citizen Science Project	Clean Up Australia
70	COLLECT—Citizen Observation of Local Litter in Coastal ECosysTems	Partnership for Observation of the Global Ocean

No.	Name of Project	Organizer
71	Australian Microplastic Assessment Project	Total Environment Centre
72	Citizen science on the Waddenzee	The Ocean Movement
73	Picking Up the Pieces	Environment Climate Change Canada, Ocean Diagnostics
74	Mass Experiment	Danish National Center for Science Education and Roskilde University

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