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

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Chapter 1

General Introduction

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Over the past century, our planet has experienced significant changes. The global population has more than doubled, greatly increasing humanity's environmental impact (Steffen et al., 2015). From habitat alteration and biodiversity loss to climate change and pollution, serious environmental challenges are shaping our planet and affecting all forms of life, including ours. To address human impacts such as plastic pollution, we need intensive monitoring, increased public awareness, and more effective mitigation measures (Nakhle et al., 2024). However, current research and governmental monitoring initiatives are lagging behind the pace of environmental changes (Fritz et al., 2019). One promising strategy to improve the spatial and temporal scale of data collection is by actively engaging the public in scientific research (Danielsen et al., 2021; Fraisl et al., 2022). This approach, called citizen science, has rapidly expanded across various research fields over the past few decades (Bautista-Puig et al., 2019; Kullenberg & Kasperowski, 2016). Public involvement not only provides valuable data for environmental science and policy but also enhances participants' scientific literacy and environmental awareness (Bonney et al., 2016; Silvertown, 2009). However, recruiting and retaining citizen scientists can be challenging, and more research is needed to understand who currently participates and how participation affects, for instance, their motivations and learning. Moreover, a narrow demographic profile persists in many citizen science projects: participants are often predominantly white, older, well-educated, and have higher incomes (Mac Domhnaill et al., 2020; Pandya, 2012; Pateman et al., 2021). New approaches are needed to engage a broader audience with citizen science.

This dissertation aims to enhance our understanding of environmental citizen scientists and investigate new methods to engage a broader audience in environmental monitoring. The rest of this chapter examines the history and evolution of citizen science, describes levels of engagement, clarifies terminology, and reviews what is known about citizen science participants. It concludes by presenting the research aims, outlining the dissertation structure, and briefly reflecting on my position as a researcher.

1.1 Citizen Science

1.1.1 History

Citizen science is broadly defined as the active participation of the public in scientific research (Bonney et al., 2009). Although the term "citizen science" emerged in the 1990s (Bonney, 1996; Irwin, 1995), it has deep historical roots and has evolved significantly over time. In the mid-19th century, before the professionalization of science, amateur naturalists conducted research independently, often as a hobby alongside their jobs. These early contributors played important roles in fields such as biology, for instance, in activities like bird counting. Some of these projects are still actively engaging the public today (Bonney et al., 2009; Miller-Rushing et al., 2012). With the professionalization of science, public participation declined in most research fields as research became restricted mainly to academic institutions. Nonetheless, researchers closely collaborated with volunteers in certain areas, such as archaeology and biology (Haklay, 2013). In the 1960s and 1970s, social movements advocated for public involvement in environmental decision-making

(Strasser et al., 2019). In response, scientists increasingly engaged with the public to foster trust, share knowledge, and democratize science. Over the past few decades, this engagement has further evolved, particularly as the so-called deficit model of science communication, which assumes that simply increasing public knowledge improves scientific literacy, proved insufficient (Smallman, 2018). Modern science communication instead focuses on interaction, dialogue, and participatory approaches like citizen science (Simis et al., 2016). Advances in digital technology over the past decades have further accelerated public involvement, enabling large-scale data collection and collaboration between professional researchers and volunteers through online platforms and mobile apps (Kullenberg & Kasperowski, 2016). Citizen science is now a widely used approach in environmental and ecological research, contributing to extensive datasets on public health, pollution monitoring, biodiversity, and more (Fraisl et al., 2022).

