Plastic detectives and wildlife guardians: impact of volunteers monitoring plastic pollution and wildlife on science, society, and nature

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Chapter 6

Synthesis, discussion, and recommendations

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Public participation in environmental monitoring has become increasingly important to address major global environmental threats and mitigate their consequences. Citizen science facilitates large-scale data collection while enhancing scientific literacy and environmental awareness (Bonney et al., 2009; Haklay et al., 2021). However, the success of citizen science depends on the recruitment and retention of participants, which requires a better understanding of their backgrounds, motivations, and engagement over time (Robinson et al., 2018). Despite the rising number of citizen science projects tackling plastic pollution, research on the characteristics and experiences of participants remains limited (Follett & Strezov, 2015; Nelms et al., 2022; Rambonnet et al., 2019). Moreover, existing studies have mainly concentrated on schoolchildren rather than adult volunteers (Locritani et al., 2019; Wichmann et al., 2022). Furthermore, innovative strategies are required to broaden participation beyond the highly educated demographic typically involved in citizen science (Pateman et al., 2021). This dissertation addresses these gaps by examining participants in plastic pollution citizen science projects and exploring alternative data collection methods for environmental monitoring. This chapter synthesizes key findings, discusses their implications, and offers recommendations for researchers and practitioners.

Plastic citizen science provides a distinctive context for studying how people engage with environmental research. Unlike many other citizen science fields, plastic pollution is highly visible and directly connected to people's daily lives, linking individual behaviour with global environmental problems (Rambonnet et al., 2019; Krawczyk et al., 2025). Its tangible and local character makes participation immediately meaningful: volunteers can see the problem and contribute to visible improvement. This combination of action and observation means that participation often feels both scientific and practical, or even activist in nature (Wyles et al., 2017; Nelms et al., 2022). Studying this context helps to understand how awareness, motivation, and civic engagement reinforce one another in citizen science (Pateman et al., 2021).

6.1 Synthesis

Aim 1: Identify background, motivation, and expectations of plastic pollution citizen scientists

This objective was addressed in the first study (**Chapter 2**), which examined citizen scientists involved in the Clean Rivers project, a collaborative citizen science initiative monitoring plastic pollution along Dutch riverbanks since 2017. We surveyed 122 Clean Rivers volunteers before and after their first year of participation to assess their backgrounds, motivations for joining, and expectations of the project. The participants were predominantly highly educated (about 75% held higher education degrees) and middle-aged (58% were between 45 and 65). The gender distribution (approximately 53% female, 47% male) closely matched that of the general Dutch population, indicating that Clean Rivers engaged both men and women nearly equally. Over half of these volunteers (52%) had participated in a cleanup activity before joining, suggesting a pre-existing interest in environmental action. However, only a small group (12%) had prior experience with citizen science specifically. When asked about their motivations and expectations,

volunteers expressed strong environmental drives. They were highly motivated by a desire to address plastic pollution at its source, gather information to inform solutions, and contribute to government or company initiatives to reduce plastic waste. Their expectations focused on making actual contributions to outcomes, such as a cleaner environment and informing policy, rather than on personal benefits. For instance, fewer participants cited learning new things or socializing with like-minded individuals as motivators compared to those who wanted to "be part of the solution" to plastic pollution. These findings established a baseline profile: Clean Rivers attracted volunteers with above-average education who were already environmentally aware, with their primary motivation being the fight against pollution and making a tangible impact.

Aim 2: Monitor changes in plastic pollution citizen scientists' motivation, attitude, and knowledge throughout participation

This aim was addressed through the one-year follow-up in Chapter 2 and the longitudinal study in **Chapter 3**, which tracked Clean Rivers volunteers from 2017 to 2021. We monitored 403 participants over several years to observe the evolution of their motivation, attitudes toward nature and science, and knowledge. Regarding motivation, both activist and project-action motivations remained high over time. In **Chapter 2**, after one year of participation, most participants were as motivated by environmental concerns and project goals as they were before the project. Motivations related to tackling litter at its source increased significantly, while personal motivations, such as "I thought it would be fun," decreased. This trend persisted in **Chapter 3**; commitment to the cause (plastic-free rivers) remained high over the four years, while personal motivations declined. Importantly, participation was primarily driven by environmental action and a desire for change rather than social or learning opportunities. Participants maintained a positive attitude toward nature and scientific research, reflecting their educational background and cleanup experience (**Chapter 3**). These pro-environmental attitudes did not change significantly with participation. Conversely, participants showed significant gains in knowledge. **Chapter 3** indicated that volunteers' understanding of plastic pollution and research methods increased, particularly after their first year, likely due to mandatory training and hands-on monitoring experiences. While the project boosted volunteers' environmental action motivations, it had a lesser impact on personal motivations or attitudes. However, it did provide measurable educational benefits, particularly in knowledge gain.

