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Quantifying the use of citizen science as a tool for biodiversity management and engagement

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Abstract

Citizen science is a rapidly growing field increasingly used by varied organizations for scientific data collection and public engagement. However, the extent to which these data are used and by whom is less explored. Using Florida, USA, as an exploratory case study, we surveyed 232 natural resource practitioners in various state, county, and municipal government agencies, a university outreach office, and variety of non-profit organizations to examine their citizen science usage, attitudes, and perceptions, as well as their citizen science usage barriers and challenges. Our findings reveal generally positive attitudes towards citizen science among both those who currently use it and those who do not, with usage patterns largely aligning with respondents' job roles. To better integrate citizen science in their roles, natural resource practitioners need tools for data collection and analysis, guidance on integrating citizen science into existing programs, and additional funding. By addressing these needs, organizations can enhance the quantity and quality of citizen science in their work, leading to improved decision-making, advanced research, and expanded opportunities for meaningful public engagement.

KEYWORDS
community science, natural resource management, participatory science, practitioners, social science

1 | INTRODUCTION

Citizen science, also known as participatory or community science, is a rapidly growing field (Ivanova & Shashkov, 2021) encompassing many disciplines in science, technology, engineering, and mathematics (STEM). Among these, biodiversity sciences are increasingly leveraging citizen science (Pocock et al., 2017) to benefit biodiversity monitoring (Callaghan et al., 2020; Chandler et al., 2017) and environmental education

(Fraisl et al., 2022; Hitchcock et al., 2021). Benefits of citizen science include broader spatiotemporal data availability to inform biodiversity monitoring and conservation (Callaghan et al., 2021; McKinley et al., 2017) as well as knowledge gain and behavioral change among participants in citizen science projects (Peter et al., 2019; Peter et al., 2021).

From an organizational perspective, natural resource practitioners who run or promote specific citizen science projects play an important role in shaping project approaches and objectives. Objectives determine how projects are implemented and performed, reflecting the diverse goals of the organizations involved. For example, citizen science is used to understand species distributions (e.g., iNaturalist; Krapf, 2023), track invasive species (e.g., Find-A-Pest, EDDMapS; Pawson et al., 2020), and contribute to policy (Callaghan et al., 2023). At the same time, participation in citizen science is useful to increase engagement and participation in the natural world, including learning and education (Roche et al., 2020), involvement in environmental planning (McKinley et al., 2017), and behavioral change regarding natural resources (Toomey & Domroese, 2013). Thus, citizen science serves as both a robust tool for scientific data collection and a means to engage the public in scientific endeavors, with positive feedback occurring between these different outcomes (McKinley et al., 2017).

Despite the growing popularity of citizen science and its diverse applications in natural resource management and public engagement, recent research suggests that natural resource practitioners are interested in citizen science but may be hesitant to fully embrace its use. This is due to concerns about data reliability, challenges in integrating data across different platforms, and limited awareness of the suite of citizen science data and potential applications (Burgess et al., 2017; Galanos & Vogiatzakis, 2022; Suškevičs et al., 2021). Despite these perceptions, some natural resource practitioners do recognize citizen science as a tool to generate valuable data, illustrate management challenges to the public, and contribute to public education (L'Astorina et al., 2023; Minkman et al., 2017). In contrast, some natural resource practitioners may avoid using citizen science entirely, either because it does not meet their data collection needs—such as requiring specialized skills, expertise, or data from remote locations (Fraisl et al., 2022)—or due to limited resources, including funding constraints or challenges in collaborating with external agencies (Latimore & Steen, 2014). While some research has examined the use of citizen science by natural resource practitioners and the barriers they face, less is known about how perceptions differ between those who adopt citizen science and those who do not. Additionally, further research is needed to understand how natural resource practitioners across different job roles—such as resource managers, public engagement professionals, and researchers—perceive and use citizen science, especially given how their diverse responsibilities may shape their perspectives and challenges. These individuals and organizations play a key role in connecting scientific research with public engagement, serving as the bridge for recruiting and involving a broader segment of society in citizen science projects. Understanding their experiences and perspectives can help guide current and future citizen science initiatives.

To explore how citizen science is used by natural resource practitioners, we conducted a survey of managers, public engagement specialists, researchers, and other professionals in Florida, USA. This study was exploratory in nature, as we sought to understand the perspectives of major state natural resource organizations rather than to obtain a generalizable sample of all natural resource practitioners in Florida. Specifically, we were interested in how natural resource practitioners involve members of the public in any part of the scientific endeavor (referred to as citizen science), and in actively connecting people with science through actions like knowledge sharing or helping with decision making (referred to as engagement). We evaluate (1) usage of citizen science, (2) attitudes and perceptions of citizen science, and (3) barriers and challenges associated with citizen science as a tool for biodiversity management and public engagement. We predicted that respondents would show widespread support for citizen science as a tool for public engagement, but that perceptions of data reliability and barriers such as lack of resources would vary by job role, given different use cases of citizen science. Our findings enhance understanding of how natural resource practitioners perceive, engage with, and utilize citizen science in their work. Additionally, we identify actions organizations can take to better integrate citizen science into outreach, research, and management.

