CITIZEN SCIENCE:
THEORY AND PRACTICE

Longitudinal Study of Motivation, Attitude, and Knowledge of Citizen Scientists Monitoring Plastic Pollution On Dutch Riverbanks

RESEARCH PAPER

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ABSTRACT

Across the world, the number of citizen science projects focusing on plastic pollution is increasing. These projects often last for multiple years, which makes retaining volunteers challenging. However, our knowledge is limited regarding the effect of long-term involvement on citizen scientists' motivation, attitude, and knowledge, especially for plastic pollution projects. Therefore, this study measured citizen scientists' motivation, attitude, and knowledge in the Dutch Clean Rivers project before and during monitoring plastic pollution on riverbanks between 2017 and 2021.

In total, 403 Clean Rivers participants completed a pre-survey, and a portion of them participated in one or multiple post-surveys throughout the years of monitoring. They were especially driven by *Project Action* motivations and *Environmental* motivations like tackling the source of pollution and doing something about the plastic soup, rather than being motivated by an *Interest in Scientific Research* like the desire to learn about scientific research. *Project Action* motivations increased significantly, especially within the first year of participation. Participants' attitudes towards nature and science were initially high and did not increase significantly. Furthermore, while participants' knowledge of plastic pollution was already high at the start, their knowledge of scientific research was not, and both increased significantly, especially in the first year of participation. The findings of this longitudinal study can contribute to improving the recruitment and retention of volunteers in current and future citizen science projects.

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INTRODUCTION

The participation of the public in scientific research, also known as citizen science, is increasingly being used in different research fields (Kullenberg and Kasperowski 2016; van der Velde et al. 2017). One of these fields is the research into plastic pollution: Volunteers may, for example, collect water samples for microplastic research, monitor beach litter, or track plastics floating in rivers (Hidalgo-Ruz and Thiel 2013; Cook et al. 2021; Kiessling et al. 2021). Using citizen science has many benefits, such as being able to conduct research on a bigger scale, increasing science literacy in volunteers, and empowering participants (Crall et al. 2013; van Emmerik et al. 2020a). However, collaboration between researchers, volunteers, and other stakeholders can also be challenging (Rambonnet et al. 2019; Nelms et al. 2022). Therefore, studying the practice of citizen science has become a topic of research itself.

One of the challenges in citizen science projects is the recruitment and retention of volunteers. In many projects, the number of people who stay with a project after the first contribution is relatively low (Franzoni and Sauermann 2014; Fischer et al. 2021). This poses a challenge, especially for plastic pollution projects, which need data for long periods (Nelms et al. 2017; Rambonnet et al. 2019). To improve the retention of volunteers, more knowledge is needed about the background and attitudes of the citizen scientists so projects can adjust accordingly (Measham and Barnett 2008; West and Pateman 2016). Therefore, increasingly more research has been conducted focusing on the motivations, attitudes, and prior knowledge of citizen scientists (e.g., Brossard et al. 2005; Geoghegan et al. 2016; Land-Zandstra et al. 2016a; West and Pateman 2016; West et al. 2021).

Motivation, attitude, and learning can differ between projects for various reasons such as the different levels of participant involvement, the target audiences, and the topics covered in the project (Lotfian et al. 2020). For citizen science projects focusing on plastic pollution, research about citizen scientists is relatively scarce. Most of the studies that have been done focused on projects with school children or students as a target audience (e.g., Kiessling et al. 2021; Oturai et al. 2022; Wichmann et al. 2022). In addition, little is known about how these characteristics are changing over time and how projects can adjust to these changes (Rotman et al. 2014; West and Pateman 2016; Aristeidou and Herodotou 2020).

To decrease these knowledge gaps and contribute to the sustainability of plastic pollution projects and citizen science projects in general, our study examined the longitudinal changes in motivation, attitude, and knowledge of citizen scientists in a Dutch plastic pollution project: Clean Rivers (Schone Rivieren, in Dutch) between 2017 and 2021.

MOTIVATION

Motivation of citizen scientists is one of the topics within the field of citizen science that has received much attention. Phillips et al. (2019) described it as "the underlying psychological need for why someone does something, expressed as the initial cause for participation or why they stay involved in the project." Many different motivational frameworks have been developed to identify volunteers' motivations in general (e.g., Clary et al. 1998; Batson et al. 2002; Finkelstein 2009). For example, Batson et al. (2002) defined "four motives for community involvement:" egoism, altruism, collectivism, and principlism. The first three motives are, respectively, about increasing the welfare of yourself, others, or a group. Principlism means that someone is motivated because of certain principles, like justice. Another framework distinguishes between intrinsic motivations, which means that volunteers are "satisfied by the volunteer activity itself" and extrinsic motivations, when volunteers "require an outcome separate from the volunteer work in order to be fulfilled" (Finkelstein 2009). For citizen science, these frameworks are being used to study participants' motivation. Also, new ones have been created. Raddick et al. (2010) found twelve motivation categories based on interviews with Galaxy Zoo users and tested these through a survey (Raddick et al. 2013).