Aim 3: Examine potential of wildlife rehabilitation centers for citizen science

This aim was addressed in **Chapter 4** through interviews and surveys with the wildlife rehabilitation community in the Netherlands. We conducted qualitative interviews with representatives from 13 WRCs and a quantitative survey involving 205 volunteer rehabilitators. This mixed-methods approach allowed us to characterize the volunteers and assess their experiences and perspectives regarding data collection and research. Unlike the Clean Rivers participants, the educational levels of the rehabilitators were more representative of the general Dutch population. Their affinity for science was similar to that of the general public, but the demographics showed a skew: 83% were female, and 52% were middle-aged (40–64 years old). Rehabilitators reported various motivations for volunteering, primarily focused on helping wildlife and their

interest in animals. They held positive attitudes toward research and data sharing, and they were willing to share their data with researchers if provided with feedback. They felt confident in the quality of their data but mentioned that there is room for improvement, with several suggesting additional training for all organizations involved in data collection. Interest in research topics was directed toward studies that could enhance their practices, such as the success of rehabilitation techniques and threats to wildlife. Educating the public was also seen as important in reducing the need for rehabilitation. A significant challenge was the limited time and resources available; many centers operate on tight budgets. In summary, wildlife rehabilitators form a group of possible participants in citizen science that are a better representation of the general public than many existing projects. In addition, they provide valuable environmental data and are open to collaboration. However, researchers must accommodate their time constraints and align with their interests. Training and feedback are essential for successful collaboration.

Aim 4: Explore potential of observations shared via news and online media for research

Chapter 5 examined a promising data source: reports of animals impacted by COVID-19 litter, specifically masks and gloves, during the pandemic. It began with a citizen scientist's discovery in early 2020 of a fish entangled in a single-use glove. An ad hoc crowdsourcing approach compiled a dataset from Dutch and English online news and social media, documenting 28 instances of animals affected by PPE litter from April 2020 to January 2021. These instances encompassed various species and locations, underscoring the pollution's widespread effects on domestic pets and wild animals across diverse environments in several countries. The impacts on animals varied: some became entangled in mask ear loops or gloves, others ingested plastic, and some birds utilized masks for nesting. Observations were made by wildlife rehabilitators, veterinarians, photographers, birdwatchers, and dog owners who noticed their pets chewing on masks. This data arose from a network of observers who were unaware of their contributions to research. By integrating fragmented reports from social media and news outlets, we clarified the issue of COVID-19 litter affecting wildlife, a task nearly impossible through traditional scientific monitoring. This study demonstrated that online crowdsourced observations could serve as an early warning or complementary monitoring tool for environmental impacts. It also emphasized the need for careful validation; we verified each case by cross-checking sources and contacting individuals for further details or evidence. Ultimately, this study illustrated that public observations via media can significantly enhance understanding of human impacts on the environment, especially when data is rapidly or geographically widespread.

6.2 Key strengths and limitations

This PhD research highlights significant strengths. First, it investigates the general adult audience engaged in plastic pollution citizen science, addressing a gap identified in previous studies primarily focused on youth. By surveying volunteers in the Clean Rivers project, we enhance our understanding of who participates in environmental citizen science and its effects. Second, it includes a longitudinal study that tracks participants' motivation, knowledge, and attitudes over several years, rare for citizen science volunteers. This long-term view is essential for understanding the lasting impacts of participation and maintaining volunteer engagement. Third, this research looks into innovative methods to increase participation, attracting a more diverse audience. Clean Rivers primarily attracted highly educated volunteers; thus, we collaborated with wildlife rehabilitators and utilized crowdsourced data from online observations of wildlife interacting with COVID-19 litter. This illustrates the potential for involving individuals less likely to engage in traditional citizen science. Overall, this dissertation demonstrates that integrating existing volunteer communities and data sources bridges knowledge gaps in environmental science and engages a broader public in monitoring.

