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Citizen science participant motivations and behaviour: Implications for biodiversity data coverage

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A R T I C L E I N F O

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A B S T R A C T

1. Increasingly, citizen science data are becoming a significant source of information on the distribution of biodiversity. Their value is affected by many biases, especially gaps and redundancies in citizen science data. Reducing or minimizing those biases remains an important task, with an important first step being an understanding of whether, and to what extent, participants are willing to alter their behaviour for the benefit of a project.
2. We surveyed participants of a popular citizen science project focused on frog biodiversity to understand how their motivations and behaviour relate to their willingness to change when and where they collect data.
3. Most respondents contributed seasonally and close to home. Both their motivations and interest in changing behaviour strongly aligned with the project aims: conserving frogs and contributing to science. Willingness to change behaviour varied little with reported motivations, and respondents displayed a high level of willingness to change when or where they collect data when presented with opportunities for less biased sampling.
4. Our results indicate there is interest among participants to sample biodiversity in a more meaningful way, potentially reducing some biases in how citizen science data are collected. Creating citizen science projects that encourage participants to collect optimal data may satisfy both participant and organizers' goals, and work towards science-driven conservation with improved biodiversity data.

1. Introduction

Biodiversity data collected through citizen science platforms has increased exponentially in recent decades (Welvaert and Caley, 2016; Pocock et al., 2017), providing data across large spatial and temporal scales (Hochachka et al., 2012; Bird et al., 2014; Sullivan et al., 2014). Evidence of the value of these data can be seen in the documentation of new (Hartop et al., 2015) and invasive species (Crall et al., 2015), phenology changes over time and space (Newson et al., 2016), and the identification of geographic and taxonomic gaps in our biodiversity knowledge (Lloyd et al., 2020).

Yet, citizen science data often includes taxonomic, temporal, and

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spatial biases due to factors including weather, time of year, time of day, site accessibility, variable search efforts, species detectability, and species desirability (Bird et al., 2014; Kays et al., 2021). Together, these biases complicate use of the data for addressing pressing conservation issues. For example, opportunistic, and presence only data collection methods, and differing data storage methods require efforts to integrate the results with professional science (Cruickshank et al., 2019; Taylor et al., 2019).

One way to reduce these biases is to improve sampling of biodiversity by citizen science participants. For example, by suggesting users travel to unsampled sites, or submit observations at times of year where samples are infrequent. Yet, the willingness of participants to adopt these behaviours remains poorly understood. Participant behaviour is typically measured in frequency of contributions and duration of engagement (Aristeidou et al. 2017; August et al., 2019; Hermoso et al., 2021). An outreach message with a focus on 'contributing to science' can attract more participants, and those participants tend to contribute more observations (Lee et al., 2018). Also, participants who perceive more benefits from their involvement also report investing more time and effort in the project (Agnello et al., 2022). While understanding frequent and regular contributions is valuable, these measures do not explain the extent to which defined behaviours directly work towards addressing specific scientific questions (Callaghan et al., 2019a).

As such, it is largely unclear whether participants are willing to modify their existing data collection behaviour to meet a *specific* goal linked with a scientific question. Such goals could include encouraging participants to sample areas previously under-sampled (Xue et al., 2016), or encouraging sampling of under-studied taxa, such as insects (New, 2018). Shifting our focus towards understanding this aspect of contributor behaviours is critical in reducing taxonomic, temporal, and spatial biases. Therefore, more work is needed to quantify the extent to which participants respond to specific opportunities to collect more 'valuable' data (i.e., taxa, species, locations, or times known to be of value to the project), potentially within a dynamic (i.e., continuously updated) sampling framework (Callaghan et al., 2019a). Understanding participants' 'willingness to sample' could improve the utility of the data in current and future citizen science projects (Callaghan et al., 2019b).

To improve the ability of citizen science projects to collect more comprehensive data for biodiversity monitoring, we aimed to understand participants' 'willingness to sample' biodiversity to meet specific project goals. We defined willingness to sample as self-reported interest in changing where and when to collect data. Our work focused on three interconnected aspects: (1) what motivates participants to sample biodiversity; (2) the prompts that would motivate participants to change where and when they sample; and (3) how social and competitive project design changes could influence interest in the project.

Important here is a need to align the data requirements of scientists with the interests and values of participants. As such, we sought to quantify the link between behaviour, motivation, barriers, and stated willingness to change sampling behaviour. We explored motivations for current and future behaviour. We also evaluated divergent themes among motivation types and demographic groups. We intend for these results to assist citizen science projects to capitalize on participants' interests and build more comprehensive biodiversity datasets to inform management decisions through an understanding of 'willingness to sample'.