The most important motivation for environmental volunteers in general and in citizen science projects in particular appears to be "helping the environment" (Bruyere and Rappe 2007; Sloane and Pröbstl-Haider 2019). However, in a study about Dutch biodiversity recorders, the most important motivations were "being connected to nature," "learning more about nature," and "contributing to nature conservation and management" (Ganzevoort et al. 2017).

Unfortunately, only a few studies monitored long-term citizen scientists' motivation. Rotman et al. (2014) found that initial motivation is more egoistic, that is, from a personal interest, whereas in the long term, more collectivistic and altruistic motivations, such as commitment to conservation, are important. However, the existing literature is ambiguous. For example, for both new and longer-committed volunteers of a flu tracking project, altruistic or collectivistic motivations were the most important (Land-Zandstra et al. 2016b). In contrast, for long-term volunteers counting birds, science and conservation motivations were the most important motivations (Larson et al. 2020). In another study on volunteers studying water flow, motivations regarding learning were important for both short-term and long-term participants (Shinbrot et al. 2021). Ryan et al. (2001) discovered that for new environmental volunteers, a desire to help the environment and to learn new things were important, but in the long term, social factors were more important. In contrast, for citizen scientists in a mosquito project, various motivations were initially important whereas learning and the feeling that participation was useful were especially important for continued involvement (Asingizwe et al. 2020).

The motivation of citizen scientists may differ between projects based on several factors such as volunteers' cultural background, the project topic (Sloane and Pröbstl-Haider 2019), and the communication strategy (Land-Zandstra et al. 2016b). However, studies on the motivation of citizen scientists in plastic pollution projects are limited to a previous study on the Clean Rivers volunteers (Rambonnet et al. 2023). Participants joined mainly because of activistic motivations like contributing to the environment and enforcing measures. Although these motivations increased after the start of their participation, their personal motivations, such as the fun of doing scientific research, decreased significantly.

In conclusion, motivation has been an important topic within citizen science research, and the longitudinal change of motivation is not fully understood yet. In addition, current knowledge of motivation for citizen science projects on plastic pollution is lacking.

ATTITUDE

Often, environmental citizen science projects aim to change peoples' attitude towards nature or science. Learning more about the impact of participation on volunteers' attitudes can help projects connect more people with science and nature. Attitude has been defined as "a learned predisposition to respond in a consistently favorable or unfavorable manner with respect to a given object" (Fishbein and Ajzen 1975). Being outdoors in places volunteers would normally not visit, engaging in more focused nature observation than they would normally do, and being involved as a researcher in a project, may all influence how volunteers perceive nature and science or their sense of connection to nature (Nisbet et al. 2009). By involving volunteers in the scientific process via citizen science projects, volunteer attitudes towards nature and science can be positively influenced (Bell et al. 2008; Bonney et al. 2009; Cronje et al. 2011).

For other projects, participation did not affect volunteers' attitude towards nature and science. For example, for volunteers studying bird houses, their attitude towards the environment and science did not change (Brossard et al. 2005). Also, for citizen scientists who monitored urban bees, their attitude towards bees and science did not change significantly (Druschke and Seltzer 2012). It could be that attitude does change after longer engagement, but the long-term impact of citizen science on attitude has not been studied extensively yet (Greving et al. 2022).

Attitude, like motivation, is often measured in different ways, making it hard to compare projects or draw clear conclusions across projects. Although it can be difficult to measure attitude, it is important to include it when studying the effect of participation on volunteers and to learn which audience is being reached.

KNOWLEDGE

Another goal of many citizen science projects is to increase the knowledge and understanding among volunteers regarding science and the project topic. As with attitude, it is important to measure if projects are achieving this goal and how the duration of participation can affect this. Participants' knowledge about how science works may increase by being involved in steps of the scientific process such as collecting and analyzing data (Bonney et al. 2009, 2016). In addition, volunteers may also learn more about the specific topic of a project (Cronje et al. 2011; Jordan et al. 2011; Crall et al. 2013).

The impact of citizen science on volunteers' knowledge may depend on the motivation of the volunteers to participate. Comparable to motivation and attitude, the project's design may also play a role. For example, the impact on volunteers' science knowledge may depend on the time spent reflecting on the scientific process and the contact volunteers have with researchers (Jordan et al. 2011; Crall et al. 2013). It is unknown if long-term involvement affects volunteers' knowledge, but previous research found that influencing adult learning needs a longer period of interventions (Merriam et al. 2007).

THE AIMS OF OUR STUDY

To increase our understanding of the motivation, attitude, and knowledge of citizen scientists and how the duration of participation affects this, we monitored volunteers of the Dutch project Clean Rivers. Our research question was: How does long-term participation in a citizen science project concerning plastic pollution affect participants' motivation, attitude towards science and nature, and knowledge about plastic pollution and scientific research?

METHODS

To study the longitudinal changes in motivation, attitudes, and knowledge of citizen scientists in a plastic pollution project, we surveyed volunteers of the Dutch Clean Rivers project over four years (2017–2021). Since 2017, Clean

Rivers volunteers have monitored plastic pollution twice a year on 100-meter tracks of river bank along large Dutch rivers such as the Meuse and the Waal (van Emmerik et al. 2020b; www.schonerivieren.org/english). These volunteers were recruited through the collaborating organisations and (social) media. They collect data on the amount and the types of (plastic) litter. The project also contains activities for groups who clean up river banks but do not collect data. In addition, various activities were organized, such as feedback sessions about the results and a yearly conference. Our study focused only on the citizen scientists, who collect data. They participated in a pre-survey when they entered the project (2017–2020) and were invited to participate in three post-surveys (2018, 2020, 2021). When we report on the volunteers of the project in general, the term volunteers will be used. We will use the term participants when we report specifically on the volunteers who participated in the surveys.