This research also has some limitations in its methodology and scope. A primary limitation is related to the measurement frameworks. Different instruments assessed motivation in the Clean Rivers studies compared to the wildlife rehabilitator study. Clean Rivers volunteers employed motivation scales from Batson et al. (2002), Raddick et al. (2010), and Land-Zandstra et al. (2016a; 2016b), along with an attitude scale for science (Price & Lee, 2013). In contrast, for rehabilitators, we utilized Levontin et al. (2022) for motivations and a science capital measure (Peeters et al. 2022b). These differences reflect the rapid evolution of the field of citizen science research, with the development of newer tools for assessment of impacts on participants' environmental attitudes, knowledge and behaviour (e.g., Somerwill & Wehn 2022). For the purpose of this dissertation, this is not a problem, since we have not directly compared Clean Rivers participants with WRC volunteers. However, caution is necessary when comparing results across chapters, as the questions and scales vary.

A second limitation involves potential biases in data collection. Participation in the surveys and interviews was voluntary, which introduces the risk of self-selection bias, as more enthusiastic volunteers may skew the results positively. In the Clean Rivers study, participation in the initial survey was strongly encouraged, resulting in a high response rate. Although follow-up surveys were optional, we found no significant demographic differences between respondents and non-respondents. Respondents may nevertheless have provided socially desirable answers, contributing to social desirability bias, such as exaggerating pro-environmental attitudes (Latkin et al. 2017). Because the measures of motivation, attitudes, and knowledge were self-reported, they should be interpreted as participants' subjective perceptions rather than objective assessments of these concepts. Self-reported data are inherently sensitive to recall inaccuracy and self-presentation effects, meaning that participants might have over-emphasized certain motivations or remembered their reasons for joining differently over time. We attempted to

minimise these biases by ensuring anonymity in interviews and framing questions neutrally, yet they remain important to consider when interpreting the findings.

We widely distributed the questionnaire in the wildlife rehabilitator survey, but centers that were more open to collaboration might have biased the sample. Nonetheless, the participants' educational and scientific backgrounds were representative of the general public, suggesting that the sample is not significantly skewed. However, participants likely had a pre-existing interest in our study topic. To reduce social desirability bias, we ensured anonymity in interviews and framed questions neutrally. Still, our findings primarily reflect the views of the volunteers who engaged with us, possibly excluding non-respondents. Future research should actively reach out to non-respondents to gain a better understanding of their perspectives.

A third limitation concerns the integration of data from online news and social media. Verifying online observations involves biases, including discovery bias, as we can only include cases shared via search engines. Cases from regions less active on social media may be overlooked, underrepresenting incidents there. Confirming information from online posts is challenging; although we contacted observers and sought photographic evidence, this process was often time-consuming and not always successful. More research is needed to establish best practices for integrating news and social media observations into scientific studies, including efficient data validation methods and understanding biases in opportunistic data.

6.3 General discussion and recommendations

This section interprets our findings in light of previous research and discusses their broader implications. The discussion is organized around key themes: participant background, motivation, participant impact, and integration of new data sources and volunteer communities. Within each theme, I also provide recommendations for researchers studying citizen science and for practitioners (including scientists and project leaders who implement citizen science projects) which are summarized in figure 6.1 at the end of this chapter.

6.3.1 Participant background

A key finding from this PhD research is that the Clean Rivers citizen science project predominantly engaged volunteers similar to those in other initiatives. The gender distribution among participants reflected that of the general public. However, differences in age and education were evident: over half of Clean Rivers participants were middle-aged (45–65), and nearly three-quarters held higher education degrees. This reflects a common trend in citizen science, wherein many projects tend to attract well-educated, middle-aged individuals (Mac Domhnaill et al., 2020; Pandya, 2012; Pateman et al., 2021). Previous studies have suggested that environmentally themed projects especially appeal to people who are already aware of or concerned about environmental issues (Crall et al., 2013). Our results support this notion: Clean Rivers volunteers

had a strong affinity for science and nature, likely related to their educational backgrounds and prior involvement in environmental activities.