2. Methods

2.1. Case study

We surveyed participants of the FrogID citizen science project in Australia. FrogID is a national citizen science project launched in 2017 by the Australian Museum (Rowley et al., 2019). The stated project aim is to engage people across Australia to help provide scientists with valuable data for the protection and conservation of frogs (Rowley et al., 2019). FrogID uses a smartphone app where participants submit 20–60 s audio recordings of calling frogs. The app adds associated metadata (time, date, latitude, longitude, and an estimate of precision of geographic location) to each submission. After a recording is submitted, a frog call expert independently identifies any frog species heard calling in the recording. With over 30,000 participants as of December 2021, they have compiled a dataset of over 600,000 frog records across Australia, successfully doubling the number of frog biodiversity records in Australia in its first four years.

2.2. Community sampled

We set a minimum target sample size of 900 respondents, representing 3 % of registered FrogID participants (at the time of survey development), based on a formula including population size (30,000), confidence level (95 %) and margin of error (5 %) (Taherdoost, 2017). Participants could complete the survey anonymously or include their FrogID username. Potential respondents were incentivized with a 1 in 10 chance to win a FrogID keep cup or a single $100 hardware store gift card (only for participants who chose to provide contact details). The survey was announced in the FrogID newsletter on August 12th, 2020 (emailed monthly to all registered users). Following the first 50 responses, we confirmed via qualitative check that answers reflected the prompts and questions were understood. The survey was also advertised on the FrogID website (www.frogid.net.au) and on social media platforms 1–2 weeks after the initial launch. The survey was left open for a total of 5 weeks, closing on September 16th, 2020.

2.3. Survey design and execution

Our goal was to understand preferences and behaviour, and so we used a closed-question survey method, a non-experimental approach, within a realist ontology (see Moon and Blackman, 2014). To allow expression of all opinions and experiences, every question block had a write-in option, so participants had the opportunity to self-describe. We also designed the survey so any question could be skipped. In this way, we hoped to alleviate pressure on the respondent (i.e., reduce survey fatigue), and to collect only meaningful responses.

Our survey design was grounded in literature that examines motivations for volunteering and citizen science participation specifically (e.g., Haivas et al., 2012; Larson et al., 2020; Maund et al., 2020). We selected prompts that were feasible for FrogID and other science programs to implement, and that represent changes that could have measurable outcomes, improving utility of the data. We developed Likert matrix-style questions (commonly used to present multi-item scales) (Boone and Boone, 2012) addressing: (1) current behaviour (over space and time); (2) motivations for participation in FrogID; (3) prompts that would motivate changes in *temporal* behaviour; (4) prompts that would motivate changes in *spatial* behaviour; (5) barriers that limit participation; and (6) how social and competitive design features would influence participation. All Likert matrix questions used a 5-point scale, comparable across matrices and respondents. While Likert data is ordinal, it is also somewhat subjective. Whenever possible, the descriptive category representing numbers 1 through 5 was clarified with a percentage range (e.g., "somewhat unlikely 25 - 49%").

In addition to motivations, other factors influence attitudes to the environment and their relationship to personal behaviour includes demographics, barriers, incentives, and rewards to behavioural change (Barr, 2006; Toomey et al., 2017). One pathway to increasing the impact of citizen science projects is to understand participant demographics, and thereby find gaps to maximize breadth of participation across society (Tulloch et al., 2013). Woods (2019) conducted a survey of FrogID participants to understand the demographics, motivations, and communication channels used by participants, and to identify areas for growth. In our questions examining personal level characteristics, we used the same age brackets as this previous survey (Woods, 2019)