2 | METHODS

2.1 | Study area

Our study takes place across the state of Florida, USA, which we selected as a case study due to its diverse natural resources and strong connections with natural resource managers. Florida hosts a large volume of citizen science programs and opportunities (Austin, 2014; Conrad & Hilchey, 2011; Guindon et al., 2015; Heres et al., 2021; Iporac et al., 2020). In terms of data, the Global Biodiversity Information Facility (GBIF), a global

TABLE 1 Table describing our survey distribution strategy.

Targeted groups	Primary function	Distribution strategy	Number of responses (response rate)
Florida Fish and Wildlife Conservation Commission (FWC)	Wildlife conservation, habitat management, and environmental stewardship	• FWC staff who are likely to use citizen science in their role ($N = 239$) were emailed by the FWC's Center for Conservation Social Science Research. • A simple random sample of FWC staff in relevant divisions ($N = 299$) were sent a pre-notification email from the FWC's Center for Conservation Social Science Research followed by a survey invitation from Qualtrics (Vaske, 2008)	131 (24.3%)
County-level governments	Local environmental management, policy-making, and community engagement	• Compiled a list of contacts by systematically reviewing county websites and sent personalized emails to each contact ($N = 151$)	24 (15.9%)
University of Florida's Extension Offices	Link between university research and the public	• Directors and natural resource agents ($N = 152$) were sent an invitation to join the survey via Qualtrics distribution	47 (30.9%)
Florida Department of Environmental Protection (FDEP)	Responsible for managing and overseeing the Florida State Parks system	• Gathered and sent personalized emails	8
Other, smaller organizations	Entities that may be associated with citizen science but represent a small portion of usage in the state	• Gathered and sent personalized emails	22

Note: We detail the target groups, their primary function, our distribution strategy, and the number of survey responses. Response rate is in parentheses for groups with a stratified sampling strategy. Response rates are not available for FDEP and other, smaller organizations because the survey was distributed through network connections and the sample size was not recorded.

repository of biodiversity data contributed mostly by citizen scientists as well as researchers and institutions, contains over 55 million observations of plants and animals in the state of Florida alone (GBIF.org, 2024). Additionally, Florida is home to numerous agencies involved in research, natural resource management, and public engagement at the municipal, county, and state levels (see Table 1 for a list of targeted agencies). These agencies face a range of emerging management challenges, including climate change, urbanization and development, invasive and non-native species, and wildlife disease (Carr et al., 2018; Romañach et al., 2020). Given the abundance of citizen science programs and the critical role of natural resource agencies, Florida provides an ideal setting to examine how citizen science is used and perceived by natural resource managers.

2.2 | Survey distribution

We administered an online survey from May to August 2024. Using a purposeful sampling approach (Palinkas et al., 2015), we sent solicitation e-mails (see appendix in Data S1, Supporting Information) containing a survey link to select state of Florida government entities and non-profits that currently use or have the potential to use citizen science data for natural resource management or conservation. While we were interested in researchers' perspectives, we specifically targeted those affiliated with government agencies or university extension offices, as they are most likely to be more directly involved in conservation and natural resource management decision-making. This focus allows us to build off of previous research that has already examined researchers' attitudes towards citizen science more broadly (L'Astorina et al., 2023). The primary groups included those we knew to be actively involved in citizen science: (1) the Florida Fish and Wildlife Conservation Commission (FWC); (2) county-level governments; (3) University of Florida's Extension Offices (UF Extension—these are UF offices located across Florida, which bring university-based knowledge and resources to the public through outreach and publications; UF IFAS Extension, 2023); (4) the Florida Department of Environmental Protection (FDEP); as well as (5) various other organizations potentially involved in citizen science such as national parks like Everglades National Park, municipalities, and conservation organizations such as the Audubon Society (Table 1;

see appendix B in Data S1 and Table S2 for our detailed distribution strategy and details about each of the above primary groups). Our recruitment strategy was designed to ensure broad stakeholder representation. While this methodology captured many of the major entities involved in natural resource management in Florida, our distribution did not include all city-level natural resource practitioners across the state or private entities, such as environmental consultants, due to challenges in obtaining their contact information. As a result, the findings reported only represent a subset of Florida natural resource practitioners because we did not capture a generalizable sample.

Survey distribution strategies varied among groups due to the differences in internal policies and the availability of email addresses. Within the FWC, surveys were emailed to both a list of employees known to use citizen science in their work ($N = 239$), as well as a random sample of employees in relevant sections of the agency ($N = 299$). The first group received an initial email invitation from the FWC's Center for Conservation Social Science Research (co-investigators on this project) that was followed by reminder emails; the second group received a pre-notification from the FWC's Center for Conservation Social Science Research, followed by a survey invitation through Qualtrics and three reminder emails (Figure S1). County-level government contacts ($N = 151$) were sent a personalized email and digital flyer for further distribution with one reminder email via a UF email address (Figures S2 and S3). Using an internal email address, we sent Qualtrics survey invitations to UF Extension agents ($N = 152$), with two reminder emails. For FDEP and other organizations, respondents were sent personalized emails that included a flyer for further distribution from a UF email address or through network connections (Figures S2 and S3). Where available, we report the response rates for each sampled group in Table 1.