Beyond its practical expansion, citizen science can also be understood as part of a broader movement towards public participation in science and environmental governance. Since the 1960s, this movement has sought not only to collect data with the public but to question whose knowledge and experiences are valued in research. Early frameworks of participation, such as Arnstein's (1969) Ladder of Citizen Participation and Rowe and Frewer's (2005) typology of public engagement, highlight that participation can range from consultation to full co-creation, each with different degrees of influence. Similar continuums have since been developed within citizen science itself, distinguishing contributory, collaborative, and co-created projects (Bonney et al., 2009; Shirk et al., 2012). However, participation in citizen science is not equally accessible to all. Many projects still attract participants with higher levels of education and scientific literacy, reflecting broader patterns of inequality in opportunities for engagement (Haklay, 2013; Phillips et al., 2019; Pandya, 2012). Scholars of public engagement have argued that genuine inclusion requires attention not only to who participates, but also to how power, trust, and accessibility are negotiated throughout the research process (Felt et al., 2007; Chilvers & Kearnes, 2016). From this perspective, citizen science can be seen as both a scientific method and a social practice, one that has the potential to democratize knowledge production, but can also reproduce existing hierarchies if inclusivity and reciprocity are not carefully considered.

1.1.2 Aims and engagement levels

While the extent of public involvement may differ across citizen science projects, their aims are often similarly diverse. Most projects seek to generate scientific knowledge, but many also strive to benefit participants, for instance by increasing participants' scientific literacy which can be defined in different ways (Cronje et al. 2011; Phillips et al. 2018). For measuring changes in scientific literacy among citizen science participants, Price and Lee (2013) based their definition on a paper by Miller (2004), focussing on "the understanding of scientific inquiry (epistemological beliefs about science) and attitudes towards organized science and knowledge (science-related activities)." Other possible aims of citizen science projects include raising awareness, changing behaviours, and influencing policies (Brossard et al., 2005; Jollymore et al., 2017; Rambonnet et al., 2019). By engaging people who might otherwise not participate in science, citizen science can

also make research more inclusive, incorporating new perspectives and democratizing knowledge production (Austen et al., 2024; Viola et al., 2022).

Citizen science projects vary in the extent to which they engage the public. Bonney et al. (2009) distinguished three models of participation: contributory, collaborative, and co-created projects. Volunteers primarily contribute to the data collection phase in contributory projects, while in collaborative projects, they contribute to multiple stages of the research process. In co-created projects, volunteers and researchers work closely together throughout all project phases, from defining research questions to gathering and analyzing data, and even disseminating the results. While most citizen science projects adopt a contributory approach, an increasing number aim for a more collaborative or co-created approach (Haklay et al., 2023; Pocock et al., 2017). Haklay (2013) proposed a similar framework with four levels of participation: crowdsourcing, where volunteers perform simple data collection tasks; distributed intelligence, where participants help interpret or classify data; participatory science, when volunteers engage in multiple project phases; and extreme citizen science, when the public co-designs and implements the research.

In recent years, technological advancements have also introduced new participation opportunities through what some call passive citizen science or passive crowdsourcing (Ghermandi & Sinclair, 2019; Nascimento et al., 2024). This refers to projects or data collection efforts where people contribute data incidentally or without a formal project structure, often via digital platforms. This publicly shared data is then collected for research purposes (Ghermandi & Sinclair, 2019; O'Neill et al., 2023). Such ad hoc observations, for example wildlife photos shared via social media, can be an important source of data for ecological research (Edwards et al 2021). This emergent form of a more passive participation blurs the lines between traditional citizen science and other types of public involvement, highlighting both the democratizing potential of widespread data sharing by the public and the challenges of ensuring data quality and meaningful engagement with the public (Haklay, 2013; O'Neill et al., 2023).

In this dissertation, I use the term citizen science broadly to include different ways in which the public contributes to scientific research. Rather than a fixed category, I approach it as a continuum of participation (Haklay, 2013; ECSA, 2020). Along this continuum, people engage with science in different ways and to varying degrees of coordination and intention. At one end are structured, researcher-led projects that train volunteers and follow established methods, such as the Clean Rivers project. At the other end are more spontaneous or incidental forms of contribution, for example observations shared through social or news media, where people may not see themselves as participants in science. Seeing citizen science in this way helps to connect the different studies in this dissertation, which together explore how people engage with and contribute to environmental knowledge in diverse ways. This diversity in participation is also reflected in the continuing discussions about how citizen science should be defined and understood.

