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"What's that weed on the street?" Motivation and attitude of contributors and followers in a citizen science project studying pavement plants

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ABSTRACT

Plants are essential for life on Earth, yet their importance is often underappreciated. Urban flora are often dismissed as weeds, for example. One solution could be plant-focused citizen science projects that can boost awareness and support conservation efforts. In this study, we conducted a survey among 241 participants of an urban flora citizen science project to examine their motivations and attitude. We compared experienced contributors, inexperienced contributors, and followers who only engaged online, and identified key motivations and attitudes across patterns of involvement. Most participants were driven by an interest in urban nature, a desire to support research, and a commitment to help nature. Contributors were more motivated to assist research than followers, while followers held similar or even more positive views of pavement plants. Our findings reveal that participants who do not contribute data are just as motivated by their care for urban nature and have an equal or more positive attitude towards wild urban flora compared to contributors. We suggest that, although less scientifically motivated, these individuals could amplify the project's reach through other types of activities, such as advocacy and education. We emphasize the importance of broad outreach, attracting diverse participants, and recognizing the value of non-contributing participants in citizen science projects aimed at supporting conservation.

1. Introduction

Plants, a significant component of biodiversity, face alarming threats, with 40 % of species at risk of extinction (Nic Lughadha et al., 2020). Despite this threat, plants are often overlooked in conservation efforts, lacking broad institutional support essential for effective biodiversity and plant conservation (Sharrock and Jackson, 2017). A lack of attention to and scant knowledge of plants has been observed in urban societies through many studies within the frame of plant awareness, plant awareness disparity, or plant blindness (Brkovic et al., 2024; Dünser et al., 2024a; Parsley, 2020; Stagg and Dillon, 2022). This disregard for plants is cause for concern and can further impede plant conservation efforts (Amprazis and Papadopoulou, 2020; Balding and Williams, 2016).

Promoting pro-nature and plant conservation attitudes and behaviors is key to safeguarding plant biodiversity. Pro-nature conservation behavior involves supporting nature conservation at any scale, including planting native plants, volunteering, and supporting pro-nature policies (Richardson et al., 2020). This is linked to nature connectedness—our feelings, knowledge, beliefs, actions and experiences regarding nature—which is best predicted by engagement in simple nature activities (Richardson et al., 2020; Whitburn et al., 2020). However, global trends show increasing disconnection from nature, driven by urbanization, less outdoor activity, and fewer human-nature interactions (Miller, 2005; Soga and Gaston, 2016).

Citizen science, the involvement of people in a non-professional capacity in scientific research, can contribute to scientific knowledge, skills, attitudes, and interest in participants, as well as to nature connectedness and conservation (McKinley et al., 2017; Peter et al., 2021; Pocock et al., 2023; Sharma et al., 2019). A UK study found that monitoring pollinators through citizen science increased participants' nature connectedness and pro-nature conservation behavior (Pocock et al., 2023). Another study by Jordan et al. (2011) shows that citizen science has the potential to increase participants' knowledge of plants. Citizen science has also been suggested as an activity that could increase public interest in plants (Chen and Sun, 2018). Studying plants with

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citizen science can involve activities proposed to increase plant awareness, specifically attention to, interest in, and knowledge of plants (Dünser et al., 2024a; Stagg et al., 2025). Plant-focused citizen science projects could draw attention to plants, involve observation of and education about plants, and also include tactile and relevant experiences in local environments (Peter et al., 2021; Sharma et al., 2019).

Research suggests that plant-focused citizen science could support plant conservation by promoting pro-conservation behavior and nature connectedness, as well as aspects of plant awareness (Peter et al., 2021; Pocock et al., 2023; Richardson et al., 2020; Whitburn et al., 2020). To organize citizen science projects that could create a significant impact, research on existing projects and participants is needed. To further investigate the role that plant-focused citizen science could play in supporting plant conservation, we studied the Stoepplantjes (Pavement Plants) Project, which encourages Dutch citizens to document wild urban plants in their environment. We studied the motivation and attitude of citizen science participants in the project.

1.1. Citizen science participation

Citizen science offers numerous benefits, not only for researchers (e.g., collecting large datasets) but also for participants (e.g., learning, enjoyment, empowerment; Robinson et al., 2018). Studying participants helps identify how projects reach, retain, and impact different groups, offering insights to improve outcomes for participants, scientists, and biodiversity conservation (Land-Zandstra et al., 2021; Pateman et al., 2021). Over recent decades, research has highlighted key prerequisites for participation, such as leisure time, financial resources, and motivation. Conversely, common barriers include lack of equipment, financial constraints, unawareness of opportunities, and feeling unqualified (Hobbs and White, 2012; Land-Zandstra et al., 2021).