2.3 | Survey design

We anchored our survey design around Burgess et al. (2017), which provides a framework for assessing citizen science initiatives. This reference served as a guide to develop questions to effectively capture the nuances of citizen science involvement. The survey was designed to capture a wide range of responses from various professionals and organizations involved in citizen science across Florida. Importantly, it was also designed to capture the perspectives of individuals who currently do not use citizen science in their work but have the potential to use citizen science in the future.

To distinguish how respondents used citizen science, we first provided definitions for key terms: citizen science (defined as "any science endeavors that involve members of the public in any part of the process. This could include tasks like data or sample collection, analysis, and more") and engagement (defined as "actively connecting people with science through actions like knowledge sharing or helping with decision making"). Recent research has explored the implications of citizen science terminology for participant recruitment and engagement, as the term "citizen" is widely understood to exclude individuals from historically marginalized communities (Eitzel et al., 2017; McLeod et al., 2025). However, Cooper et al. (2021) describe that this term was coined by practitioners to include individuals without formal scientific knowledge in the scientific endeavor. While some agencies are rebranding their programs to be called "community science" or "participatory science," these terms are not widely agreed upon by practitioners. Therefore, we chose to use "citizen science" in this study to make our survey and findings more widely accessible to practitioners, who we expect to be more familiar with "citizen science" than other terminologies.

The survey was rigorously reviewed for clarity, relevance, and to ensure it adhered to ethical standards of research. To ensure clarity, we pilot tested the survey with natural resource practitioners familiar and unfamiliar with citizen science ($N = 11$), then revised it based on their feedback.

2.4 | Measures

The survey encompassed five main sections, including: organization information, citizen science use, thoughts and attitudes regarding citizen science, questions geared towards citizen science users or non-users, and additional comments (Figure 1). The questionnaire primarily consisted of dichotomous and categorical questions, as well as some open-ended write-in questions. For attitudinal measures, Likert scales (ex. strongly agree to strongly disagree) were used to measure respondents' degree of agreement or disagreement with survey items. The survey was programmed to include six different paths users could take based on their job role and use of citizen science data (for complete details see appendix A in Data S1 and Figure 1). Our survey, in its entirety, is available in appendix A of Data S1 and Table S1.

2.5 | Statistical analysis

Specific measures included for analysis included: agency (categorical), years of experience (open text), citizen