1.1.3 Terminology

Despite its growing popularity, the definition of citizen science remains a topic of debate among scholars (Eitzel et al., 2017). The term was first introduced by Irwin (1995) in the context of democratizing science by aligning scientific research more closely with the public's needs and values. Around the same time, Bonney (1996) coined the term citizen science to describe projects that actively engage the public in scientific research, such as helping to collect data. Since these two initiatives, opinions have varied on what constitutes citizen science. For instance, Strasser et al. (2019) argued that citizen science requires an active role for participants, thereby excluding more passive forms of public contribution to science, like donating computer power for large-scale research analyses. More recently, a study by Haklay et al. (2021) found that definitions vary across countries and communities, further complicating how we classify different public participation initiatives. This study also revealed that people are less likely to regard the previously mentioned passive contributions to science as citizen science since they are unaware that the data is used for scientific purposes. To address the different characteristics of citizen science, the European Citizen Science Association developed ten principles to guide various stakeholders on conducting effective citizen science (Robinson et al., 2018). They argue that instead of discussions about what is and is not considered citizen science, we should focus on criteria for good practice of citizen science. The ten principles include criteria such as the active involvement of participants, genuine scientific outcomes, mutual benefits, and ethical and legal considerations.

Additionally, the term "citizen science" has sparked discussions, as it may be perceived as excluding non-citizens (Eitzel et al., 2017). In response, some scholars and organizations have suggested alternative labels, such as "community science" or "civic science" (Cooper et al., 2021). In 2024, the American Citizen Science Association rebranded itself as "Advancing Participatory Sciences" (Shirk, 2024), though the impact of this change is still debated (Cooper et al., 2021). The terminology used in a project is crucial, as it can influence who feels invited to participate and even the quality of the data collected (Eitzel et al., 2017; Lewandowski et al., 2017). During the time that this research for the PhD dissertation was conducted, "citizen science" remained the most widely used term for public participation in research. Therefore, this term is consistently used throughout the dissertation.

1.2 Participants in citizen science

1.2.1 Background

Understanding who participates in citizen science is crucial for designing inclusive projects that can have a broader impact on science, society, and the environment. Previous studies show that the demographic composition of citizen science participants can vary based on the project's topic, design, and level of engagement (Geoghegan et al., 2016). For example, online projects typically attract more male and younger volunteers, while in-person environmental monitoring projects tend to engage more middle-aged or older adults and may feature equal or greater

female participation (e.g. Mac Domhnaill et al., 2020; Domroese & Johnson, 2017). One of the most consistent findings across various projects and countries is the overrepresentation of highly educated individuals among citizen science volunteers (Curtis, 2018; Edwards et al., 2018; Paleco et al., 2021). This overrepresentation likely reflects several factors; for instance, individuals with higher education may feel more confident in contributing (Haklay, 2013). Such demographic imbalances can limit the potential reach and impact of citizen science by underrepresenting specific backgrounds and restricting the diversity of perspectives that contribute to scientific inquiry (Pandya, 2012; Pateman et al., 2021). Engaging underrepresented groups, including those with lower educational backgrounds or limited prior exposure to science (i.e. lower science capital), can help bridge knowledge gaps and democratize scientific participation. In turn, involving a more diverse group of volunteers can enhance scientific research, as the inclusion of a wide array of experiences and viewpoints can improve science itself and ensure that findings are relevant to a broader public (Austen et al., 2024; Viola et al., 2022).

1.2.2 Motivation

To effectively recruit and retain participants in citizen science projects, understanding volunteer motivations is essential (Land-Zandstra et al., 2021). Studies indicate that volunteers' motivations vary based on factors such as project topic, participants' backgrounds, and cultural contexts (Lakomy et al., 2020; Sloane & Pröbstl-Haider, 2019). For instance, volunteers engaged in classifying galaxies in an online astronomy project were primarily motivated by a desire to contribute to scientific research (Raddick et al., 2010). In addition to this motivation, participants in a water quality monitoring project were also driven by the goal of helping the environment or their community (Alender, 2016). Volunteers monitoring air quality aimed to contribute to scientific research and were also motivated by their interest in the topic (Land-Zandstra et al., 2016b). These examples demonstrate that motivations can range from altruistic goals, such as helping science or the environment, to personal interests including enjoyment, learning, or social interaction.