PARTICIPANTS

Between 2017 and 2021, 438 participants filled in the pre-survey; this was almost all of those who participated in the required training session, providing us with a representative sample of the active citizen scientists. Participants were encouraged to fill out the survey in the welcome mail and when they arrived at the training session. Thirty-five participants were removed because their responses were too incomplete, resulting in a total of 403 participants in this study. The response rate for the post-surveys was 70% (n = 142) in 2018, 54% (n = 183) in 2020, and 45% (n = 154) in 2021.

On average, the participants were 52 years old, 55% identified as female, and 72% were highly educated, having completed their highest degree at either a university of applied sciences or a research university (Table 1). We checked for differences in participants' backgrounds to estimate the effect of the non-response on our sample. We did not find any significant differences in the backgrounds of people who participated in the first and the last surveys regarding age, gender, and education.

	FREQUENCY	PERCENTAGE (%)
Age (n = 390)		
≤24	15	4
25–34	41	11
35–44	63	16
45–54	78	20
55–64	99	25
≥65	94	24
Gender (n = 399)		
Female	219	55
Male	180	45
Education (n = 396)		
Secondary school	36	9
Vocational training	67	17
University of applied sciences	170	43
Research university	115	29
Other	8	2

Table 1 Background of the Clean Rivers' participants during the pre-survey.

DATA COLLECTION

The pre-survey was distributed before volunteers attended training about the project and the research protocol. The post-surveys were distributed after the first round of monitoring and then again in years 3 and 4 of the project. The pre- and post-surveys were distributed online using the web-based software Qualtrics. The pre-survey was also distributed on paper to volunteers who had not completed the survey before they arrived at the training session.

The survey was conducted in Dutch, but for this manuscript, relevant statements were translated into English (see Supplemental File 1: Pre- and post-survey questions). Before answering the questions, participants gave informed consent to use their data. Participants scored different motivation statements on a Likert scale from 1 to 5 (completely disagree to completely agree). Their motivation was assessed with two sets of statements: 1) to participate in the project in general and 2) to participate as a citizen scientist (river litter researcher) in particular. Questions related to motivation in the pre-and post-survey were based on previous surveys by Batson et al. (2002), Raddick et al. (2010), and Land-Zandstra et al. (2016a). Statements about attitude were divided into eight statements about attitude towards science (based on Price and Lee, 2013) and nine statements about attitude towards nature (based on Nisbet et al. 2009). Three of these last statements were negatively formulated and reverse-coded. Both types of attitude statements were scored on a Likert-scale from 1 to 5 (completely disagree to completely agree). We have chosen existing surveys focusing on broad concepts of attitude, so that these outcomes could be compared with other projects. For the questions on knowledge level, the topics were based on input from the Clean Rivers project team and were specific for this project. Participants scored their self-perceived knowledge level for each topic on a scale of 1 to 10 (comparable to the Dutch school grading system with 6 being a sufficient grade).

The survey was tested with a group of volunteers from a pilot version of the project. We previously reported on the pre-survey and the first post-survey of the first group of volunteers who started in 2017 (Rambonnet et al. 2023).

STATISTICAL ANALYSIS

Descriptive statistics of participants' backgrounds were performed using Excel (version 16.67; see Supplemental File 2: Dataset 2017–2021 for the total dataset). For the Likert-scores, the mean, median, and interquartile range were calculated to show both the average score as well as the spread in the data. Other statistical analyses were conducted in R, version 4.2.1, using the RStudio IDE (R Core Team 2022, RStudio 2022; see Supplemental File 3: Data analysis report). Logistic regression was used to estimate differences in age, gender and education by survey participation (first or last survey). No significant differences were observed. A conditional independence network was estimated to determine clusters of related statements, using the rags2ridges package (Peeters et al. 2022). This analysis determines groups of statements that correlate strongly to each other but not to other statements (for a more detailed description, see Supplemental File 4: Conditional independence networks: motivation, attitude, and knowledge). To account for the repeated measures of individuals, mixed models were fitted, using the glmmTMB package (Brooks et al. 2017). Violations of distributional assumptions (i.e., can the test statistic be reasonably assumed to follow a normal distribution) were checked through visual diagnostics with the DHARMa package. Marginal effects plots of the resulting models were generated using the package sjPlot, as these show the effect of one predictor on the outcome while keeping the other predictors constant at a representative level (Lüdecke 2023). No confounding effect of age, gender, or education was observed. The effect size is expressed on the scale of the linear predictor (in terms of logits for logistic models and mean change for normal models). When p-values were 0.0001 or larger, the actual p-value was reported.