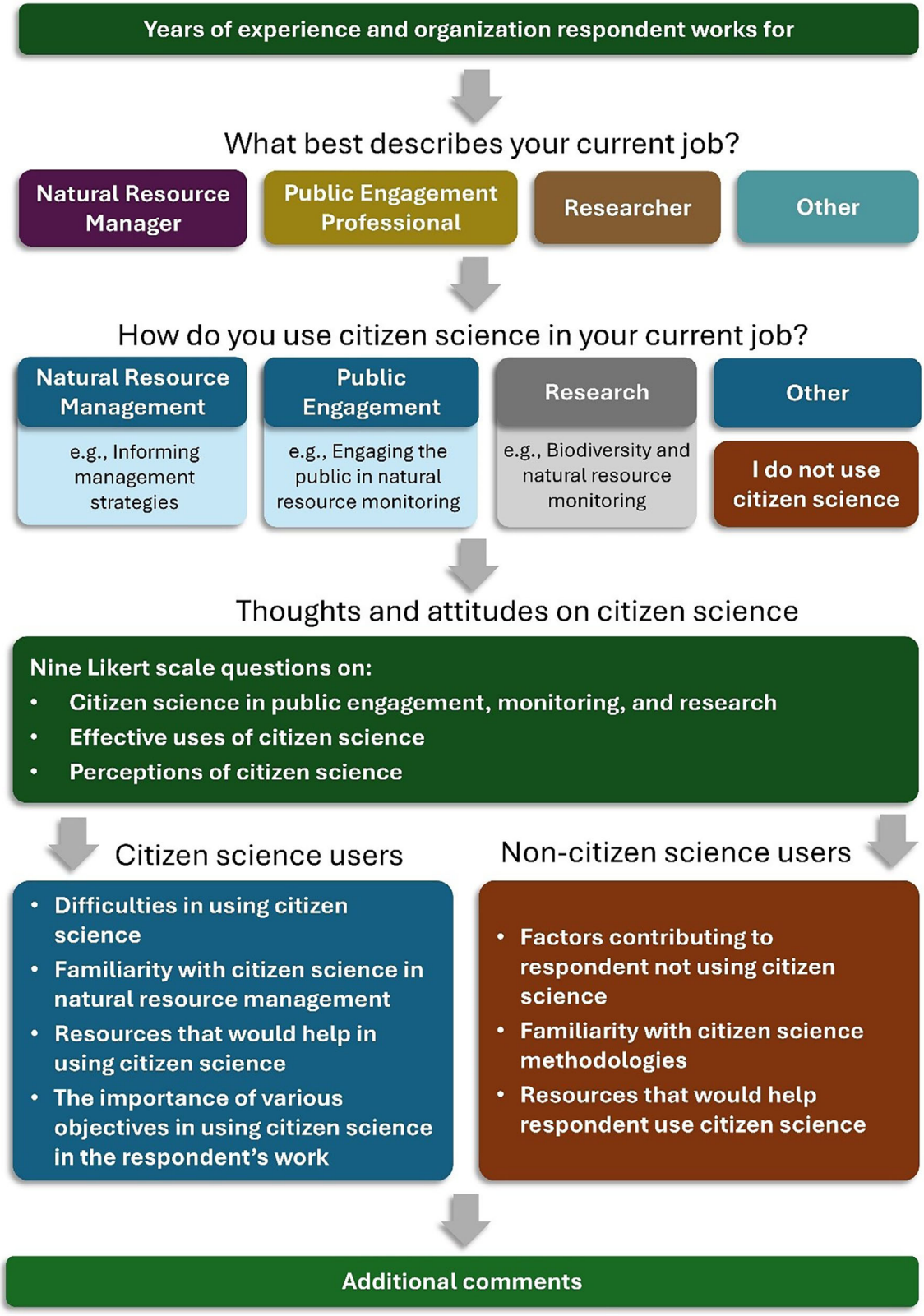

FIGURE 1 Diagram of survey design. The first four rows represent questions asked to all respondents. For analysis, we compared thoughts and attitudes across different job roles.

science use (categorical), attitudes and perceptions of citizen science (Likert), importance of citizen science objectives in respondent's position (Likert), challenges to using citizen science (categorical), familiarity with citizen science in natural resource management (Likert), resources that would help respondent's use of citizen science in

their position (Likert), and write-in comments. The write-in comments were not formally analyzed, but quotes from these comments were used to illustrate points in the discussion.

All analyses and visualizations were conducted in R (R Core Team, 2023), primarily using the "tidyverse" ecosystem (Wickham et al., 2019). Incomplete survey responses, defined as surveys where the respondent exited the survey before reaching the end to submit their responses, were excluded from analyses. To identify the commonality of multiple use types of citizen science by respondents, we performed a co-occurrence analysis. This analysis was conducted using the map_chr function from the "purrr" R package (Wickham & Henry, 2023). For Likert-type scale questions, we treated the values as ordinal and used the Likert function from the "likert" R package (Bryer & Speerschneider, 2016) to analyze and visualize this data. For the comparison of perceptions among citizen science users and non-users from the Likert-type questions, we ran Wilcoxon-rank sum tests where strongly disagree was treated as 1 and strongly agree was treated as 5 (De Winter & Dodou, 2010; South et al., 2022). Due to the small sample size, we did not conduct statistical comparisons across job roles but rather reported raw data, following the exploratory nature of this paper.

3 | RESULTS

3.1 | Respondents

We received 232 complete responses (Table 1). Of these, 173 (74.6%) respondents used citizen science in their work while 59 (25.4%) did not. Respondents had between 0 and 50 years of experience in their field, with the median being 11 years (see Figure S4 for the distribution). Most participants worked for the FWC (56.5%), followed by the University of Florida's Extension Offices (20.3%), county-level government (10.3%), municipality-level government (4.31%), FDEP (3.5%), and other organizations (5.2%), including non-profit groups and other government agencies. More than one-third (34.1%) of respondents identified as public engagement/outreach specialists or environmental educators, while one-fifth identified as natural resource managers (21.0%) or scientific researchers (21.1%). Nearly one-quarter (23.7%) of respondents identified with an "other" position type, writing in other job roles such as program manager, administrator, planner, data specialist, and sustainability or environmental manager.

3.2 | Usage patterns

We found that respondents tended to use citizen science in ways that aligned with their job titles, though there was some variability (Figure S6). Among public engagement specialists, 84.8% reported using citizen science, primarily for public engagement (58.7%), followed by natural resource management (16.5%), research (16.5%), and other uses (8.3%). For natural resource managers, 77.6% used citizen science, with most applying it to natural resource management (45.3%), followed by public engagement (25%), research (12.5%), and other uses (17.2%). Researchers most commonly used citizen science for research (52.6%), followed by natural resource management (22.8%), public engagement (17.5%), and other purposes (7.0%), with 71.4% of researchers using citizen science in some way. Lastly, among respondents in other job categories, 60% used citizen science—most frequently for public engagement (37.7%), then research (23.0%), natural resource management (19.7%), and other uses (19.7%).