In contrast, wildlife rehabilitators had a more varied educational background, aligning more closely with the national population. This suggests that by engaging existing communities of volunteers collecting data, we might reach individuals who do not typically participate in citizen science. It is worth noting, however, that the wildlife rehabilitator group was predominantly female, consistent with patterns in the animal care and wildlife rescue sector reported in other studies (e.g. Englefield et al., 2019; Haering, 2020b). We did not collect detailed background data for the ad hoc COVID-19 litter reporters. Still, it included a diverse mix of scientists and members of the public, including wildlife rehabilitators, veterinarians, dog owners, and photographers. Social media as a reporting platform can potentially engage a broad audience. A very large proportion of the Dutch population for example, uses social media; approximately 88% of those aged 12 and older are active online daily, with the youngest age groups being the most active (CBS, 2020). This indicates that social media content like wildlife observations could come from a broad audience, including younger people who are typically harder to reach in volunteering and citizen science (e.g. Ganzevoort & van den Born 2020; Pateman et al., 2021). However, more research is needed to understand the background of those who share data that can be used in scientific research.

Some argue we don't need everyone to participate, as individuals self-select based on interests (Montanari et al., 2021). However, a primary goal of citizen science is to democratize science and involve communities in relevant issues (Heigl et al., 2019; Strasser et al., 2019). Engaging diverse participants can make science inclusive and empower those who might not interact otherwise. A diverse volunteer base also brings different perspectives and innovations to research (Bäckstrand, 2003; Lidskog, 2008). Thus, researchers and practitioners should strive to expand participation. Our work suggests integrating established volunteer communities, like WRCs, to better represent and benefit the public. By connecting with volunteers who are already active on the topic, we can diversify contributions to citizen science.

It is also crucial to consider the barriers that prevent certain groups from participating. While our project, Clean Rivers, did not specifically study non-participants, we can identify potential barriers such as accessibility, time, and costs. For example, Clean Rivers required volunteers to physically visit riverbank locations to collect data, which could exclude individuals without access to a car or the ability to afford travel expenses (Pateman et al. 2021; Skarlatidou et al. 2019). Thus, a project that does not reimburse travel may inadvertently exclude lower-income individuals. In the case of wildlife rehabilitators, many cited time constraints as a barrier to getting involved in additional activities like research or public education and the need to prioritize animal care. Researchers who wish to collaborate with such groups need to be mindful of these limitations: for instance, by aligning research activities with rehabilitators' existing work interests, including funds for their involvement, developing simple data collection methods that fit into their routine, and sharing the research results with that community. Communication and framing also play

a key role in overcoming participation barriers. Clean Rivers may have framed its call to action in ways that appealed more to those already environmentally aware. If recruitment materials emphasized "citizen science" and data collection, it might attract individuals with a science background and higher education, as familiarity with the term is greater among those with more education (Lewandowski et al., 2017). Among rehabilitators, only 25% recognized "citizen science," the same percentage found in the study by Lewandowski et al. (2017). This suggests that many potential contributors might not identify with the concept if it is not well-known or explained.

Implications for researchers: Examining the drivers and barriers faced by underrepresented groups, such as financial limitations or a lack of familiarity with the terminology, is crucial. Further research is needed on how the public perceives citizen science and which communication strategies are most effective for increasing participation from diverse backgrounds.

Implications for practitioners: Understanding participants' demographics and addressing potential barriers, such as financial support and accessible communication, can help recruit and retain a diverse audience. Integrating existing volunteer groups, a more diverse audience could also be engaged in scientific research. This is especially true when the focus is not just on scientific outcomes, but also on how these outcomes relate to people's interests and needs, such as the benefits for wildlife.

6.3.2 Motivation

Motivation plays a crucial role in both attracting and retaining citizen science volunteers. A key finding in this research was that Clean Rivers volunteers and wildlife rehabilitators had motivations closely aligned with the respective project goals. Clean Rivers participants were primarily driven by a desire to address plastic pollution at its source and contribute to policy solutions. Over time, action-oriented and environmental motivations increased, while personal motivations, such as an interest in scientific research, diminished. This suggests that while initial curiosity may attract volunteers, long-term commitment is sustained by a sense of purpose and impact. Wildlife rehabilitators' motivations were diverse but largely centered on helping animals and supporting conservation, aligning with the mission of rehabilitation centers. Since these volunteers did not join for research purposes, integrating scientific tasks into their work should connect with their core motivations, such as improving animal care. People are likely to take on additional tasks if they align with their primary interests (Clary et al., 1998; Deci & Ryan, 2000).