Several theoretical frameworks have been proposed to categorize and compare motivations for citizen science. A commonly used approach is based on the functional theory of volunteerism from social psychology (Clary et al., 1998), which classifies motivations into categories such as values (altruism), understanding (learning), social, career, protective, and enhancement (personal growth). Another framework used is Batson et al.'s (2002) four types of motivation for community involvement: egoism (increasing own welfare), altruism (increase someone else's welfare), collectivism (increase group welfare) and principlism (moral principle). More recently, Levontin et al. (2022) developed a motivation framework for citizen science that is grounded in Schwartz's theory of human values (2012). Their framework highlights the interplay between individuals' core values (e.g., altruistic vs. egoistic), their desires for knowledge, and community-oriented goals, providing a nuanced way to examine why people engage in citizen science.

Importantly, motivations are not static but can evolve over time. Newcomers may initially join out of curiosity, a general interest in science, or a desire to connect with nature, while long-term volunteers often become more strongly driven by the feeling that they are contributing to a

more significant cause, such as advancing research or protecting the environment (Crowston & Fagnot, 2018; Rotman et al., 2012). A study by Ryan et al. (2001) showed that while helping the environment and learning were important motivations at the start of participation, social factors and project organization predicted long-term involvement of participants. However, most studies examining changes in motivation have compared different cohorts of participants at various stages rather than tracking the same individuals over time (Land-Zandstra et al., 2021) Longitudinal studies are needed to assess how an individual's motivation may increase, decrease, or shift focus with ongoing participation. Various barriers can also influence whether initial enthusiasm is maintained. Common challenges include time constraints, lack of feedback or recognition, and complicated protocols that frustrate volunteers, all of which can dampen motivation in the long run (Nov et al., 2014; West & Pateman, 2016). Understanding these factors is essential for sustaining volunteer engagement.

1.2.3 Impact on knowledge and attitude

Beyond contributing to scientific research, citizen science can offer learning benefits for participants themselves. Involvement in data collection and other research activities may enhance volunteers' topic-specific knowledge (e.g., understanding local water quality or wildlife ecology) as well as their overall scientific literacy including knowledge about science and attitude towards science (Brossard et al., 2005; Price & Lee, 2013). Attitude can be defined as "a learned predisposition to respond in a consistently favourable or unfavourable manner with respect to a given object" (Fishbein & Ajzen, 1975). For example, participants in a frog-monitoring project improved their knowledge of amphibian biology and conservation after their involvement (Jordan et al., 2011). Some projects also reported increases in participants' understanding of the scientific process and boosted confidence in conducting science (Burgess et al., 2017).

In contrast, the evidence regarding changes in attitudes, such as those toward science or environmental issues, is mixed. In a study of a citizen science birdhouse project, participants' factual knowledge increased significantly, yet their attitudes toward bird conservation did not show a comparable change (Brossard et al., 2005). Similarly, a follow-up study found little change in general environmental attitudes or civic attitudes among volunteers, despite the knowledge gains (Crall et al., 2013). The extent of what participants learn or how their attitudes shift may depend on their prior knowledge, motivations, and whether the project includes structured educational components (Brossard et al., 2005; Phillips et al., 2018). Those with higher education or interest in the topic might exhibit smaller knowledge gains (Trumbull et al., 2000). However, even highly educated volunteers can increase their knowledge (Burgess et al., 2017). These learning gains can subsequently improve project outcomes: more knowledgeable volunteers often collect higher-quality data (Crall et al., 2013; Land-Zandstra et al., 2021). Further research is necessary to clarify how participation influences knowledge and attitudes over more extended periods.