Interestingly, little is known about non-contributing participants: those who sign up for projects but do not submit data. Most studies focus solely on contributors, but quite recently, there has been a call for research on potential participants (Pateman et al., 2021; Richter et al., 2021). Non-contributors form a majority in many citizen science projects and online communities (Haklay, 2018). For example, 92 % of bird organization members in the UK and USA do not engage in participatory activities or monitoring, and 62 % of users on the citizen science platform iSpot have never submitted an observation (Cooper and Smith, 2010; Silvertown et al., 2015).

Non-contributors are interesting as they are aware of citizen science and likely have some interest but cannot or choose not to participate actively. Relatively little active participation might prevent citizen science from reaching its potential or intended societal impact, as a high percentage of non-contributors might not engage with activities known to impact pro-conservation behavior, nature connectedness, and plant awareness. For example, they might not spend more time outdoors, make nature observations, or engage with the environmental/biological education materials or other project activities. However, non-contributors might support project aims indirectly, for instance, by talking about or promoting a citizen science project to others. Research on online citizen science participation found that "lurkers" (non-contributors) often held positive attitudes and stayed engaged with projects over a long period of time (Aristeidou et al., 2017). Including non-contributors in citizen science research could provide valuable insights into their motivations and the broader impact of these projects.

1.2. Citizen scientist motivation and attitude

Understanding the motivations and attitudes of both contributing and non-contributing participants is crucial for developing successful citizen science projects aimed at supporting plant conservation. Motivation is generally defined as a force driving individuals to act in a certain way and sustain their actions (Brophy, 1983), whereas attitude can be defined as "a psychological tendency that is expressed by evaluating a particular entity with some degree of favor or disfavor" (Eagly and Chaiken, 1993, p. 1). Studies of conservation and biodiversity citizen science projects show that participants are primarily driven by their valuation of wildlife and the environment, a desire to learn, individual interests and a willingness to support research (Levontin et al., 2022; Maund et al., 2020). Maund et al. (2020) also surveyed different groups of citizen science participants who reported sick or dead wildlife in their garden, finding very little difference between the motivations and nature connectedness of opportunistic and more active systematic contributors. In further interviews, systematic contributors mentioned helping research more often whereas, opportunistic contributors mentioned wildlife health, such as the health of hedgehogs and other wild garden animals, more as one of their main reasons for contributing. This suggests that there is no straightforward link between the mode of participation and underlying motivations or connection to nature. In general, studies on participant motivations have predominantly looked at biodiversity citizen science projects that study animals, and few have compared different types of participants based on their contribution. We will contribute to this field with our study on the motivation of different types of participants in a plant-focused citizen science project.

Studies generally show that attitudes towards plants are often neutral or positive (Dünser et al., 2024b). However, the general public might be more unfamiliar with and indifferent or adverse towards wild plants in urban spaces. Knowledge of native wild plants is especially scarce compared to knowledge of crops and other commercially attractive plants (Pedrera et al., 2023). Pavements with spontaneous wild vegetation can contribute to urban biodiversity, align with societal values, and potentially support plant conservation (Bonthoux et al., 2019; Deparis et al., 2023; Soanes et al., 2019). However, vegetation on streets is often removed by municipalities and citizens as "weeds". Similarly, streets and parks with more spontaneous vegetation can be perceived as unkept, unattractive, and low in societal value and biodiversity (Kopnina, 2013; Phillips and Lindquist, 2021). Thus, assessing attitudes towards pavement plants is particularly relevant in a citizen science project about these plants. Citizen science and science communication have been shown to increase attitudes towards less attractive or misunderstood animal species, such as rats and salamanders (Aivelo and Huovelin, 2020; Reimer et al., 2014). Contributing participants who have experience with nature engagement, for example as volunteers, might have a more positive attitude compared to participants who do not (Aristeidou et al., 2017). Their attitude might already be quite positive to begin with and unlikely to change (Ganzevoort and van den Born, 2021). Our work contributes to the study of citizen scientist attitudes towards different organisms and the growing body of literature on the perception of wild urban flora.

1.3. Aims and research questions

It is important to explore why certain people participate in plant-focused citizen science projects and what their attitudes are, given the potential role such initiatives could play in plant conservation. Therefore, we investigated the motivation and attitudes of participants in the Dutch Stoepplantjes project. This project focuses on urban flora, an interesting ecological group that is accessible but often overlooked and weeded. Our study included both contributing participants and followers who engaged only via newsletters and social media, in order to gain insight into how participation in plant-focused citizen science is shaped. Our research addressed the following questions:

Q1. What motivates experienced contributors, inexperienced contributors, and followers in a citizen science project about urban flora, and how do their motivations differ?

Q2. What are the attitudes of experienced contributors, inexperienced contributors, and followers towards urban flora, and how do their attitudes differ?