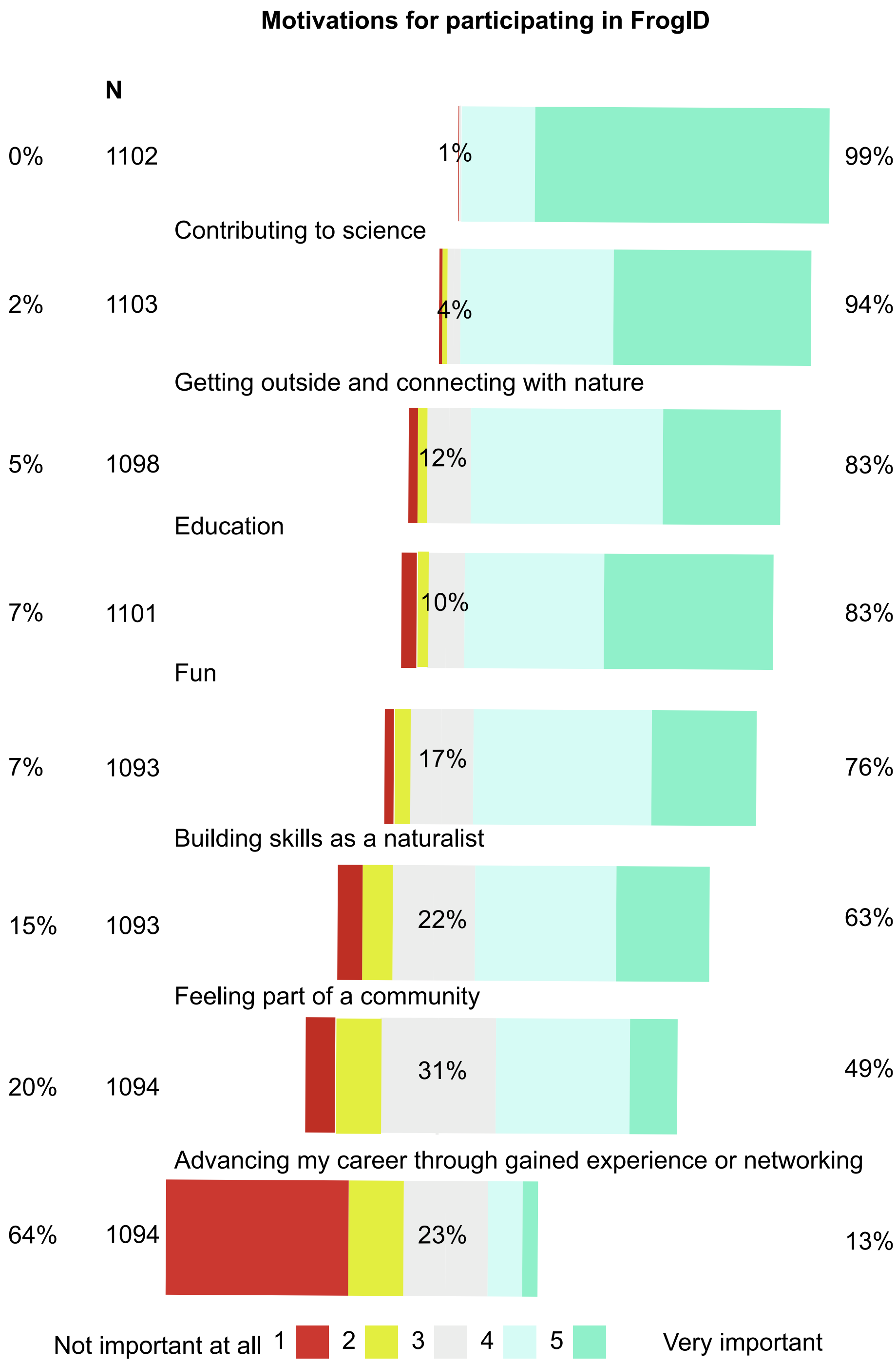

Fig. 1. Reported motives for participation in the citizen science project FrogID arranged from most important to least important (5–1), as a percentage of responses. Total number of responses to each prompt are listed along the right margin.

(approximately 520 respondents), to provide opportunities to compare responses to previously collected data (see Supplementary Material for the full survey prompts and response options). We used an online survey platform (Qualtrics) to collect data and all advertising and reminders were online (via email and social media), potentially biasing our results towards technologically active users comfortable with online surveys (Keeter et al., 2015). However, the project from which we recruited, FrogID, is a smart phone app. So, while the app could influence the user base of FrogID, this bias was unlikely to have influenced our participant pool in respondents of the survey.

Final survey and administration procedures were approved by the Human Ethics Committee at UNSW Sydney (HC200544). Informed consent was obtained from all participants. Participants received a participant information sheet consent form at the beginning of the survey and were only directed to the remaining questions if they agreed to the terms.

2.4. Analysis

Summary statistics were produced, and figures plotted using R statistical programming (R Core Team, 2020). Likert matrix response plots were created using the R package “likert” (Bryer and Speerschneider, 2016), suited to ordinal survey response data. Standard statistical procedures (e.g., regression) were not suitable as likert responses are arranged in ranking order and this scale does not show the relative magnitude and distance between two responses quantitatively (Joshi et al., 2015). Further, because groups are formed from each answer selected on the scale, the sampling size becomes too small to draw meaningful comparisons. As such, although not a standard significance test, correlation coefficients are suitable for ordinal non-parametric data (Joshi et al., 2015). We quantified the correlation between variables, using heatmaps indicating the strength and direction of the relationship. We created heatmaps using the "ggcorrplot" package (Kassambara and Kassambara, 2019), to assess high overlap across the responses of interest (i.e., between frequent use (5) and very motivating factors) (5). When a question was skipped and no response selected, it was excluded from analysis, resulting in variable response rates to individual questions. When N/A, undecided, or neutral was an option, the response was incorporated into analysis. Responses per category are therefore presented as the percent of responses to each question, rather than the total number.

3. Results

We received a total of 1281 survey responses, exceeding our minimum sample size expectations. Respondents skewed towards middle age and older (most selected 55–64 years of age), and slightly more female (55 %) than male (Supplementary Fig. 1).