Previous research has identified common motivations for volunteers, including environmental concern, knowledge gain, enjoyment of nature, and social interaction (Measham & Barnett, 2008). Clean Rivers volunteers prioritized environmental impact over social aspects, indicating they were attracted to the project because of its direct, action-oriented approach. To maintain engagement, project leaders could highlight volunteers' primary motivations, such as policy

impact and environmental improvements. Although social interaction and learning were not primary motivators for most, organizers could still offer optional workshops or networking opportunities to accommodate volunteers who value those aspects. Since Clean Rivers primarily attracted environmentally conscious individuals, outreach strategies could be adjusted to engage broader audiences, such as younger participants or those not initially concerned with plastic pollution. Highlighting different benefits, such as community engagement, could help diversify participation. However, recruitment messages and communication in general should be transparent to avoid misrepresenting the volunteer experience, as inaccurate expectations may lead to disappointment (Skarlatidou et al., 2024; Vegt et al., 2023). Monitoring shifts in motivation over time is important for sustaining engagement. Introducing new activities or responsibilities can help maintain interest if initial enthusiasm declines. For instance, Clean Rivers participants' decreasing interest in learning suggests they may have felt overqualified; offering advanced training or new roles could re-engage these volunteers. Similarly, wildlife rehabilitators should be actively involved in designing data collection processes to ensure they are simple, relevant, and seamlessly integrated into their existing routines. This approach would improve both motivation and data quality (e.g. Hoover, 2016; Pandya, 2012).

Although motivations for reporting COVID-19 litter incidents were not formally assessed, contributors likely shared observations to raise awareness. Acknowledging their contributions and informing them about their data use could encourage continued participation in environmental monitoring efforts.

Implications for researchers: To understand what influences retention, researchers need to monitor participants' motivation, especially after the impact of the first years on motivation. We recommend comparing those who remain involved with those who stop participating.

Implications for practitioners: To keep volunteers motivated, projects could organize activities and adjust their communication in ways that align with volunteers' motivations. For example, science projects on plastic pollution could highlight the actions participants can take, such as advocating for policy changes. To keep wildlife rehabilitators involved, projects could stress how their contributions to scientific research also contribute to wildlife preservation, for example, via lectures.

6.3.3 Impact on participants' knowledge and attitude

Citizen science often aims to enhance participants' understanding of project topics and shape their attitudes toward science. In the project Clean Rivers, although the participants were generally well-educated, we observed significant improvement in their understanding of plastic pollution and scientific research practices, especially during their first year of involvement. This improvement can be linked to the mandatory training they received at the start, which aligns

with studies showing that proper training can increase volunteers' knowledge (e.g. Brossard et al., 2005; Phillips et al., 2019). Clean Rivers conducted annual events to share results and workshops, transitioning to an online format in 2020-2021 due to COVID-19, which may have affected their effectiveness. We only assessed participation in monitoring sessions and did not account for involvement in other activities. To better evaluate the impact of these initiatives during long-term participation on participants' knowledge and attitude, we recommend including them in future research.

Our findings align with previous studies indicating that volunteers maintain positive attitudes toward nature and science, which remain unchanged by participation (Brossard, 2005). Positive attitudes may be more difficult to shift or may require different interventions. Engaging a more diverse audience with a lower affinity for science could lead to greater changes in attitude (Edwards et al., 2018). Since the science capital of wildlife rehabilitators reflects that of the general Dutch public, linking them to scientific research could positively affect this capital.

Implications for researchers: To understand how participation in citizen science affects participants' knowledge and attitude, we need to monitor their engagement in different project activities, such as training sessions and webinars.

Implications for practitioners: Organize training and other learning activities relevant to the projects' topic or scientific research to potentially increase participants' knowledge, regardless of their educational background.

6.3.4 Integrating other data and volunteers

This dissertation explored new methods of integrating existing sources of volunteers and data into scientific research. While structured citizen science projects adhere to protocols to ensure data quality, blending external data sources presents challenges. Wildlife rehabilitators prioritize animal care over research, possibly resulting in inconsistencies in the data gathered. Social media observations also differ in detail and reliability. Nevertheless, WRC volunteers regard their data as valuable and are receptive to standardization (Grogan & Kelly, 2013). To enhance data quality, projects should provide training and ensure that rehabilitators receive feedback on research outcomes.