2. Methods

2.1. Research setting

The Stoepplantjes citizen science project, carried out by Hortus botanicus Leiden (Leiden University's botanical garden), aims to increase plant awareness and study urban flora to promote greener, more sustainable cities. The Netherlands is a suitable location for this study due to its high urbanization rate, which surpasses that of the UK, where plant awareness disparity has been widely observed (Stagg and Dillon, 2022; World Bank, 2023). Participants submitted data (location, date, and plant species) on urban flora via the project website (www.stoepplantjesonderzoek.nl). Physical and online tools for plant identification were provided including two apps, ObsIdentify and PlantNet, with the latter integrated into the website to allow photo uploads for automated identification. Participants were encouraged to observe plants near their homes or in their everyday surroundings. All these factors contribute to the project's design, aiming to provide accessibility for a wide range of participants (with regard to technical skills, time at hand, location) and uphold responsible research practices.

In October 2021, the citizen science project was launched nationally in partnership with FLORON (Flora Research Netherlands), which inventories and aims to protect Dutch wild flora. Social media channels and newsletters managed by Hortus' staff, initiated two years prior, built a substantial online following. During its first year, the project received local and national media coverage as part of a government-supported initiative to enhance scientific literacy.

2.2. Survey development

To study a large group of participants, we conducted an online survey from April to June 2022 to assess the motivations and attitudes of adult followers and contributors of the Stoepplantjes project. The questionnaire was developed in Qualtrics and distributed via email and social media. While the project targeted individuals aged eight and older, the survey was limited to adults to enable comparison with other citizen science research and for pragmatic reasons.

The survey contained eight sections: informed consent, demographics, project contribution, prior nature volunteer experience, motivation, attitude, science capital, emotional memory, and the impact of participation on knowledge. The latter three sections were part of a separate study and are not reported here (Land-Zandstra et al., 2023). In total, the survey included 50 questions comprising open-ended questions, multiple choice, 5-point scales, and 0–100 sliding scales. Demographic data included gender identity, education level, and zip code.

Motivation was measured using the validated Citizen Science Motivation Scale (CSMS), based on Schwartz's theory of basic human values (Levontin et al., 2022). This standardized survey was chosen to enable comparison between citizen science projects regardless of subject or location. To keep the survey concise, 17 statements from 11 categories (Supplementary data, Table A1), particularly relevant to nature and research, were included and rated on a 5-point agreement scale (1 = completely disagree, 5 = completely agree). Attitudes towards pavement plants were assessed using eight semantic differential statements (e.g., "ugly vs. beautiful," "worthless vs. valuable"), using a 0–100 sliding scale. This section was adapted using Ganzevoort and van den Born's (2021) study, which assessed attitudes towards bees in participants of a citizen science project that studied native bees. We replaced 'bees' with 'pavement plants' and removed the obviously non-relevant pairs, i.e., scary vs. cute and dangerous vs. not dangerous. Participants gave informed consent within the survey, agreeing to the use of their anonymized data. Limited personal information was collected. The survey was tested and refined based on feedback from a handful of experts from the botanical garden staff and the science communication research group, including two citizen science experts.

2.3. Data collection

The survey was distributed seven months after the launch of the citizen science project, which at that time had around 3000 followers on social media (Instagram, Facebook, Twitter/X) and 3284 urban plant observations from over 240 registered users. It was distributed via email to 158 contributors who had provided their email addresses via the project website. Additionally, invitations were shared on social media and through the project newsletter to reach non-registered followers. The survey was closed after six weeks, yielding 241 respondents.

2.4. Data analysis

Data cleaning and analysis were performed using SPSS Statistics version 27 (IBM, USA). Descriptive statistics, including frequencies, means, and standard deviations, were calculated. Respondents were grouped as contributors or followers based on a question about participation. Contributors were those who submitted urban flora data to public biodiversity platforms (e.g., Stoepplantjes project, observation.org, iNaturalist). Others were considered followers. Contributors were further categorized into inexperienced and experienced volunteers based on prior volunteer experience or engagement with nature organizations. These divisions enabled us to compare groups based on differences in citizen science and nature engagement.

Motivation and attitude variables were assessed for normality using histograms, values for skewness and kurtosis, and Shapiro-Wilk tests. These checks indicated non-normal distributions but primarily equal variance among groups. Depending on Levene's test results for variance equality, either Student's *t*-test or Welch's *t*-test was used to compare groups on a single item level, as these methods are robust for skewed distributions with sample sizes over 20 (Fagerland, 2012; Fagerland et al., 2011). Effect sizes were calculated using Cohen's *d* and identified as small ($d = 0.2$), medium ($d = 0.5$), or large ($d = 0.8$; Cohen, 1988).

3. Results

3.1. Respondent demographics

Of the 241 respondents, 125 were followers of the project (52 %) and 116 were contributors (48 %; Supplementary data, Table A2). Contributors included 63 inexperienced (IV; 54 %) and 53 experienced nature volunteers (EV; 46 %). The median age of the entire sample was 60 years and mean age was 57.31 years (SD = 14.42; range 20–86). The gender identity of respondents was mostly female (72 %). However, there were comparatively less female contributors (60 %) and even less female contributors who were also experienced nature volunteers (49 %). The majority of respondents finished a tertiary education at a University of Applied Sciences (35 %) or University (32 %). The zip codes of respondents and geographical data input for the Stoepplantjes project were comparable, indicating that the data is geographically representative of our target group.