3.1. Willingness to change where and when

Whether contributing at home or far from home, respondents were much more likely to contribute seasonally, rather than daily or weekly. On a scale from 1 (seasonally) to 4 (daily), the periodicity of behaviours was similar across spatial scales. Most respondents contributed within 1 km of home (62 %), and few submitted recordings further than 50 km from home (9 %). Most respondents contributed seasonally (71 %) and very few contributed daily (2 %) (Supplementary Fig. 2).

Importantly, respondents expressed high willingness to change both where and when they contribute data under certain conditions. In response to the question about likelihood of changing spatial patterns of data collection, on a scale from 1 (extremely unlikely) to 5 (extremely likely), the prompts that scored highest were "If I knew there were areas near me where recording frogs would be more valuable" (mean = 3.3), and "If I was presented information about a species helped by my efforts" (3.1), followed by "If I was asked to regularly visit a particular area near me", and "If I was provided resources about how to sample and why" (means = 3.1) (Fig. 2A). The low score for "If I could engage in a local challenge to submit the best recordings," mean = 2) suggests respondents were not motivated by competition (Fig. 2A).

The same pattern emerged for factors motivating temporal change (Fig. 2B). "If I knew there were areas near me where recording frogs would be more valuable" (3.3), and "If I was presented information about a species helped by my efforts" (3.1) were most motivating, followed by "If I was asked to regularly visit a particular area near me" and "If I was provided with resources about how to sample and why" (means = 3.1). Just as we found for spatial change, opportunity for competition was least likely to motivate temporal change (mean = 2) (Fig. 2B).

We present a correlation heatmap – a matrix visualizing the pairwise relationships between responses to motives and behaviour change question blocks (Fig. 3). For each pairwise comparison, values close to 1 (red) indicate a strong positive correlation, while values close to −1 (blue) indicate a strong negative relationship. Values close to zero indicate minimal relationship between the two response categories. Correlations between willingness to change behaviour and motives for participation were all positive and all insignificant (Fig. 3), with skill building being the motivation most positively correlated to prompts for both spatial and temporal change. Correlations between reported willingness to change spatial and temporal behaviour were higher, though low to moderate overall (Supplementary Fig. 3). Similar questions were the most highly correlated (i.e., "If I could engage in a local challenge to submit the best recordings", had a correlation coefficient of 0.84 between the spatial and temporal question blocks), indicating the reason for changing behaviour mattered more than the type of change requested. Young respondents (18–34) were generally more open to changing their behaviour (spatially and temporally). The most dramatic difference across age ranges was in response to the opportunity to compete in a local challenge, and the prompts with the least variance across age groups were opportunities for regular sampling (Supplementary Fig. 4C). Correlations between reported willingness to change and frequency of app use were generally positive but negligible (Supplementary Fig. 5). The strongest positive correlation (0.2–0.23) was between respondents contributing regularly at significant distances (5–50 kms from home) and interest in opportunities for competition.

3.2. Motivations and barriers

Respondents were overwhelmingly motivated by the aims of the program itself: to collect data on frogs that is useful to science and effective conservation. On a scale from 1 (not important at all) to 5 (very important), the most important motivational themes (Fig. 1) were conserving frogs (mean = 3.8), contributing to science (mean = 3.4), getting outside and connecting with nature (3.2), and education (3.1). These common responses were followed by fun (3), building skills as a naturalist (2.7), feeling part of a community (2.4), and advancing one's career through gained experience or networking (1). The lowest ranking overall motive had the greatest variance across age groups, with younger respondents much more likely to report this among their motivations (Supplementary Fig. 4A).

The factors most limiting engagement were related to time limitations rather than a lack of interest or opportunities. On a scale from "not limiting at all" (1) to "very limiting" (5), the most limiting factors to participant contributions were free time when frogs are active and free time in general (means = 2.2). All other barriers (technological glitches, convenient places near me, frog habitat near me, safe places near me, health or disability, level of interest, and transportation) had means trending downward between neutral (2) and not limiting at all (1) (Supplementary Fig. 6). Younger respondents were more likely to report barriers to participation across all categories. Respondents 75 years and older were much less likely to report free time in general and free time when frogs are active as limiting compared to all other age groups (Supplementary Fig. 4B), though these two categories were, overall, the most limiting factors for participation.

We did not detect strong correlations overall between motivations and barriers (Supplementary Fig. 7). Among the barriers, level of interest had a uniformly negative correlation to all motivations. Strong interest in contributing to science was negatively correlated with all barriers, and conversely, respondents motivated by career advancement were most likely to report their participation was limited by barriers. Correlations between barriers and frequency of app use at five spatial scales were insignificant, and generally negative (Supplementary Fig. 8), indicating more frequent users were less likely to report barriers to participation. The strongest correlation (−0.28) was between frequent participants at the 1 km scale and frog habitat nearby, confirming that access to frog habitat is not a barrier to participation among frequent local participants.