RESULTS

MOTIVATION

Before their training, when participants were asked about their motivation to join the project in general, they most strongly agreed with the statements that litter disturbed them (*Disturbing,* 4.77), that they wanted to do something about plastic soup (i.e., plastic pollution in the oceans; *Plastic Soup,* 4.72), and that they wanted to commit themselves to a better environment (*Environment,* 4.71). Participants also picked their most important motivation to participate in the project. Almost a third chose *Disturbing* (33%, n = 133) and another third chose *Plastic Soup* (32%, n = 129). When asked about their reasons for becoming a citizen scientist specifically, the highest scoring statements indicated that volunteers wanted to tackle the source of the litter (*Source,* 4.65), wanted to help make sure measures were taken against companies/government (*Measures,* 4.60) and believed it is important to gather information about river litter (*Information,* 4.53). For this set of statements, almost half of the participants chose *Source* (49%, n = 193) as the most important reason to participate as a citizen scientist, and almost a third chose *Measures* (32%, n = 126).

To look for patterns and to ease further analysis, we analyzed the conditional independence networks of all motivation statements together and found three clusters. The first set of motivations was labeled *Environmental*, covering motivations related to how participants see themselves contributing to a better environment (*Disturbing, Plastic soup, Environment,* and *Bigger movement*; Table 2). The second cluster was labeled *Project Action*, focusing on motivations related to what actions the project could take (*Source, Measures,* and *Information)*. We labeled the third cluster *Interest in Scientific Research*, including motivations regarding a personal interest in and enjoyment of conducting scientific research (*Fun, Learn, Contribute,* and *Perform)*. All other motivations did not cluster together. Further analyses were performed using the three clusters only.

Longitudinal change of motivation

To analyze how motivation may have changed throughout participation in the project, we analyzed the longitudinal changes with respect to the number of months people had participated in the project through a mixed effect model (Figure 1). The first cluster, *Environmental,* showed an increasing but not significant trend (Figure 1a; effect size 0.00534, p = 0.311). The *Project Action* cluster did show a significant increase over time (Figure 1b; effect size 0.03549, p = 0.00056). The cluster of *Interest in Scientific Research* motivations showed a decrease over time, which was not significant (Figure 1c; effect size –0.00457, p = 0.0668).

ATTITUDE

Regarding participants' attitudes towards nature and science, we measured their average agreement with a set of statements on a 5-point Likert-scale. Table 3 shows the average scores for each statement during the pre-survey. The last four statements were reversely coded to correct for their negative wording. Both types of attitudes were positive at the start of the project (all scores above three for positive statements and below three for negative statements).

I PARTICIPATE IN CLEAN RIVERS, BECAUSE…	**KEYWORD**	**CLUSTER**	**LIKERT-SCORE**	
			MEAN	**MEDIAN (IQR)**
litter in nature or on the streets disturbs me	*Disturbing*	*E*	4.77	5 (5–5)
I can help doing something about the Plastic Soup	*Plastic Soup*	*E*	4.72	5 (5–5)
I want to commit myself to a better environment	*Environment*	*E*	4.71	5 (5–5)
I like to be outdoors	*Outdoors*		4.41	5 (4–4)
I like to join a bigger movement to improve the world	*Bigger movement*	*E*	4.22	5 (4–5)
I like to commit myself to volunteer work	*Volunteering*		3.90	5 (3–5)
I'm interested in the kinds of litter present in the rivers	*Interest*		3.79[b]	4 (3–5)
I like to recreate near or on the water	*Recreation*		3.70[a]	4 (3–5)
I live or used to live close to the Maas or the Waal	*Neighborhood*		3.61	4 (3–5)
it is part of my tasks/responsibilities I have at my work/association	*Responsibility*		2.32[a]	2 (1–3)
I WANT TO BECOME/HAVE BECOME A RIVER LITTER RESEARCHER, BECAUSE…				
with the results we can tackle the litter at its source	*Source*	*PA*	4.65[c]	5 (5–5)
my contribution can help the government/companies take measures	*Measures*	*PA*	4.60[c]	5 (4–5)
it's important to gather as much information about litter in the rivers as possible	*Information*	*PA*	4.53[c]	5 (4–5)
I like to contribute to scientific research	*Contribute*	*ISR*	3.98[c]	4 (3–5)
to me it seems fun to perform scientific research	*Fun*	*ISR*	3.92[c]	4 (3–5)
I hope to learn something about performing scientific research	*Learn*	*ISR*	3.88[c]	4 (3–5)
I'm interested in the performance of scientific research	*Interest*	*ISR*	3.81[c]	4 (3–5)

Table 2 Pre-survey motivation of Clean Rivers participants.

Note: E: Environmental, PA: Project Action, and ISR: Interest in Scientific Research.

Mean, median and interquartile range (IQR), on a 5-point Likert-scale ranging from totally disagree (1) to totally agree (5) (n = 400). [a](n = 399), [b](n = 398), [c](n = 395), because of missing data.