3.2. Motivation

For the entire sample, the mean highest scoring motivations were feeling a strong connection to nature (*connection to nature*; 4.40), interest in urban nature (*interest*; 4.39), wanting to protect the environment (*protect environment*; 4.34), wanting to *help wildlife* (4.32) and wanting to contribute to knowledge about wild urban plants (*contribute knowledge*, 4.30; Table 1). The lowest scoring motivations were that other people were doing it as well (*social*; 2.21) and liking to compete with others (*competition*; 2.05). This indicates that respondents are primarily motivated by an interest and concern for (urban) nature and a desire to contribute knowledge rather than by comparing themselves to or interacting with other people. Looking at the different motivational categories in the CSMS (Supplementary data, Table A1), wanting to help

Table 1
Motivation of all respondents and divided between followers and contributors. Contributors are further divided into inexperienced nature volunteers (IV) and experienced nature volunteers (EV). Values were calculated from a 5-point scale ranging from 1 = completely disagree to 5 = completely agree. The table is ordered by mean descending score for all respondents with the top five motivations written in bold. Independent *t*-test results are shown comparing followers and contributors, and within the contributors, comparing the IV with EV, $*p < .05$ and $**p < .001$.

	All respondents				
	(n = 231)	Followers	Contributors		
		(n = 118)	(n = 113)	IV	EV
				(n = 60)	(n = 53)
Motivation item keywords	Mean (std)	Mean (std)	Mean (std)	Mean (std)	Mean (std)
Connection to nature	**4.40 (0.69)**	**4.40 (0.70)**	**4.41 (0.68)**	4.27 (0.75)*	**4.57 (0.57)***
Interest	**4.39 (0.66)**	**4.33 (0.72)**	**4.45 (0.59)**	**4.32 (0.65)***	**4.60 (0.49)***
Protect environment	**4.34 (0.72)**	**4.31 (0.76)**	**4.38 (0.68)**	**4.35 (0.75)**	**4.42 (0.60)**
Help wildlife	**4.32 (0.73)**	**4.30 (0.78)**	4.34 (0.68)	**4.35 (0.73)**	4.32 (0.64)
Contribute knowledge	**4.30 (0.71)**	4.19 (0.79)*	**4.41 (0.59)***	**4.35 (0.6)**	**4.47 (0.57)**
Learn	4.29 (0.67)	**4.24 (0.74)**	**4.35 (0.59)**	**4.37 (0.58)**	4.32 (0.61)
Being outdoors	4.15 (0.84)	4.09 (0.88)	4.20 (0.79)	4.10 (0.87)	4.32 (0.67)
Contribute research	4.05 (0.80)	3.80 (0.87)**	4.32 (0.61)**	4.25 (0.70)	**4.40 (0.49)**
Meaningful action	3.99 (0.81)	3.90 (0.90)	4.08 (0.69)	3.98 (0.72)	4.19 (0.65)
Fun	3.98 (0.72)	3.92 (0.75)	4.04 (0.68)	3.97 (0.66)	4.13 (0.70)
Worthwhile involvement	3.93 (0.81)	3.88 (0.80)	3.98 (0.82)	3.92 (0.84)	4.06 (0.79)
Teach	3.85 (0.88)	3.82 (0.89)	3.88 (0.87)	3.83 (0.88)	3.94 (0.86)
Help	3.77 (0.77)	3.74 (0.77)	3.80 (0.78)	3.78 (0.82)	3.81 (0.73)
Novelty	3.46 (0.95)	3.45 (0.96)	3.48 (0.94)	3.52 (0.94)	3.43 (0.95)
Challenge	3.38 (0.94)	3.40 (0.99)	3.35 (0.89)	3.32 (0.91)	3.40 (0.88)
Social	2.21 (1.09)	2.17 (1.00)	2.25 (1.17)	2.23 (1.15)	2.26 (1.21)
Competition	2.05 (0.94)	1.95 (0.93)	2.15 (0.94)	2.08 (0.90)	2.23 (0.99)

nature, personal interests, and helping research are the most prominent motivations among respondents of the Stoepplantjes project. Most respondents agreed or strongly agreed with most statements. However, for the statements *social* and *competition*, a clear majority disagreed or strongly disagreed (Fig. 1), suggesting these motivations are less relevant for contributors and followers of the Stoepplantjes project. These