Most respondents used citizen science in one way (65.1%) or two ways (20.7%). The most common co-occurrent uses of citizen science were in public engagement activities and research (16.8%), public engagement and natural resource management (17.7%), and natural resource management and research (14.2%). Other combinations encompassed less than 10% of responses (Figure S5).

3.3 | Attitudes and perceptions of citizen science

3.3.1 | Comparison between users and non-users

When comparing attitudes about citizen science between users ($N = 173$) and non-users ($N = 59$), we generally found similar trends, although non-users leaned more towards neutral responses (i.e., less agreement) and users tended more towards strongly agree than agree (Figure 2). The Wilcoxon rank-sum test revealed significant differences between citizen science users and non-users in their agreement that citizen science is an effective means of achieving high-quality public engagement ($W = 6163$, p-value $= .003$) and monitoring ($W = 6063$, p-value $= .009$). These differences are likely driven by the tendency of citizen science users to strongly agree with these statements. While most respondents in both groups agreed or strongly agreed that citizen science is a way to accomplish high-quality public engagement, users exhibited higher levels of strong agreement (Figure 2a). Additionally, we found a significant difference in attitudes towards citizen science in research

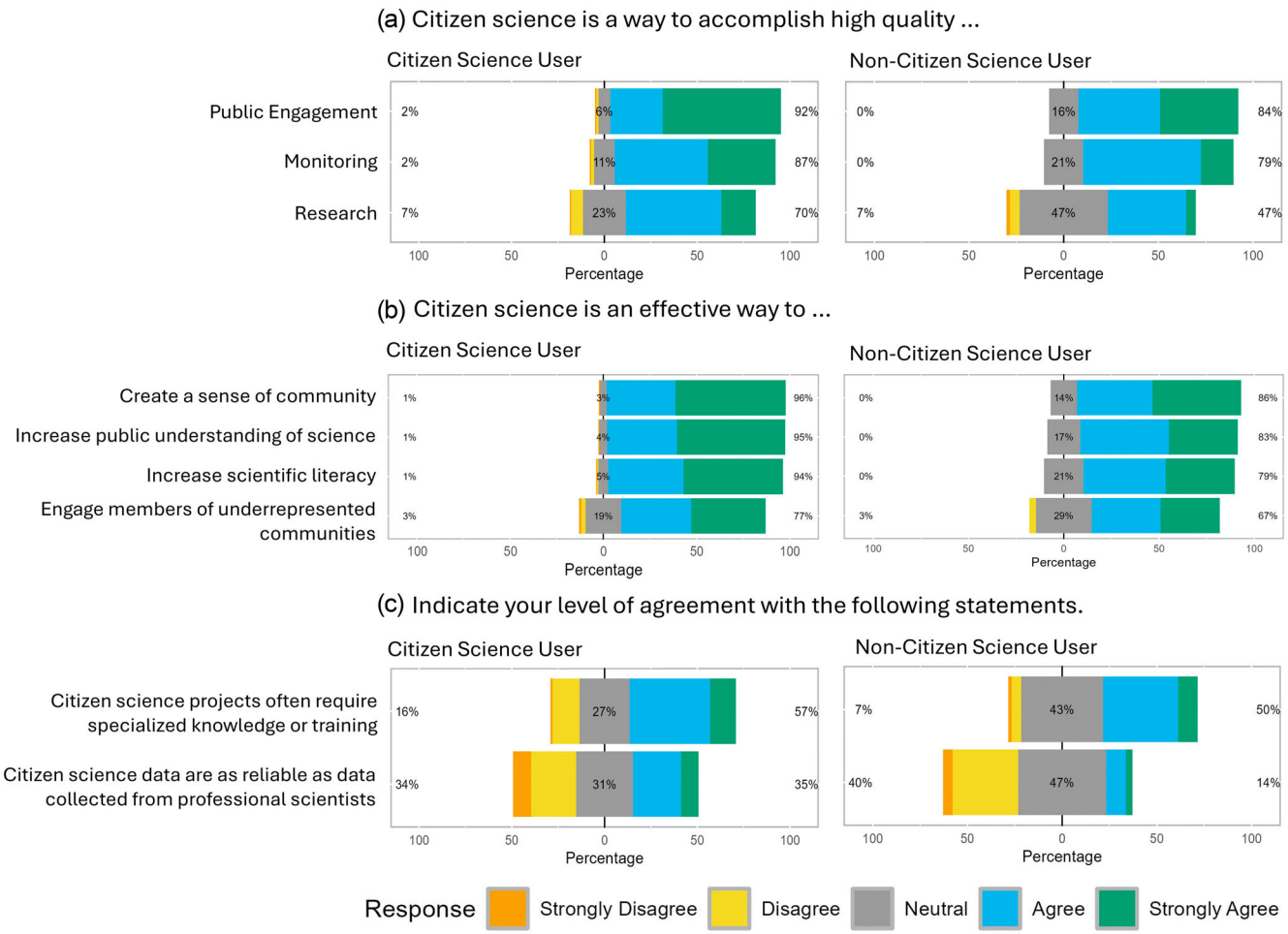

FIGURE 2 Likert ratings on questions asked to all respondents about their attitudes towards citizen science. The graphs on the left represent respondents who use citizen science in their profession and the right represent respondents who do not use citizen science in their profession. The percentage on the left represents the percentage of respondents who strongly disagree or disagree, the middle represents the percentage of respondents who are neutral, and the right represents the percentage of respondents who agree or strongly agree.

between users and non-users ($W = 6363$, p-value $< .001$), where a higher percentage of non-users were neutral on the topic (46.5%) compared to users (23.1%; Figure 2a).