1.3 Research aims

Our understanding of citizen scientists' backgrounds, motivations, and the impact of participation on their knowledge and attitudes has expanded in recent years. Since the topic and type of project can influence who volunteers and how their knowledge and attitudes are affected, it is essential to broaden our understanding in areas that remain understudied. One such area is plastic pollution, a growing environmental issue where citizen science is increasingly employed to monitor the extent and sources of this pollution (Nelms et al., 2022; Rambonnet et al., 2019; Zettler et al., 2017). However, few studies have focused on plastic pollution citizen science participants. One exception involves work with schoolchildren in educational settings (e.g. Locritani et al., 2019; Wichmann et al., 2022). But there is a significant gap regarding adult citizen scientists outside of formal education. We know little about who volunteers for plastic pollution monitoring, what motivates them, and how participating in such projects may influence their perspectives. Therefore, we collaborated with the Dutch Clean Rivers project (Schone Rivieren in Dutch) to conduct survey research among their participants.

At the same time, to enhance the impact of environmental citizen science, we must explore new strategies for engaging a broader audience than those typically reached. As noted, many projects struggle to attract volunteers beyond a relatively homogeneous group. One way to broaden participation is by tapping into existing communities or networks of individuals already active in environmental or animal-related work, even if they are not currently connected to research. By examining such communities, we can assess whether they are open to contributing data or participating in scientific research and what support they would need. A promising example of an existing volunteer community is that of Wildlife Rehabilitation Centers (WRCs). These organizations operate worldwide and often rely on volunteers to care for injured and orphaned wildlife. WRCs keep records of every animal admitted, which could be valuable for research on wildlife health, conservation threats, and environmental change (Mullineaux & Pawson, 2024; Pyke & Szabo, 2018a). As the records are collected largely by volunteers, the involvement of these volunteer communities could be perceived as citizen science. Although researchers are increasingly collaborating with WRCs, our understanding of the volunteers in this emergent field of citizen science, including their backgrounds, motivations, and data collection practices, is limited. Only a few studies, mainly from Australia and New Zealand, have examined aspects of WRCs' volunteers and their data collection practices (Englefield et al., 2019; Haering et al., 2020b; Yeung et al., 2017). To evaluate the potential of wildlife rehabilitators as contributors to citizen science, we need to investigate who these volunteers are, why they volunteer, what kinds of data they collect, and how they feel about collaborating with researchers. We did this among a group of WRCs in the Netherlands. To understand their affinity with science, the science capital framework was used which measures peoples' knowledge of scientific developments, attitude towards science, participation in scientific activities, and engagement with science in daily life (De Witt et al., 2016; Peeters et al., 2022b).

In addition to organized volunteer groups, today's general public also shares data online through social media and other digital platforms. These public observations, such as photos or reports of environmental phenomena posted on Twitter, Facebook, or news sites, are increasingly being utilized in scientific studies. Researchers have begun to recognize that this emergent form of more passive citizen science with incidental data can provide valuable insights, particularly on topics of broad public interest or rare events (Edwards et al., 2021). For instance, posts on social media have been used to track invasive species, document wildlife sightings, and even monitor pollution incidents (Abreo et al., 2019; Nascimento et al., 2024). However, the potential of this more passive form of citizen science remains largely underexplored for many research questions. In the context of plastic pollution and its effects on wildlife, observations shared by members of the public could offer information that formal citizen science projects might miss. For this purpose, we have collected pictures globally that were shared online about entanglement of animals in COVID-19-related personal protective materials such as gloves and face masks. This project focuses on the publics' potential to contribute to scientific research. The study emerged from an opportunistic discovery during a side project coordinated by the PhD candidate: the citizen science project 'The Canal Watch' ('De Grachtwacht' in Dutch), in which volunteers clean the canals of Leiden, the Netherlands. The discovery of a fish entangled in a single-use glove during the COVID-19 pandemic led to a spontaneous and innovative investigation into the potential of observations shared via social media for scientific purposes, as an emergent form of citizen science for environmental monitoring. This chapter will also broadly touch upon the types of audiences that can be reached. This dissertation addresses existing knowledge gaps to enhance our understanding of citizen scientists involved in plastic pollution research and explore methods for engaging more diverse participants in environmental monitoring. The specific research aims are to:

1. Identify the background and motivation of citizen scientists participating in plastic pollution research.
2. Monitor changes in these volunteers' motivation, attitudes, and knowledge over time through a longitudinal study.
3. Examine the potential for incorporating volunteer wildlife rehabilitators into scientific research as a form of citizen science.
4. Explore how public observations shared through news and social media can contribute to understanding plastic pollution's impact on wildlife.