3.3. Social and competitive project design change influence on interest

The FrogID website hosts a leaderboard, a competition and community space where participants are ranked on the number of frog records and number of submitted recordings. Respondents were generally not interested in changing this format, but expressed highest interest in changes that reward contributions of important species or species new to that particular user. On a scale from 1 (I would be very interested) to 5 (I would lose interest), recognition for recording important species was

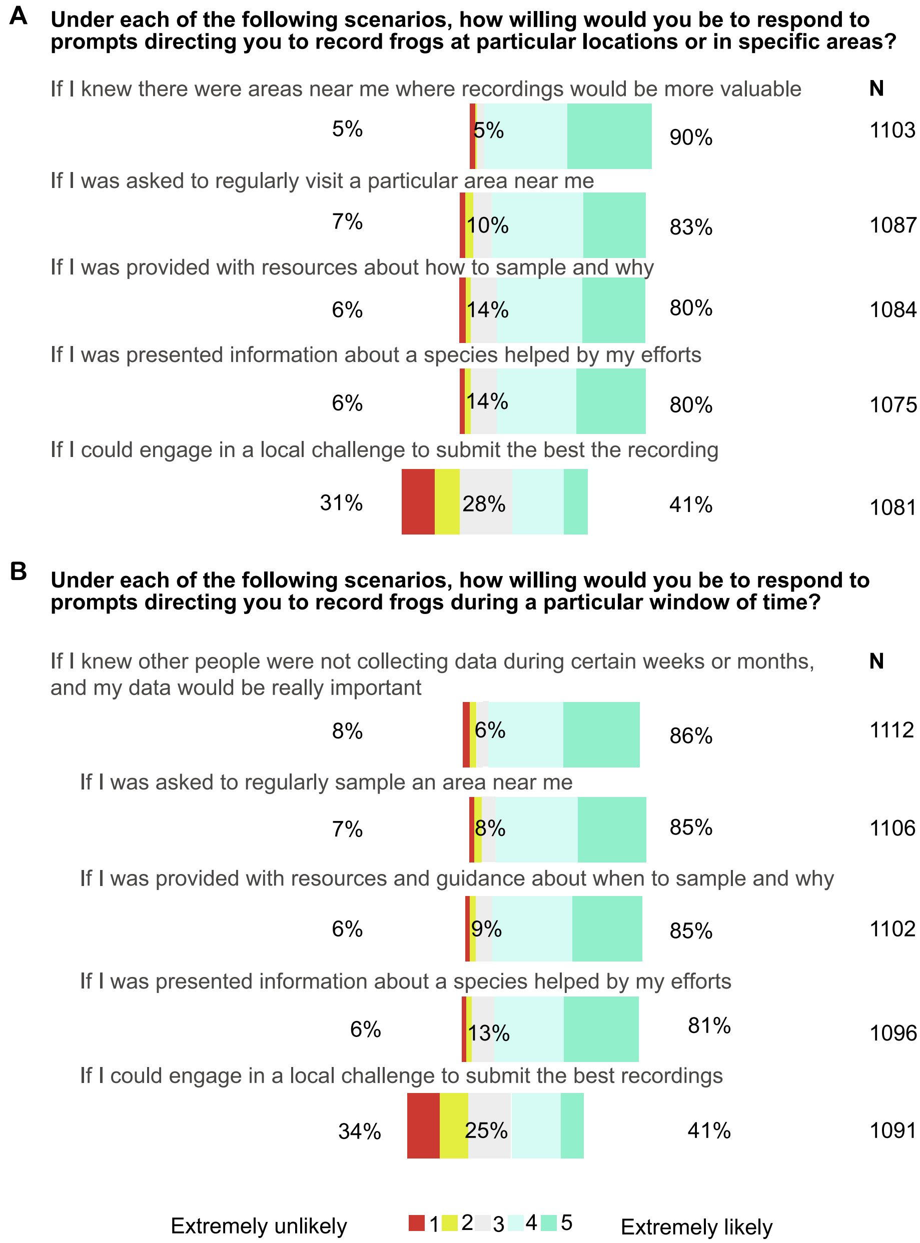

Fig. 2. Interest in changing (A) spatial and (B) temporal behaviour in the citizen science project FrogID. Responses arranged from most likely to least likely (5–1), as a percentage of responses. Total number of responses to each prompt are listed along the right margin.

most highly regarded (mean = 2.3), followed by recognition for adding new species to 'my list of personal observations' (2.7), recognition for surveying seldom visited areas (2.7), and recognition for regular, sustained contributions (3). The lowest ranking prompts were competition related, such as easier access to the leaderboard (3.2), and opportunities to engage in local competitions (3.2) (Fig. 4). Younger respondents expressed higher interest in project changes overall, and were dramatically more interested in opportunities for competition than older respondents (83 % positive responses among 18–24 year olds, compared to 9 % positive among the age group 75 or older) (Supplementary Fig. 4C).