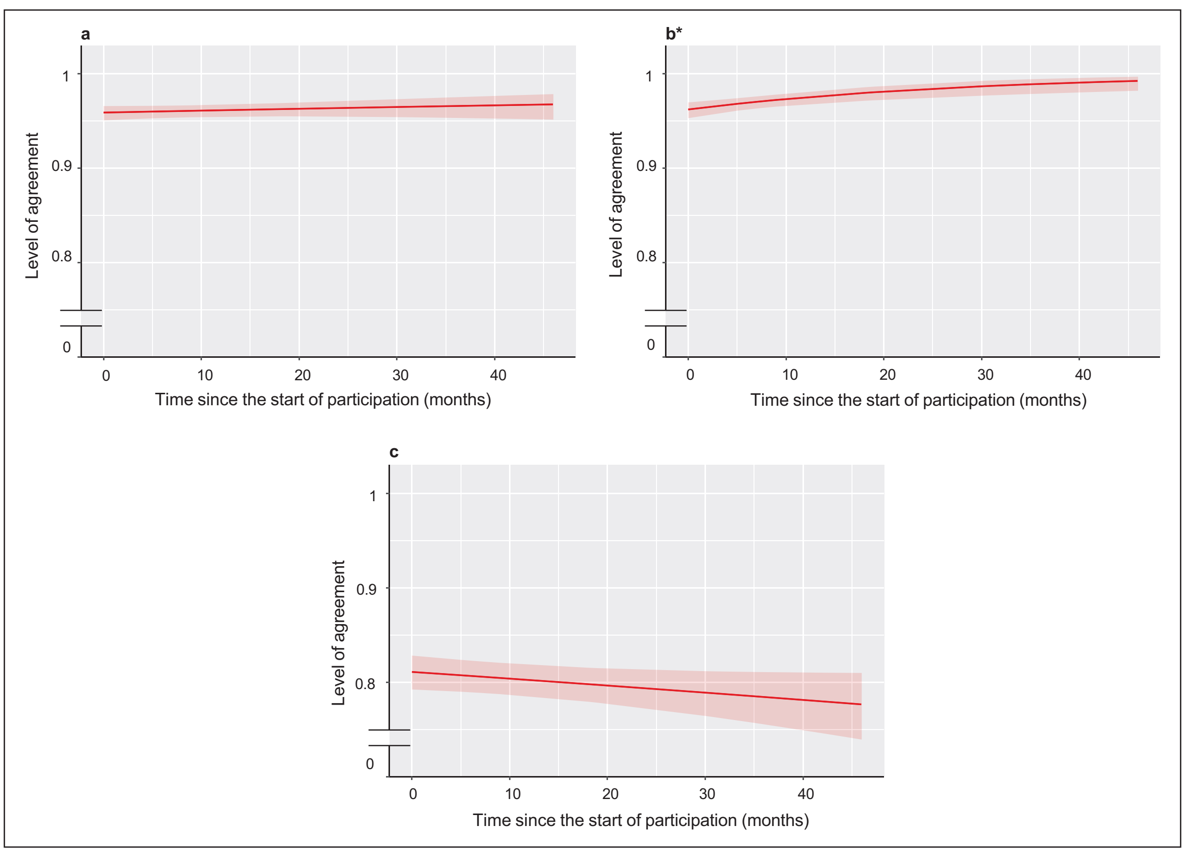

Figure 1 Trends in average agreement score of **(a)** *Environmental*, **(b)** *Project Action*, and **(c)** *Interest in Scientific Research* motivations. *$p = 0.00056$. Scores range from 0 (corresponding to Likert-score 1) to 1 (corresponding to Likert-score 5). Shaded areas represent the uncertainty in the predicted trend (95% confidence band). Note that we have truncated the y-axis to increase visibility of the trends.

ATTITUDE TOWARDS SCIENCE	LIKERT-SCORE	
	MEAN	MEDIAN (IQR)
I am interested in news about natural science	4.14	4 (4–5)
I am interested in science	4.10	4 (4–5)
I pay attention if a natural science news item crops up in a media source I am already following	3.90	4 (3–5)
I use knowledge of natural science in everyday life	3.43	4 (3–4)
I actively seek out stories about natural science in the news	3.38	3 (3–4)
I use knowledge of natural science to evaluate claims made about natural science	3.23[a]	3 (3–4)
I am knowledgeable about natural science	3.19	3 (2.5–4)
I am likely to attend a lecture or course about natural science	3.03	3 (2–4)
ATTITUDE TOWARDS NATURE		
I do mind if some plants and animal species become extinct	4.41[b]	5 (4–5)
Conservation is necessary because nature is not strong	4.40[b]	5 (4–5)
I feel very connected to all living things and the earth	4.37	5 (4–5)
My relationship to nature is an important part of who I am	4.36	5 (4–5)
People don't have the right to use natural resources in any possible way	4.30[b]	5 (4–5)
I always think about how my actions affect the environment	4.12[a]	4 (4–5)
The thought of being deep in the woods, away from civilization, is not frightening	4.01[b]	4 (3–5)
I enjoy being outdoors, even in unpleasant weather	4.00	4 (4–5)
My ideal vacation spot would be a remote wilderness area	3.75	4 (3–5)

Table 3 Clean Rivers participants' attitude towards science and nature (pre-survey).

Note: Mean, median and interquartile range (IQR), on a 5-point Likert-scale ranging from totally disagree (1) to totally agree (5) (n = 399). [a]n = 398, because of missing data. [b]Originally formulated as negative statements, scores have been reversed.