1.4 Dissertation outline

Figure 1.1 provides an overview of the dissertation's structure and how the chapters address different or similar concepts. In brief, the dissertation is organized as follows:

- **Chapter 2** quantitatively examines the demographic background, motivations, and expectations of volunteers participating in Clean Rivers, a Dutch citizen science project on plastic pollution. Since 2017, this project has actively involved volunteers in cleaning up litter and monitoring the amount and types of plastic on riverbanks in the Netherlands, with the goal of achieving plastic-free rivers in 2030. This chapter focuses on the participants' profiles and motivations at the start of their involvement. In 2017, volunteers completed an initial survey before participating, and in 2018 a subset completed a follow-up survey after one year. This pre- and post-participation study of 122 respondents allowed us to evaluate the motivations of the volunteers, their expectations from the project, and how their motivation evolved after the first year.
- **Chapter 3** presents a longitudinal follow-up study that monitored Clean Rivers participants from 2017 to 2021. Through surveys, this study tracked 403 participants over several years to investigate the long-term effects of their involvement. This chapter examines how sustained engagement in the project influenced volunteers' motivation, attitudes toward nature and scientific research, and their understanding of plastic pollution and research methods. By monitoring the same group of volunteers over time, this chapter provides insights into motivation changes and whether continued participation impacts volunteers' knowledge and attitudes.
- **Chapter 4** utilizes a mixed-methods approach to explore the potential participation of wildlife rehabilitators in scientific research. Through in-depth interviews with representatives from thirteen Dutch WRCs and a survey among 205 volunteer rehabilitators, this chapter investigates the backgrounds and motivations of wildlife rehabilitators, their current data-collection practices, and their views on contributing to research. We evaluate rehabilitators' familiarity with citizen science, their willingness to share data with scientists, their confidence in the quality of the data they collect, and the topics and support they find most relevant for potential collaboration on research. This chapter also examines the opportunities and challenges of incorporating a largely untapped volunteer community into environmental citizen science.
- **Chapter 5** explores the role of public observations via social and news media as an emerging method for understanding the impact of plastic pollution on wildlife. This chapter investigates a specific case: the rapid increase of littered personal protective equipment (PPE) like face masks and gloves during the COVID-19 pandemic and its effects on animals. We compiled observations of wildlife and domestic animals affected by PPE litter by searching online news articles, social media posts, and other online reports. Chapter 5 discusses how these digital platforms can enhance data collection on environmental issues.
- **Chapter 6** synthesizes the dissertation's main findings, highlights the key strengths and limitations of this research, discusses its broader implications, and offers recommendations for researchers and practitioners interested in studying or using citizen science for environmental monitoring and conservation.