4. Discussion

Individual participant behaviour drives the very nature of the spatial, temporal, and taxonomic data collected through citizen science. We contribute to the growing body of evidence that successful citizen science projects result from an alignment of participant motives and project aims (Frensley et al., 2017; Lee et al., 2018; Maund et al., 2020; Agnello et al., 2022). We also provide new insights on how participant self-reported 'willingness to sample' relates to conservation motivations. The most common motivations in our sample of participants were conserving frogs and contributing to science; and the most compelling reasons to change sampling behaviour were to collect data known to add value and to engage in regular sampling of a nearby area. Both reasons relate strongly to improving the scientific value of the data and require an effective feedback loop with the project organizers, data, and participants.

Respondents expressed greatest interest in opportunities for sampling scenarios where they would be informed of the value their contributions make to collective scientific discovery. They also indicated that if they were informed of how to make their contributions more valuable, then they might be willing to sample in different ways. Given that many participants are already involved in FrogID because they want to contribute to science and conservation, feedback specific to these

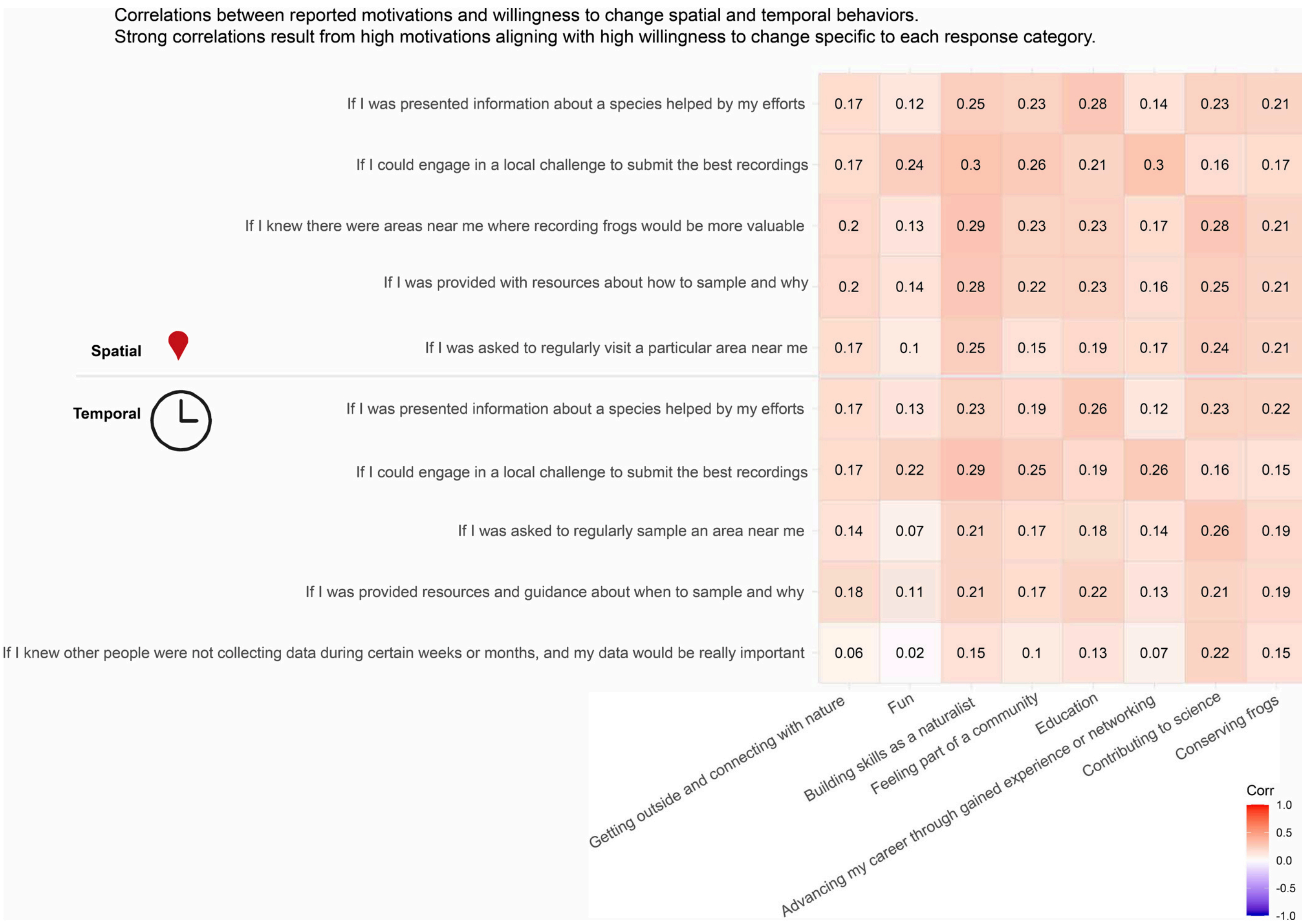

Fig. 3. Correlation plot showing the relationship between willingness to change spatial or temporal behaviour with motivation for participation. High correlation (maximum 1) in an area of intersect would result from all respondents selecting "extremely likely" for the prompt on the left and "very important" for the motivation along the bottom axis.

aims may be an important consideration for successful engagement and long-term success across demographic groups.