Conditional independence networks showed that the two lists of statements neatly clustered together within attitude towards science and attitude towards nature. Therefore, we calculated means for further analysis. Participants' attitude towards science was positive, with an average Likert-score of 3.55. Their attitude towards nature scored even higher, with an average score of 4.19.

Longitudinal change of attitudes

We again performed a mixed model regression analysis to detect any changes in attitude throughout participation in the project (Figure 2). Although the attitude towards science showed a positive trend, it did not change significantly (Figure 2a; effect size = 0.00117, p = 0.504). Attitude towards nature also did not change over time (Figure 2b; effect size = 0.00013, p = 0.922).

KNOWLEDGE

We measured participants' self-reported knowledge by asking them to rate their knowledge about seven topics on a scale of 1 to 10 (from very little knowledge to a lot of knowledge). Participants' knowledge was sufficient (above 6; aligning with the Dutch scoring system in schools) for three of the seven topics: *ways to act sustainable in daily life*, consequences of litter for nature, and *causes of litter*. Conditional independence network analysis showed two clusters of questions, one containing topics more related to plastic pollution (*causes*, *extent*, and *consequences)* and another with topics related to scientific research (*using protocols*, *conducting scientific research*, and the *OSPAR protocol).* Table 4 shows the average score for each topic, with higher scores for all topics concerning plastic pollution.

Longitudinal change of knowledge

Regression analysis with a mixed effects model showed a significant increase in participants' knowledge of plastic pollution (Figure 3a; effect size = 0.11587, $p < 0.0001$) as well as their knowledge of scientific research (Figure 3b; effect size = 0.42933, $p < 0.0001$). The increase was the steepest after the first-time people participated in the project, although their knowledge kept increasing in the long term.

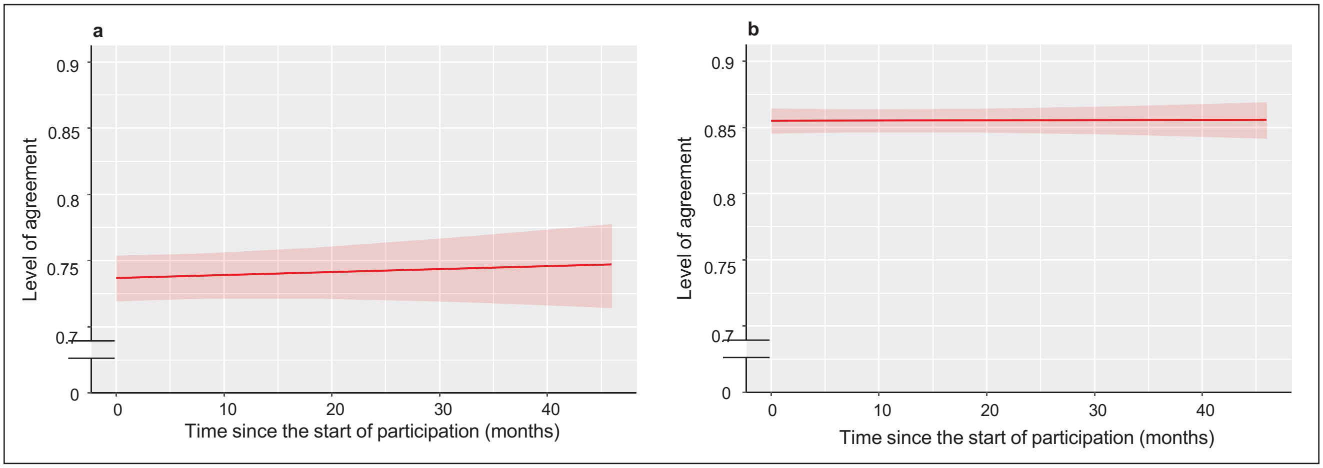

Figure 2 Trends in average agreement score of **(a)** attitude towards science and **(b)** attitude towards nature. Scores range from 0 (corresponding to Likert-score 1) to 1 (corresponding to Likert-score 5). Shaded areas represent the uncertainty in the predicted trend (95% confidence band). Note that we have truncated the y-axis to increase visibility of the trends.

TOPIC	CLUSTER	SCORE
Ways to act sustainable in daily life	Plastic pollution	7.2
Consequences of litter for nature	Plastic pollution	6.9
Causes of litter	Plastic pollution	6.5
The extent of plastic pollution in the Netherlands	Plastic pollution	5.5
The process of scientific research	Research	5.0
The use of protocols (like observation schedules and tally sheets) during scientific research	Research	5.0
The OSPAR-declaration	Research	2.2

Table 4 Average self-reported score for knowledge of plastic pollution and scientific research (pre-survey).
Note: Scored from 1 to 10 (n = 398).