Significant differences were observed between citizen science users and non-users on attitudes towards its effectiveness in creating a sense of community ($W = 5811$, p-value $= .040$), increasing public understanding ($W = 6384.5$, p-value $< .001$), and improving scientific literacy ($W = 6060$, p-value $= .008$). Although most respondents in both groups agreed or strongly agreed, the differences likely stem from non-users being more neutral on these topics (Figure 2b). When asked for respondents' level of agreement on the statement "Citizen science projects often require specialized knowledge or training," we found no significant difference in opinion ($W = 5196.5$, p-value $= .667$). Similarly, there was no difference in opinion between citizen science users and non-users on the statement "Citizen science data are as reliable as data collected from professional scientists" ($W = 5803$, p-value $= .064$). For both statements, both groups had mixed opinions between disagreement and agreement (Figure 2c).

3.3.2 | Objectives based on job role

We determined the importance of five objectives among users of citizen science, stratified across four job roles: natural resource managers ($N = 36$), public engagement professionals ($N = 67$), scientists/researchers ($N = 23$), and other job roles ($N = 30$; Figure 3). Overall, a majority of respondents in all groups rated engaging the public and generating high-quality data as very or extremely important to their job. The use of citizen science-generated data for scientific research had mixed importance for each job role, with more researchers finding this very (26.1%) or extremely important (43.5%) to their role than the other three job roles. Similarly, there was mixed importance on the use of citizen science-generated data