Transparency about the need for bias reduction and specific ways participants can make improvements may be empowering and promote feelings of autonomy. FrogID participants receive species identifications and personalized feedback after each submission (Rowley et al., 2019). Popular proposed project changes in our questionnaire involved feedback and personal recognition, suggesting that participants are interested in maintaining agency and receiving individual feedback, which can promote feelings of relatedness (Tiago et al., 2017). Positive performance feedback enhances intrinsic motivation (Deci, 1971; Badami et al., 2011) and can increase participant retention by maintaining their interest in a project (van der Wal et al., 2016).

Participants predominantly reported contributing data close to home and on an irregular basis, confirming other quantitative approaches that have found similar biases in citizen science data (August et al., 2020). We did, however, find a high willingness to change behaviour, where the reasons for doing so (i.e., in pursuit of valuable or important data) mattered more than the type of change requested (i.e., altered spatial or temporal sampling) (Supplementary Fig. 3). Changes to *when* and *where* data are collected have distinct implications for our ability to understand biodiversity over *space* (Chandler et al., 2017; Lloyd et al., 2020) and *time* (Newson et al., 2016; Rowley, 2021). Our findings that younger respondents were more willing to sample if it involved guidance and competition, and more likely to seek career advancement and skill building (when compared to older participants) has been noted elsewhere (West et al., 2021) (Supplementary Fig. 4, plates A, C, and D). This pattern suggests there is a desire for the type of outcome more commonly associated with traditional, in-person, volunteer opportunities (e.g., mentorship, skill sharing, and relationship building) among participants of app-based citizen science projects. The finding also suggests that these participants may respond to specific guidance from project organizers with goal-oriented data collection.

Willingness to change behaviour varied little with reported motivations (Fig. 3), frequency of participation (Supplementary Fig. 5), and barriers (Supplementary Fig. 7); indicating that direct communication of project goals may appeal to different, albeit existing, participants. Similarly, Davis et al. (2019) found that pro-ecological values did not differ across citizen scientist participation rates, however, other studies of biodiversity focused citizen science projects have found motivations vary across levels of participation (Tiago et al., 2017; Larson et al., 2020).

Another form of feedback often suggested as a tool to enhance motivation and reward is gamification (Feng et al., 2018). We found little support that gamification (Fig. 4) or competition (Fig. 2) were important contributing factors to participation or retention in FrogID. We found that respondents were uninterested in competition, expressed moderate interest in program changes overall, and were more likely to lose interest in the project if competitive aspects were further developed (Fig. 4). Yet, competition can facilitate intrinsic motivation for some people if the focus of the competition is on doing well and the interpersonal competition does not feel controlling (Reeve and Deci, 1996). People enjoy accomplishing a task that, through competition, they understand is valued by the group as a collective goal (Deci and Ryan,