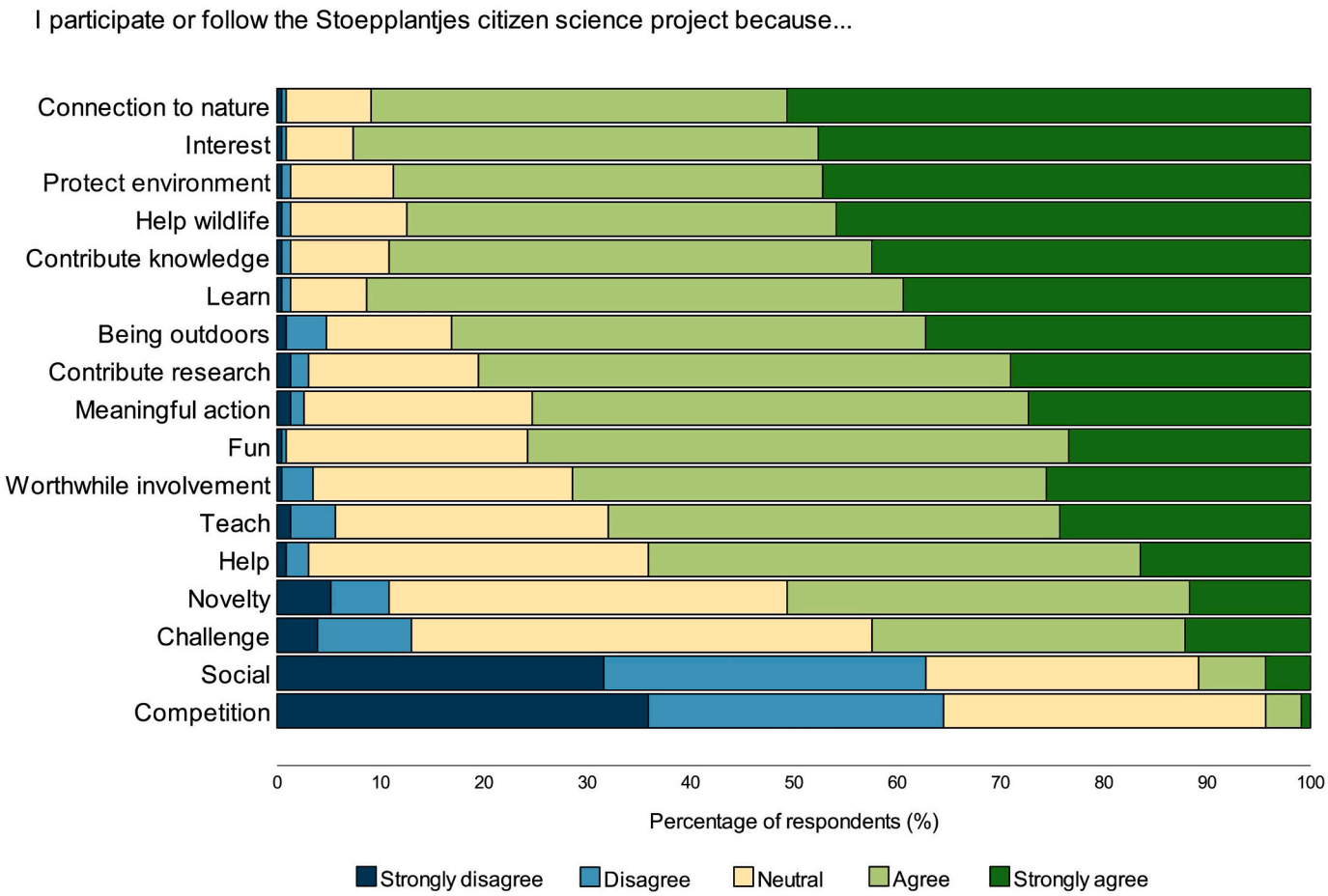

Fig. 1. Motivation of all respondents (n = 231 listwise) ordered by mean descending score.

statements are consistently scored lowest for all compared groups (Table 1).

Another way to interpret our results and make comparisons is to look at the top five of highest scoring motivations. Contributors (C) and followers (F) only differ in one of the top five motivation statements: *contribute knowledge* was included in the top five motivations of contributors whereas *help wildlife* was in that of followers. Otherwise, the top five consisted of the same four motivations for both groups: *connection to nature, learn*, *interest,* and *protect environment*. The *t*-test revealed that the two groups differed significantly on two motivational items. For contributors, both *contribute knowledge* (4.41(C) vs. 4.19(F); $t(229) = -1.287$; $p = .023$; $d = -0.301$) and *contribute research* (4.32(C) vs. 3.80(F); $t(229) = -5.230$; $p < .001$; $d = -0.688$) scored significantly higher compared to followers, with a small and medium/large effect size, respectively.

Looking solely at contributors, *protect environment*, *interest* and *contribute knowledge* were part of both experienced (EV) and inexperienced nature volunteers' (IV) top five motivation statements. The groups differed in two items: *connection to nature* and *contribute research* were included in the EV top five, whereas *learn* and *help wildlife* were included in the IV top five. A *t*-test showed significant differences for two statements. *Connection to nature* was scored significantly higher by EV with a medium effect size (4.27 (IV) vs 4.57 (EV); $t(111) = -2.349$; $p = .021$; $d = -0.443$), while, *interest* was scored significantly higher by IV, also with a medium effect size (4.32 (IV) vs 4.60 (EV); $t(108.6) = -2.659$; $p = .009$; $d = -0.493$).