Training should be adapted to the available time and experience of volunteers. Short online tutorials, onboarding sessions, or peer-learning workshops can strengthen confidence in data collection without adding large time commitments. Periodic refresher sessions or training volunteers of an organization as ambassadors of the project can maintain data quality and motivation over time.

Successful collaboration between scientists and volunteers requires reciprocity and ongoing feedback. In practice, this can include sharing summarized results with participants through for example newsletters, websites, or short annual reports that clearly show how their contributions informed analyses or policy outcomes. This could lead to continued engagement of volunteers and demonstrates the impact volunteers can have on science, society and nature. Feedback should not only communicate results but also invite dialogue, for instance by asking participants for input on research questions or interpretations of data. The citizen science project Clean Rivers communicates their findings in different ways and formats, including a newsletter, yearly event, webinars, reports and factsheets.

Collaboration should build on the existing practices and capacities of volunteers and organizations. In wildlife-rehabilitation settings, this could mean integrating standardized data fields into existing registration software. Co-design sessions or advisory groups involving both scientists and volunteers can ensure that research questions reflect community priorities and that results are translated back into practice. Structural support from funders and institutions is vital. Including budget lines for coordination, volunteer training, and feedback activities in citizen science projects enables long-term collaboration and inclusivity. These relatively small investments can substantially increase data quality and retention while ensuring that citizen science projects remain mutually beneficial for researchers and participants. Social media and news observations provide a scalable but unstructured data source for environmental monitoring. Our COVID-19 litter study showed that integrating online reports provided insights impossible to gain through traditional citizen science. Experts' verification, cross-referencing reports, and platforms like Observation.org could improve data reliability (Ghermandi & Sinclair, 2019; Nascimento et al., 2024). The terminology surrounding such data is debated. Some researchers classify passive data collection as crowdsourcing rather than citizen science, as contributors are often unaware that their posts are being used for research (Haklay et al., 2021; Strasser et al., 2019). While WRC volunteers already collect data, they could be informed about and engaged in scientific collaborations. Establishing standardized databases and co-developing protocols with WRCs would enhance data consistency and usability (Department of Planning, Industry and Environment NSW, 2020). However, social media contributions may continue to be viewed as opportunistic data collection rather than active participation, which complicates adherence to the ten principles of citizen science (Robinson et al., 2018). Despite these limitations, informal data sources can complement traditional monitoring. Our findings indicate that rehabilitators and citizen-based observations yield valuable insights into environmental issues, such as the impact of plastic pollution on animals. Policy makers have already utilized crowdsourced data to tackle environmental concerns (Tulloch et al., 2013)

In conclusion, integrating non-traditional data sources expands citizen science participation, especially among underrepresented groups. Although challenges persist in assuring data quality and ethical usage, these approaches can improve environmental monitoring and policymaking.

Implications for researchers: Further research is needed on the potential of existing volunteer communities like wildlife rehabilitators and online data sources for scientific research, their data quality and validation.

Implications for practitioners: Support the integration of existing volunteer communities and data sources in scientific research by being aware of peoples' limited time and resources. Explore volunteers' needs and interests, and when needed involve them in funding proposals, co-create data collection methods, offer training and actively share the results with the volunteers.

6.4 Final reflections

Building on the practical recommendations outlined in Section 6.3, this final reflection looks beyond the specific case studies of this dissertation to consider what they reveal about the broader role of citizen science as a societal practice. While **Chapter 5** focused more on public contributions through incidental observations than on participants themselves, it broadens our understanding of how diverse forms of engagement, both active and passive, can support environmental monitoring and potentially reach wider audiences. Together, the studies in this dissertation contribute to two central goals: understanding the current demographic and motivational profiles of citizen scientists, and identifying strategies to engage broader and under-represented audiences in environmental research.

This dissertation sheds light on the backgrounds, motivations and knowledge of citizen scientists participating in plastic pollution research. As reflected in broader citizen science trends, participation was mainly limited to highly educated individuals. While participants' knowledge of the topic and of scientific research increased during their involvement, their attitudes towards science and nature were already positive and remained largely unchanged. To make citizen science more inclusive, it is crucial to recognise that knowledge, interest and motivation exist across many social groups, but that opportunities to participate often do not.