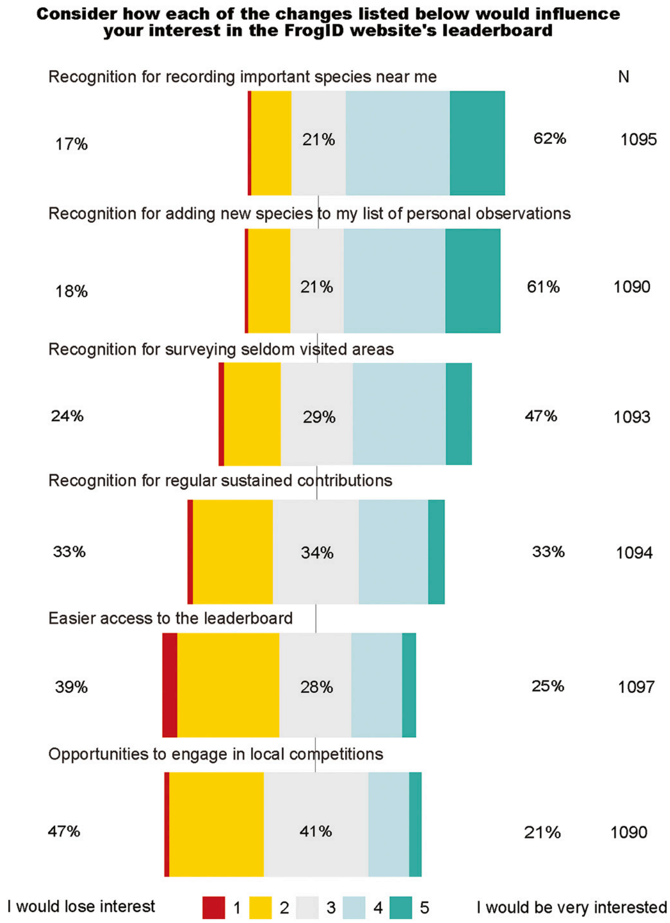

Fig. 4. Interest in project changes arranged from most positive response to least positive (5–1), as a percentage of responses. Total number of responses to each prompt are listed along the right margin.

2000). For example, the most popular of our proposed leaderboard changes was personal recognition for recording important species. Understanding what participants perceive as 'important species' could provide insights to inform project messaging and more broadly to understand social-ecological connections in the context of citizen science (Newman et al., 2017). There may be opportunities, if done correctly and focused on valuable needs, for behavioural nudges to play a role without being perceived as competitive (Xue et al., 2016). Appealing broadly across society and bringing techniques of adaptive management into the citizen science realm may involve personalized gamification elements tailored to participants with different motivation and participation profiles (Tondello and Nacke, 2020). Our results highlight the need for a more nuanced understanding of how competition and gamification influence citizen science engagement and retention.

While establishing goals that work towards project success and data quality, it is important to calibrate expectations from participants (Kollmuss and Agyeman, 2002; Barr, 2006; Toomey et al., 2017). Participants can choose how they want to engage with the project, if at all. Across various citizen science initiatives, most participants contribute very few records and do not remain engaged for long (Lee et al., 2018; August et al., 2020). Self-reported willingness to change is distinct from actual behaviour change. People tend to over-estimate their socially desirable behaviour (Gosling et al., 1998), and pro-environmental behaviour specifically (Kormos and Gifford, 2014) on self-report measures when compared with direct observations of behaviour. Although gamification research is in its infancy, we know of only one study that compared self-reported design feature interest with actual behaviour, and found they did align (Tondello and Nacke, 2020). Additionally, the respondents of our survey were more active than the average FrogID user (they averaged 31 submissions per year, compared with an average of eight submissions per year across all users, Supplementary Material Fig. 9).

A targeted reduction in bias (i.e., a change in behaviour) may involve small changes in the behaviour of a small percentage of participants. Potentially, dynamic programming can suggest sites that fit participants' behaviour and vary with both changes in participant interest (home range, submission rate, focal taxa) and project needs (Callaghan et al., 2019a, 2019b; Tondello, 2019). Specifically, messaging and incentives could focus on rewards for regular sampling, undersampled areas, undersampled times of day, underrepresented taxa, or locations that are important because of a timely threat (i.e., natural disaster or human development) or biological phenomena (i.e., migration). These results support the notion of a "Plan, Encourage, Supplement" approach to reducing biases and increasing the quality of the citizen science data (Kays et al., 2021). Employing some of these methods, Xue et al. (2016) demonstrated remarkable success with participants of eBird, and, importantly, saw an exponential increase in submissions when they added features to allow participants to track and rank their contributions. Designing structures that resonate with the inclinations of different users (i.e., an optional, targeted competition with feedback on personal and project success) is an important consideration for project success, especially considering that motivations of under-represented demographics may differ from those already participating (West et al., 2021).

By surveying participants of a popular citizen science project, we identified their self-reported behaviour and motivations for participating, and specifically related those traits to future involvement in the project. The strong alignment between the interests of citizen science participants and the goals of the project indicates the biases common to many citizen science programs have the potential to be reduced through a more nuanced communication with participants, focused on highlighting the most valuable times and places to submit observations. Understanding what motivates action, not just intention, is a further step towards assessing the potential of citizen science to address data gaps important to biodiversity assessment, including reducing bias at multiple spatial scales. We hope our results encourage citizen science project organizers to use messaging, in advertisements and feedback, that iteratively works towards project aims. This can include suggesting or incentivizing the types of behaviour changes that would improve scientific merits of the project by providing resources and feedback known to motivate participants. Optimally, applying knowledge about participant motivations and project rewards can be used to predict behavioural outcomes and meet project goals.

Credit authorship contribution statement

MMT and CTC conceived of the project idea. KM, AW, and MMT designed methodology; JJR and the Australian Museum conceived of FrogID and made those data available; MMT analysed the data; MMT led the writing of the manuscript with substantial advice and revisions from KM. All authors, including AGBP and RK, contributed critically to the manuscript, figures, and interpretation of results. All authors gave final approval for publication.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors do not have permission to share data.

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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.2023.110079.

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