3.3. Attitude

Overall, respondents were extremely positive about pavement plants, with all the mean semantic differentials scoring above 75 and most of them even above 85 (Supplementary data, Table A3). The highest scoring differentials were *important for nature* (as opposed to *unimportant*; 91.4), *natural* (as opposed to *unnatural*; 91.2), *valuable* (as opposed to *worthless*; 89.9), and *strong* (as opposed to *weak*; 89.4). The lowest scoring, but still positive, differential was *unique* (as opposed to *ordinary*; 75.3). The scores for this differential were also the most widespread (Fig. 2).

When comparing contributors and followers using a *t*-test, we found two significant differences: Followers rate pavement plants as more *important for nature* than contributors (93.0(F) vs 89.8(C); $t(230) = 2.700$; $p = .007$; $d = 0.278$) and they rate pavement plants as more *beautiful* than contributors (as opposed to *ugly*; 88.8(F) vs 84.2(C); $t(230) = 2.118$; $p = .035$; $d = 0.355$). Both effect sizes are small. We did not find any significant differences in attitude towards pavement plants between experienced and inexperienced nature volunteers among the contributors.

4. Discussion

This study explored the motivations and attitudes of biodiversity citizen science participants, focusing on differences in engagement. The unique characteristics of the Stoepplantjes project, such as low technological, knowledge, and practical barriers, along with its extensive outreach via social media, newsletters, and traditional media, enabled us to compare three distinct groups: experienced contributors, inexperienced contributors and followers who engaged only online.

Scores for motivation and attitude across all participant groups emphasized appreciation, importance, and protection of pavement plants and nature. Non-data contributing followers had a similarly positive attitude towards pavement plants as active contributors and their main motivations to engage, outside of research, matched as well. As followers seem driven by the same attitudes and motivations as contributors, we suggest that it is worthwhile to consider their possible contributions to other activities related to urban nature, such as education and advocacy. More broadly, our research might suggest that non-contributing citizen science participants should not be ignored in conservation science and practice.

4.1. Important motivations and prominent attitudes of participants

Our findings show that respondents were primarily motivated by their interest in urban nature and their desire to support research, learn, and help nature. This aligns with other studies on biodiversity citizen science participants (Levontin et al., 2022; Maund et al., 2020), which highlight that universal values, such as doing something meaningful, helping nature, contributing to research, and fostering personal interest in nature, as key motivators. Interestingly, in contrast to Stoepplantjes participants, users of the online citizen science platform Zooniverse scored achievement (corresponding to our *competition*) highest (Jeong

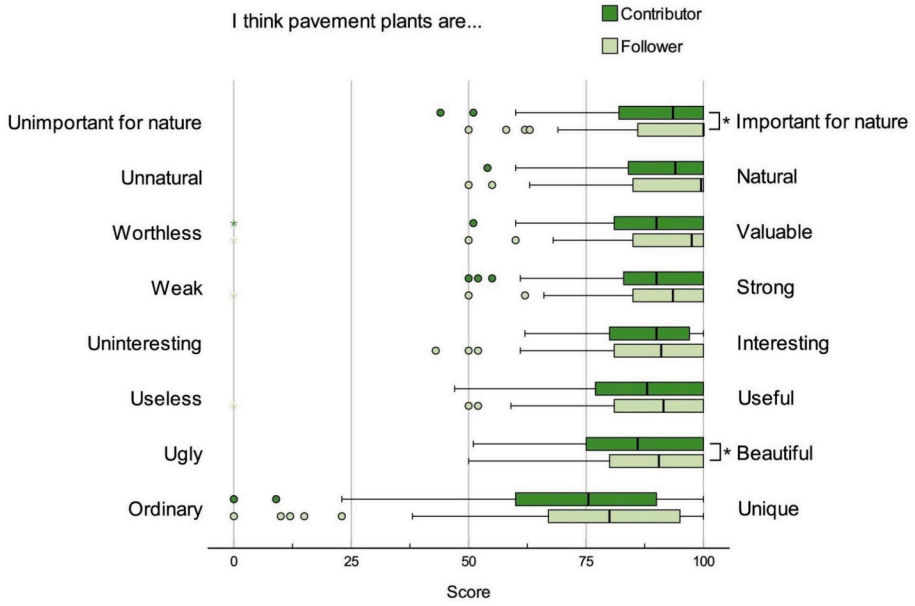

Fig. 2. Attitude of contributors and followers towards pavement plants. Scored on a sliding scale of 0–100. Attitude statements are ordered by descending mean score. Outliers are signified with a colored *. Independent t-test results comparing contributors and followers, *$p < .05$.

et al., 2023). Different topics, formats, and foci of citizen science projects likely attract participants with distinct characteristics and motivations.

Respondents' attitudes towards pavement plants were extremely positive, as they found them important for nature, valuable, interesting, useful, and beautiful. This overall positive attitude may reflect a pre-existing appreciation of urban plants. As in other citizen science projects, the Stoepplantjes project could have attracted participants who were aligned with the project's goals and had a positive attitude towards pavement plants from the start. However, these results also reflect other recent studies on the view of spontaneous urban flora and attitude towards plants in general (Deparis et al., 2023; Dünser et al., 2024b).