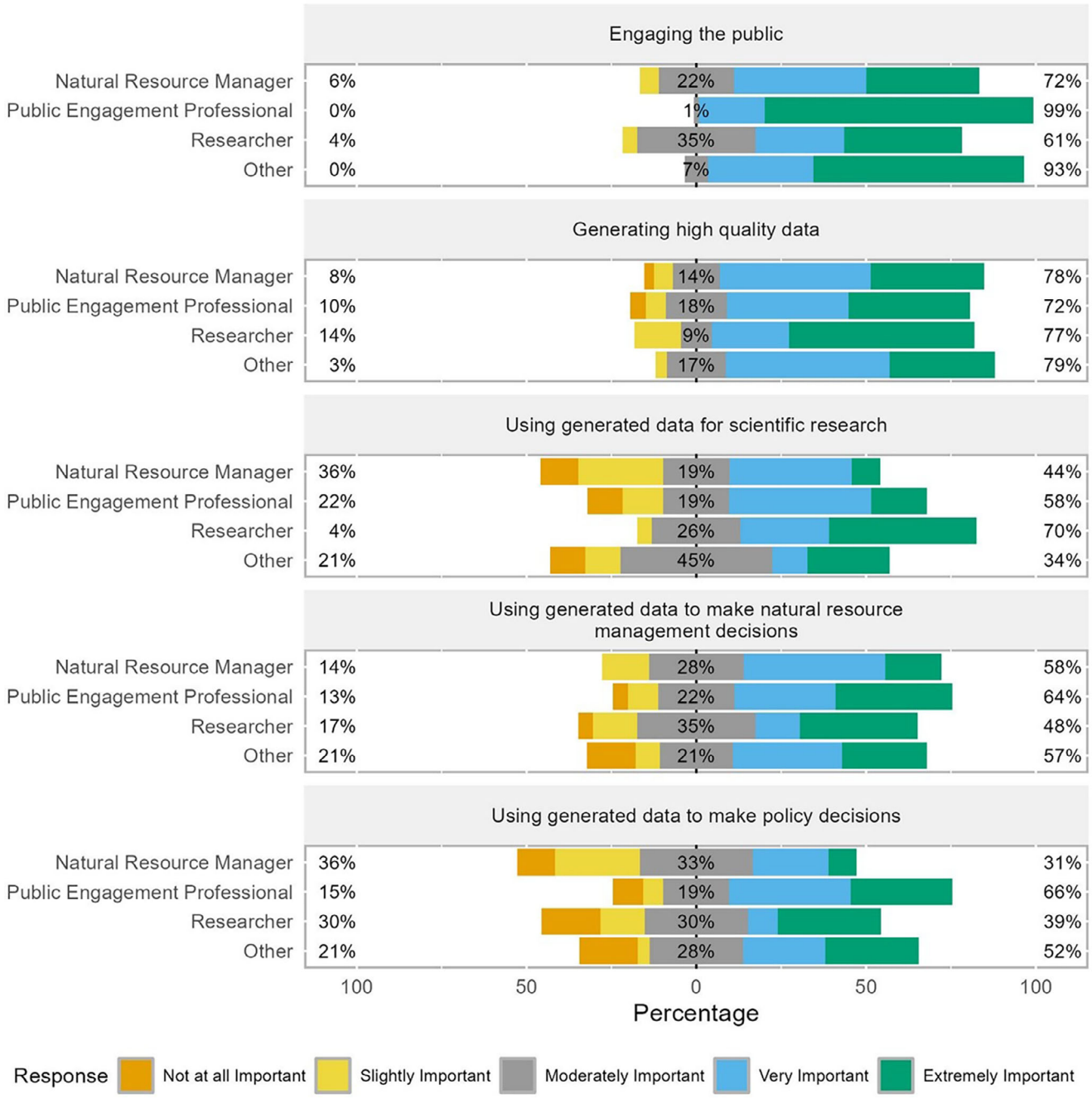

FIGURE 3 Respondents who use citizen science were asked how important the above objectives are in their use of citizen science data. The responses are stratified by the user's job role. The percentage on the left represents the percentage of respondents who strongly disagree or disagree, the middle represents the percentage of respondents who are neutral, and the right represents the percentage of respondents who agree or strongly agree.

to make natural resource management decisions by job role, with no job role standing out as being the most focused on this objective. Regarding the use of citizen science data for policy decisions, public engagement professionals felt this was most important to their role (very important = 35.5%, extremely important = 29.9%), followed by other professionals (very important = 24.1%, extremely important = 27.6%), researchers (very important = 8.7%, extremely important = 30.4%), and natural resource managers (very important = 22.2%, extremely important = 8.3%).

3.4 | Barriers and challenges

3.4.1 | Respondents who use citizen science data

Among citizen science users, the most common limitations of citizen science use were a lack of staff or volunteer support (natural resource managers = 40.8%, public engagement professionals = 36.7%, researchers = 20.4%, other = 30.9%) and concerns about data