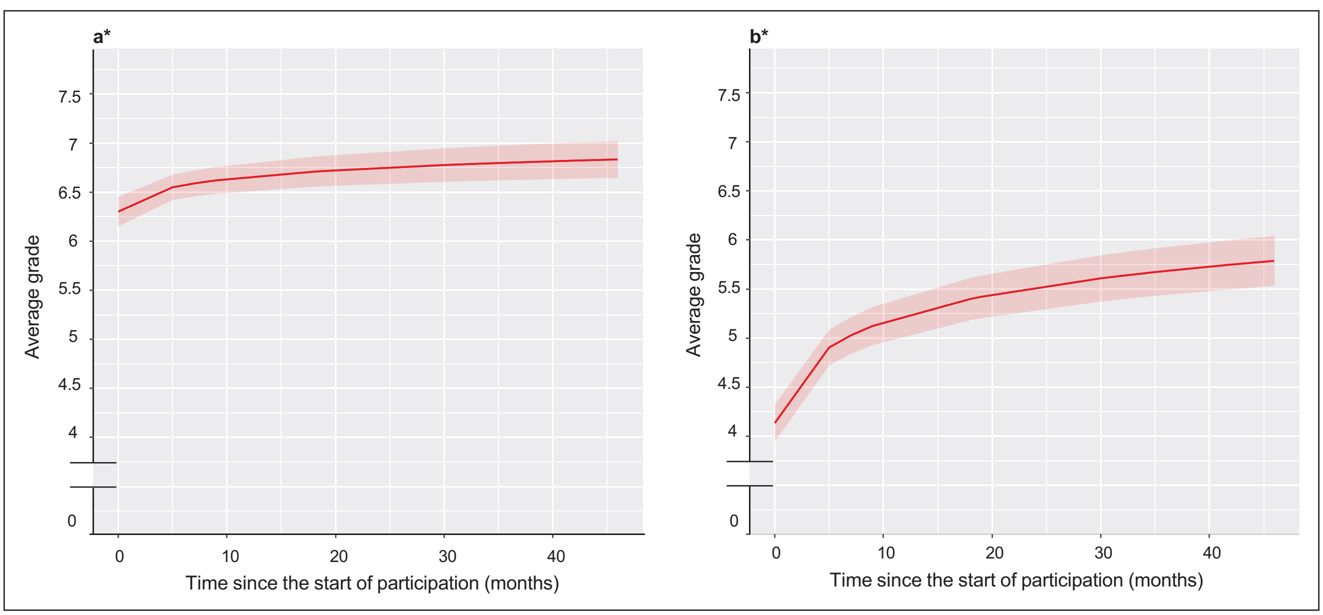

Figure 3 Trends in average knowledge score about **(a)** plastic pollution and **(b)** research. **p* < 0.0001. Measured on a scale of 1 to 10. Shaded areas represent the uncertainty in the predicted trend (95% confidence band). Note that we have truncated the y-axis to increase visibility of the trends.

DISCUSSION

In this study, we surveyed volunteers of the Dutch citizen science project Clean Rivers about their motivation, attitude, and knowledge during four years of the project. Below, we discuss the most important findings in more detail.

MOTIVATION

At the beginning of the project, the most important general motivations for Clean Rivers participants were that they found litter *Disturbing,* wanted to do something about *Plastic Soup,* and wanted to commit to a better *Environment*. Their most important motivations to become a citizen scientist were to tackle litter at the *Source,* contribute to *Measures,* and gather as much *Information* about litter as possible. Analysis showed three clusters of related motivational statements; *Environmental, Project Action,* and *Interest in Scientific Research. Environmental* and *Project Action* motivations scored higher than more personal motivations during the pre-test.

These types of motivation are in line with most environmental and conservation projects, where helping the environment was found to be the most important motivation of volunteers (Bruyere and Rappe, 2007; He et al. 2019). In contrast, for biodiversity recorders in the Netherlands, the most important motivations were a personal connection to nature, learning about nature, and contributing to nature conservation—both personal and environmental motivations (Ganzevoort et al. 2017). Possibly, the Clean Rivers project attracted people with *Environmental* and also *Project Action* related motivations, rather than motivations related to an *Interest in Scientific Research*, partly through the framing of recruitment messages (Land-Zandstra et al. 2016b; Lee et al. 2018). Clean Rivers communicates that they want to tackle the source, and their main goal is to have plastic-free rivers in 2030.

Over time, *Project Action* motivations increased significantly, where *Environmental* and *Interest in Scientific Research* motivations did not change significantly. This indicates that people became more focused on solving plastic pollution rather than a growing concern for the environment in general or because of personal interests. Possibly, even if their *Project Action* motivations were already high, they got more excited about being able to make a difference through their experiences with the project and the actions that were taken by the project.

Our findings contrast with previous studies in which the more personal and environmental motivations changed significantly throughout participation (Ryan et al. 2001; Larson et al. 2020). However, the literature is ambiguous and longitudinal studies tracking citizen scientists' motivation throughout participation are limited. Most studies compared new volunteers with longer committed volunteers or only looked at one pre- and post-survey (Ryan et al. 2001; Land-Zandstra et al. 2016b; Shinbrot et al. 2021).

Understanding participants' motivation to participate is important to take into account for the further development of the Clean Rivers project and similar projects. For example, in the Clean Rivers project, more attention was given to what the project was doing with the data to change government regulations instead of solely focusing on detailed analyses of the data to generate new scientific knowledge. This may have further impacted the *Project Action* motivation, which could explain the significant increase of this type of motivation over time.