Despite many similarities, our analysis also revealed some differences in attitudes and motivations based on levels of engagement and prior experience. Contributors who submitted plant occurrence data were significantly more motivated by their desire to support research compared to followers, who engaged via social media and newsletters but did not contribute data. This is similar to findings from a study on opportunistic and more active systematic contributors of a wildlife disease citizen science project (Maund et al., 2020). We suspect that followers are interested in seeing the project evolve but do not feel the need to contribute data themselves. They can be considered "lurkers" in citizen science (Aristeidou et al., 2017), who demonstrate positive attitudes and long-term project engagement without submitting data.

Contrary to our expectations, followers rated pavement plants as more *important for nature* and more *beautiful* than contributors, while other attitudes did not differ significantly. More positive attitudes towards plants are usually linked to a higher amount of active interaction with plants and visual attention (Parsley, 2020; Stagg and Dillon, 2022). Our results may be due to followers primarily experiencing curated, zoomed-in photos of flowering plants and positive messaging online, whereas contributors also encountered pavement plants "in the wild", where they may seem smaller, less attractive, and insignificant in comparison.

Contributors with prior nature volunteer experience were more motivated by their strong connection to and interest in nature compared to inexperienced contributors. Both groups had largely similar attitudes towards pavement plants. These results could align with the idea that interest develops over time through ongoing engagement, positive feelings, and growing knowledge (Hidi and Renninger, 2006). Inexperienced contributors, and potentially non-contributors, have a similar positive attitude towards urban flora but may have more room to further develop their interest in it. Research suggests that persistent exposure to nature and outdoor time is key to fostering such interests (Hecht et al., 2019). Participation in the Stoepplantjes project and similar citizen science initiatives could play a role in nurturing this interest, fostering greater appreciation for and engagement with plants and nature.

4.2. Potential value of non-contributing participants

Although we did not investigate why followers did not contribute observations to the project, previous studies provide valuable insights into potential barriers to participation. For example, an interview study by Hobbs and White (2012) found biodiversity recording organizations, such as the British Trust for Ornithology, were described as "high brow" and having "lots of bearded experts" by the public. Despite efforts to make biodiversity citizen science projects more accessible, participants often remain a skewed representation of the general population (Hobbs and White, 2012). Jones et al. (2018) compared citizen scientists and non-citizen scientists who shared a common interest in activities like birding or astronomy. The non-citizen scientists were less driven by an interest in science. However, both groups reported engaging in science-related activities such as interacting with scientists, educators, peers, the public, and the media.

Likewise, non-contributing participants may still play a meaningful role in citizen science projects by engaging in other science-related activities better aligned with their interests and skills. Ganzevoort and van den Born (2020) identified four main types of activities among Dutch nature volunteers: recording, restoration, education, and administration. Notably, two-thirds of volunteers were involved in more than one activity. In the Stoepplantjes project, contributions were largely limited to submitting data, i.e., recording, as is often the case in citizen science projects (Land-Zandstra et al., 2021). However, as followers had similarly strong nature related motivations and positive attitudes towards pavement plants but could not or chose not to contribute data, they may have spent time on other types of urban nature-related activities. For example, anecdotally, we know that during the time of the Stoepplantjes project, but unrelated to the project or the botanical garden, local citizens in Leiden organized educational activities centered on urban flora. Additionally, a local political party successfully proposed changes to municipality policies on pavement plant weeding (van Schaik et al., 2022). Both followers and contributors could have taken part in these activities or acted in their support. These studies and examples demonstrate the broader impact citizen science projects might achieve on concrete conservation policy (van Noordwijk et al., 2021).

4.3. Implications for participation in biodiversity citizen science

In many citizen science projects, non-contributors or lurkers constitute a large part of the community. This may be because participants do not view themselves as potential researchers, feel ill-equipped to meet the skills or knowledge required for contribution, or face practical barriers to participating (Hobbs and White, 2012). Projects often aim to encourage these non-contributing participants to become active contributors. For the Stoepplantjes project, outreach efforts largely focused on fostering interest in pavement plants through positive messaging but paid limited attention to the scientific processes behind the project. Correspondingly, while attitudes towards urban flora were positive across participants, the motivation to contribute data was distinctly linked to an interest in supporting science. Including more communication about the scientific aspects of the project might have encouraged more followers to contribute observations if they had the time and means.

Even so, a high percentage of lurkers in citizen science might not necessarily be a drawback. Non-contributing participants can still advance a project's overarching goals in other meaningful ways, through education or advocacy. These participants may also help to establish roles and activities that were not originally anticipated during the project's design. Instead of focusing on converting lurkers into contributors, it may be more effective to acknowledge lurkers' roles and broaden outreach efforts to engage other parts of the public, such as minority or underrepresented groups. Engaging a more diverse audience can enhance inclusivity and reach of the project, which offers benefits for both research outcomes and societal impact (Pateman and West, 2023).