This dissertation also explored new ways of reaching and benefiting a wider public through citizen science by examining an existing community of volunteers who already collect data with scientific potential, and by studying observations shared online. These approaches demonstrate that a broader range of people can meaningfully contribute to research, even if they do so informally or unintentionally. The challenge lies in connecting with and motivating these contributors, to both share their knowledge and deepen their own understanding and engagement. Scientists should actively involve the public in research when possible and share results that highlights participants' contributions to research, society and nature. Doing so strengthens scientific knowledge while also benefiting society and the environment.

Stronger links between science, society and policy are particularly important given the urgency of today's environmental challenges. Yet while current citizen science initiatives are valuable, they are not sufficient to reach or benefit a truly diverse audience. To involve a more representative segment of society in the co-creation of scientific knowledge, researchers must also create space for people to share ideas, raise questions and participate in shaping the research process itself. This requires dialogue, mutual respect and a willingness to learn from non-academic perspectives.

If science is to be truly democratised, it must open its doors more widely and build inclusive, mutually beneficial relationships with society. Researchers could also look for other doors that are, or could be, opened, such as those of wildlife rehabilitation centers. Rather than expecting the public to enter the doors of science, researchers might more often step through the doors of society.

Just as effective science communication is increasingly based on dialogue rather than one-way dissemination, citizen science should also be a two-way street. Researchers cannot expect the public to engage simply because they are asked to, or because science needs them. They must also engage with society to understand its motivations, questions and concerns. Citizen science should be as much about helping society as it is about helping science. At the same time, researchers must remain aware of their own positionality and maintain independence, objectivity and critical reflection.

Volunteering, especially for students and early-career researchers, can help scientists stay grounded in the world beyond academia, to understand how knowledge circulates in society and what motivates people, much like an anthropologist observing a culture of practice. Researchers are, after all, explorers of knowledge not only behind laptops or in laboratories but also through listening to and learning from people. Truly democratising science also requires structural change in how research is funded, evaluated and communicated, so that inclusive and collaborative public engagement is not merely encouraged but genuinely sustained.

An open, inclusive and reflexive approach to citizen science is not only possible but necessary to make research more relevant and impactful. Recognising citizens not merely as data collectors but as partners in knowledge creation can move science towards being more democratic, more responsive and more deeply connected to the living world it seeks to understand.

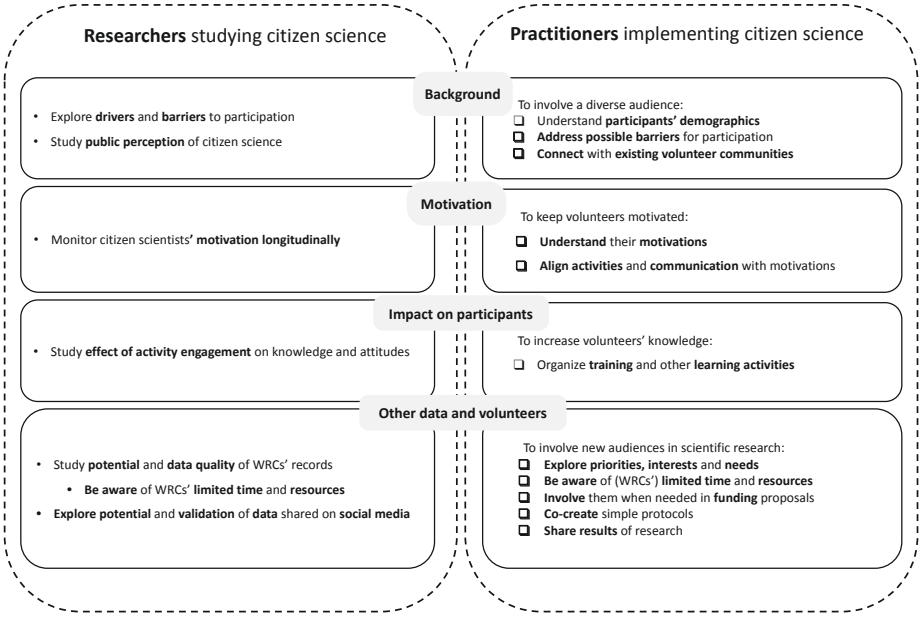

Figure 6.1 Recommendations for researchers studying citizen science and practitioners implementing citizen science regarding the background of volunteers, their motivation, a projects' impact on participants and the integration of other data and volunteer sources in scientific research.