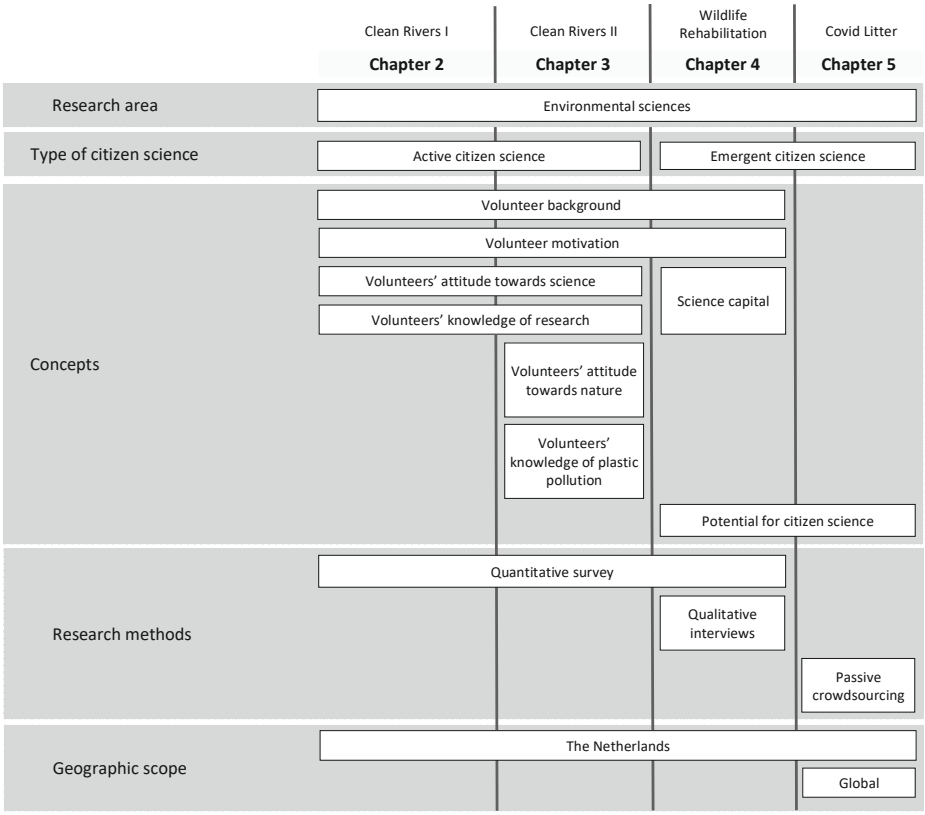

Figure 1.1 Overlap and differences between chapters in terms of research area, type of citizen science, studied concepts, research methods and geographic scope.

1.5 Positionality

This dissertation examines topics in which I have been actively involved both professionally and personally. Therefore, it is important to reflect on my positionality, the background and biases I bring to the research, and to consider how these may have influenced the research process and outcomes (Holmes, 2024; Berger 2015). By being transparent about my role and perspective, I aim to ensure that the research remains both ethically sound and robust.

Before starting my PhD, I studied best practices and challenges in citizen science projects focused on plastic pollution by interviewing project coordinators across various initiatives (Rambonnet et al., 2019). This inspired me to become the founder and coordinator of a citizen science project addressing plastic pollution. This hands-on experience provided me with firsthand insight into volunteer engagement and project management. However, it is essential to note that in this dissertation, my focus is on the participants' experiences rather than the coordinators' perspectives. In other words, while my professional work with citizen science informed my

understanding of project operations, this PhD research centers on volunteers in other projects, not on those I directly coordinated.

I also have extensive personal involvement in wildlife rehabilitation, having volunteered at a local wildlife rehabilitation center (WRC) since 2014. This experience inspired my bachelor's research on hedgehog rehabilitation in 2015 and made me aware of some challenges and ethical issues inherent in wildlife rescue work. My dual role as both a researcher and an insider in the world of wildlife rehabilitation presents advantages and risks. On one hand, it likely helped build trust and rapport during interviews and surveys with rehabilitators, as I could relate to their experiences and demonstrate an understanding of their work. On the other hand, I needed to remain critically aware of potential biases, such as expectations or assumptions I might have due to my own experiences. To mitigate these risks, I collaborated closely with co-researchers who were not involved with the WRCs, providing an external check on the research design and interpretations. I also intentionally stepped back from some of my volunteer duties at the local bird shelter during the data collection period to avoid conflicts of interest and ensure that my interactions with study participants remained as impartial as possible.

By reflecting on these aspects of positionality, I acknowledge how my background may have influenced the research and have taken steps to ensure the credibility and neutrality of the findings. All interviews and analyses were conducted with an awareness of this dynamic, striving for a balance between insider insight and objective distance. This reflexive approach aimed to strengthen the integrity of the research outcomes presented in the chapters that follow.