Our results show that participants have a very positive attitude towards pavement plants, which aligns with research on attitude towards plants in general (Dünser et al., 2024b). Deparis et al. (2023) found a majority of French city dwellers had positive attitudes towards spontaneous vegetation but a considerable part also had mixed, indifferent, or negative views. It could be that the Stoepplantjes project mainly attracted citizens who already had positive attitudes, as there were few differences between groups of participants. Even though their attitudes would be unlikely to change (Ganzevoort and van den Born, 2021), there are other aspects to plant awareness, nature connectedness, and pro-conservation behavior that might have greater potential for promoting plant conservation. Finding more suitable activities than data generation, such as outreach and advocacy, could not only deepen the participants' engagement but broaden the project's impact. Engaging new groups could contribute to changing social norms and grow support for political action (van Noordwijk et al., 2021).

4.4. Limitations and future perspectives

A few limitations should be taken into account with regard to our study. Our results, particularly the strongly positive attitude towards pavement plants, may have been influenced by sampling bias, as survey respondents could have been more engaged or committed to the project than the average participant. Nevertheless, groups differed significantly and could be meaningfully compared. Future studies could minimize bias by conducting randomized surveys at citizen science events or targeting specific communities and by following up with non-responders. Secondly, since the survey was conducted only after participation in the Stoepplantjes project, we could not assess impact directly. Pre- and post-participation surveys were not feasible due to the project's anonymous, flexible design aimed at maximizing accessibility. Future impact assessments of plant-focused citizen science should make use of existing validated instruments and frameworks for conservation action (Lampert et al., 2023). Especially plant awareness has been assessed inconsistently and assessments rarely include all components (i.e., attention, attitude, knowledge, and interest; Brkovic et al., 2024).

In the field of citizen science participation, more research is also needed to understand low- or non-contributors and their potential roles. Studying online and offline participant behavior, as well as different engagement pathways (Aristeidou et al., 2017), could reveal how diverse contributions can support biodiversity citizen science projects and conservation goals. Incorporating appreciation for alternative activities may stimulate broader action for nature and highlight the extensive impact of biodiversity citizen science (Ganzevoort and van den Born, 2020; van Noordwijk et al., 2021). Frameworks for assessing citizen science's wider impacts can guide these efforts (Pateman and West, 2023; Wehn et al., 2021).

Research has shown how plant-focused citizen science can support plant conservation through scientific outcomes but no studies have demonstrated definitive links between conservation and societal outcomes (Buldrini et al., 2015; García et al., 2021; Havens et al., 2012). Research does link citizen science or related activities to impact pro-conservation behavior, nature connectedness, and plant awareness which could support plant conservation (Peter et al., 2021; Pocock et al., 2023; Sharma et al., 2019). The Stoepplantjes project and other plant-focused citizen science can involve many of these types of activities (Havens et al., 2012; Jordan et al., 2011). Our results suggest that looking only at individual data contributions might side-step the community-level contributions that cannot be easily quantified and observed as specific data. While studies point out that nature connectedness, knowledge of native flora, and interest in plants are low in urbanized societies, citizen science could provide opportunities to promote interaction with plants and nature and support botanical education (Stroud et al., 2022). Beyond plant monitoring, other citizen science related activities, such as education, restoration, and policy advocacy, can directly benefit plant conservation. When considering the impact of citizen science in support of plant conservation for research or project design, we suggest adopting a broad view of citizen science project activities and engagement.

5. Conclusion

Our study reveals the diverse motivations and attitudes of participants in a biodiversity citizen science project focused on urban flora. In general, all participants of the Stoepplantjes project, independent of whether they provided data or not, shared a love of and strong motivation to care for urban flora and nature. Future research should explore methods to develop successful plant-focused citizen science projects and study their impact on participants' conservation behavior, nature connectedness, and plant awareness. Specific attention should be given to the broader societal impact and often-overlooked contributions of followers or lurkers, which may support project aims. Such initiatives might provide opportunities that can highlight the vital ecological and societal role of plants, and support their conservation.

CRediT authorship contribution statement

Nienke Beets: Writing – review & editing, Writing – original draft, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Anne M. Land-Zandstra:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Funding acquisition, Conceptualization. **Tuomas Aivelo:** Writing – review & editing. **Paul J.A. Keßler:** Funding acquisition, Supervision, Conceptualization, Writing - review & editing.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used ChatGPT in order to improve the readability and language of the manuscript. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

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Declaration of competing interest

Paul Keßler is prefect emeritus and Nienke Beets is staff of the Hortus botanicus Leiden. Nienke Beets organized the Stoepplantjes citizen science project as part of her Ph.D. Anne Land-Zandstra advised in the organization of the project.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.biocon.2025.111408.

Data availability

All relevant data is available at https://doi.org/10.17605/OSF.IO/VXK82.

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