ATTITUDE

Participants' attitudes towards science and nature were already highly positive when they started participating in the Clean Rivers project. Both did not change significantly throughout their participation. Our results align with participants of the invasive species citizen science project that Crall et al. (2013) studied. They also found a "slightly positive attitude towards science and a strong positive attitude towards the environment before participation." Also comparable to our results are volunteers who monitored birdhouses, as their attitudes towards science did not change (Brossard et al. 2005). Although one study did find a change in attitudes (Price and Lee 2013), attitudes seem to be challenging to change, especially when already high. Possibly this kind of project attracts people with high science and nature attitudes (Bonney et al. 2016). Therefore, if a project wants to attract a diverse audience to citizen science and have a greater impact on volunteers' attitudes, it is important to try to recruit and attain people with different science and nature attitudes.

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Participants' self-reported knowledge about scientific research and about plastic pollution increased significantly throughout participation in the project, especially after the first training and first monitoring round. This is in line with many other citizen science projects that show a learning effect (Bonney et al. 2016). It seems plausible that the training before their first monitoring session contributed to this learning impact. Previous research also shows that learning is influenced by participating in a project's "social components" and not only by contributing data (Price and Lee 2013). The fact that knowledge did not increase as much in later years may have been because the protocol for data collection remained the same throughout the project or because of the method of asking for self-reported knowledge. In addition, participants were not strongly motivated by a desire to learn, possibly explaining the lack of increase in knowledge in later years.

Interestingly, participants' initial knowledge of science was relatively low compared with their topic knowledge, even though 72% of the participants was highly educated. A possible explanation is that the project attracted people who were already aware of plastic pollution rather than people who had an interest in scientific research. This is also reflected in their motivations.

LIMITATIONS

An important limitation is the choice of questions in the survey. First, the self-reported questions could influence participants' judgments and may have resulted in more socially desirable answers (Milfont 2009). To tackle this, anonymous data processing was ensured, and it was emphasized that the answers would not influence their participation. In addition, the researchers were independent of the project organisation.

Another challenge is that comparing results from different projects is difficult because various frameworks and questions are used across projects. Although we do make some overarching comparisons, more specific comparisons such as meta-analyses are impossible because different studies use various instruments. It would help the field if projects administer universal instruments for measuring motivation and attitudes, for example, the newly developed framework for motivation by Levontin et al. (2022) and the review on measuring the impact of citizen science on environmental attitudes, behavior, and knowledge by Somerwill and Wehn (2022). However, a possible trade-off of generalizable surveys could be that we are missing some changes in more specific, topic-related attitudes (e.g., towards plastic pollution).

The last limitation is that we do not have complete data on the number of times participants have performed a monitoring session. We asked them if they had monitored in the year before each survey. This gave us a general indication of whether they had been active during the project. More detailed information could have made our analysis more fine-grained. However, even without monitoring, volunteers could have been involved in the project in other ways, such as co-organizing online events.

CONCLUSION

Action-related motivations are the most important for participants monitoring plastic pollution on Dutch riverbanks in the Clean Rivers project, and these motivations increased significantly throughout the project. Participants' attitude towards nature and science was already positive and did not change significantly during participation. However, participants' knowledge about plastic pollution and scientific research increased significantly, especially after the first training and monitoring session. Knowing that the motivations of plastic pollution volunteers are mainly related to the actions the project might take could contribute to the recruitment and retention of volunteers in this project and other citizen science projects focusing on plastic pollution. For example, when a project aims to tackle the source of plastic pollution, emphasizing this aspect in the projects' recruitment message may effectively attract volunteers. Furthermore, communicating how the results contribute to prevention may enhance the retention of volunteers. However, to impact people's attitudes and knowledge towards science and nature, it is important to try to recruit and attain people with different science attitudes to attract a more diverse audience.

DATA ACCESSIBILITY STATEMENT

All relevant data for this research is available in Supplemental File 2.

SUPPLEMENTARY FILES

The supplementary files for this article can be found as follows:

- **Supplemental File 1.** Pre- and post-survey questions. DOI: https://doi.org/10.5334/cstp.667.s1
- **Supplemental File 2.** Dataset 2017–2021. DOI: https://doi.org/10.5334/cstp.667.s2
- **Supplemental File 3.** Data analysis report. DOI: https://doi.org/10.5334/cstp.667.s3
- **Supplemental File 4.** Conditional independence networks: motivation, attitude, and knowledge. DOI: https://doi.org/10.5334/cstp.667.s4

ETHICS AND CONSENT

This research was conducted in accordance with the Dutch codes of conduct for academic practice and research integrity. At the time of this research, no specific ethics approval was required at our institution. The participants in this study gave informed consent to use their data for the purpose of this research.

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COMPETING INTERESTS

The authors have no competing interests to declare.

AUTHOR CONTRIBUTIONS

AMLZ acquired the funding for this study. LR and AMLZ contributed to the design and implementation of the research. FJR analyzed and visualized the data. LR led the first draft of the manuscript and AMLZ reviewed further drafts of the manuscript. All authors approved the submitted version.

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An edit was made to the title of this article on 18/07/2024. 'Riverbank' was changed to 'Riverbanks'. All other content remains the same.

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