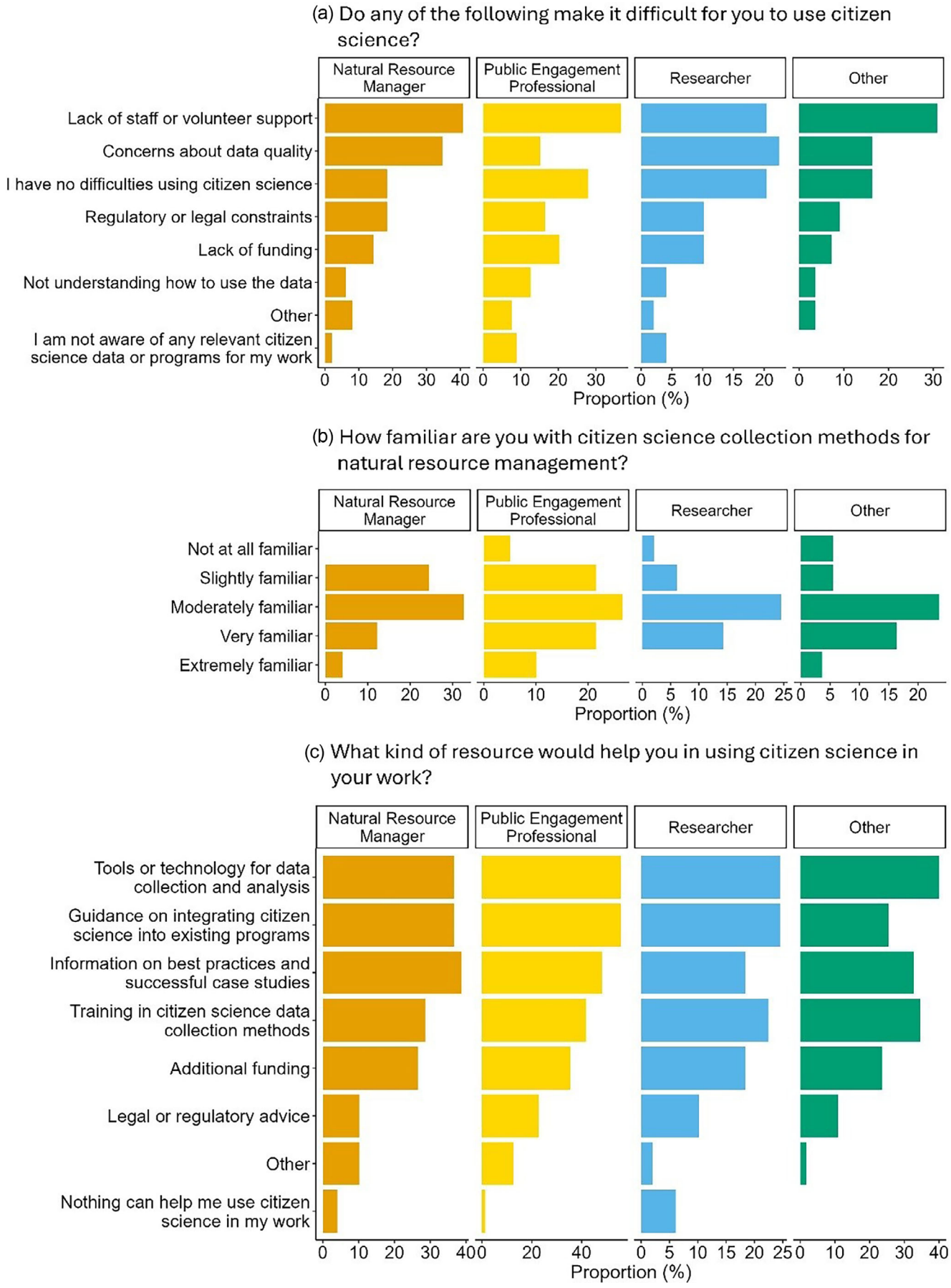

FIGURE 4 Legend on next page.

quality (natural resource managers = 34.7%, public engagement professionals = 15.2%, researchers = 22.4%, other = 16.4%; Figure 4a). Some respondents reported having no difficulties using citizen science data, including 18% of natural resource managers, 27% of public engagement professionals, 20% of researchers, and 16% of other professionals. Familiarity with citizen science data collection methods for natural resource management was relatively consistent across job roles, with most respondents in each group indicating they were moderately familiar (Figure 4b). The top resources that would help respondents use citizen science in their work are tools or technology for data collection and analysis (natural resource managers = 36.7%, public engagement professionals = 55.7%, researchers = 24.5%, other = 40.0%), guidance on integrating citizen science in existing programs (natural resource managers = 36.7%, public engagement professionals = 55.7%, researchers = 24.5%, other = 25.5%), information on best practices and successful case studies (natural resource managers = 38.8%, public engagement professionals = 48.1%, researchers = 18.4%, other = 32.7%), training in citizen science data collection methods (natural resource managers = 28.6%, public engagement professionals = 41.8%, researchers = 22.4%, other = 34.5%), and additional funding (natural resource managers = 26.5%, public engagement professionals = 35.4%, researchers = 18.4%, other = 23.6%; Figure 4c). Very few respondents (5.1% of all respondents) felt that nothing could help them use citizen science more in their work.

3.4.2 | Respondents who do not use citizen science data

Concerning challenges and barriers faced by natural resource practitioners that do not use citizen science in their role, responses were analyzed across four job roles: natural resource managers ($N = 11$), public engagement professionals ($N = 12$), scientists/researchers ($N = 14$), and other professionals ($N = 22$).

Non-users of citizen science (25.4% of respondents) experienced a variety of barriers to citizen science use (Figure 5). Among natural resource manager non-users ($N = 11$), the most commonly cited barrier to citizen science use was a lack of awareness of any relevant citizen science data (Figure 5a). Public engagement professional non-users ($N = 12$) most often pointed to insufficient staff or volunteer support, lack of knowledge on how to use citizen science data as a tool for public engagement, and lack of funding. Researcher non-users ($N = 14$) experienced mixed barriers, with the top selection being "other," followed by concerns about data quality and inconsistency in data collection methods. In write-in comments, respondents stated concerns about the public working with sensitive species, not being able to share sensitive data with the public, the effort required to administer citizen science projects was too great, or simply that citizen science is not relevant to their work. For other professionals ($N = 22$), the majority also selected "other" as their reason for not using citizen science. Write-in comments indicated that respondents found that citizen science was not relevant to their position, and respondents cited a lack of awareness of citizen science as their main barrier.

Additionally, we found that natural resource managers (moderately familiar = 36.4%, very familiar = 9.1%) and public engagement professionals (moderately familiar = 83.3%, very familiar = 8.3%) were generally more familiar with citizen science in their field than researchers (moderately familiar = 21.4%, very familiar = 0%) and other professionals (moderately familiar = 0%, very familiar = 4.6%; Figure 5b).

When asked about resources that would help them begin using citizen science, public engagement professionals, researchers, natural resource managers, and other professionals identified a strong need for guidance on integrating citizen science into existing programs (Figure 5c). Natural resource managers also identified a strong need for information on best practices and case studies of successful citizen science applications.

4 | DISCUSSION

Overall, we found support for citizen science by natural resource practitioners throughout the state of Florida, across different agencies. Citizen science is currently being applied for public engagement, natural resource management, and research. Of natural resource practitioners who use citizen science, we found that nearly a third of these professionals used citizen science for multiple purposes. Although a fourth of respondents did not use citizen science, few felt that nothing could encourage

FIGURE 4 For respondents who use citizen science data for natural resource management, public engagement activities, and other purposes, we asked: (a) what factors make using citizen science difficult in their job, (b) how familiar respondents are with citizen science data collection methods for natural resource management, and (c) which resources would help respondents start using citizen science. Responses are grouped by job role, with the x-axis scale varying by job. The questions in plot (a) and (c) were select all that apply.

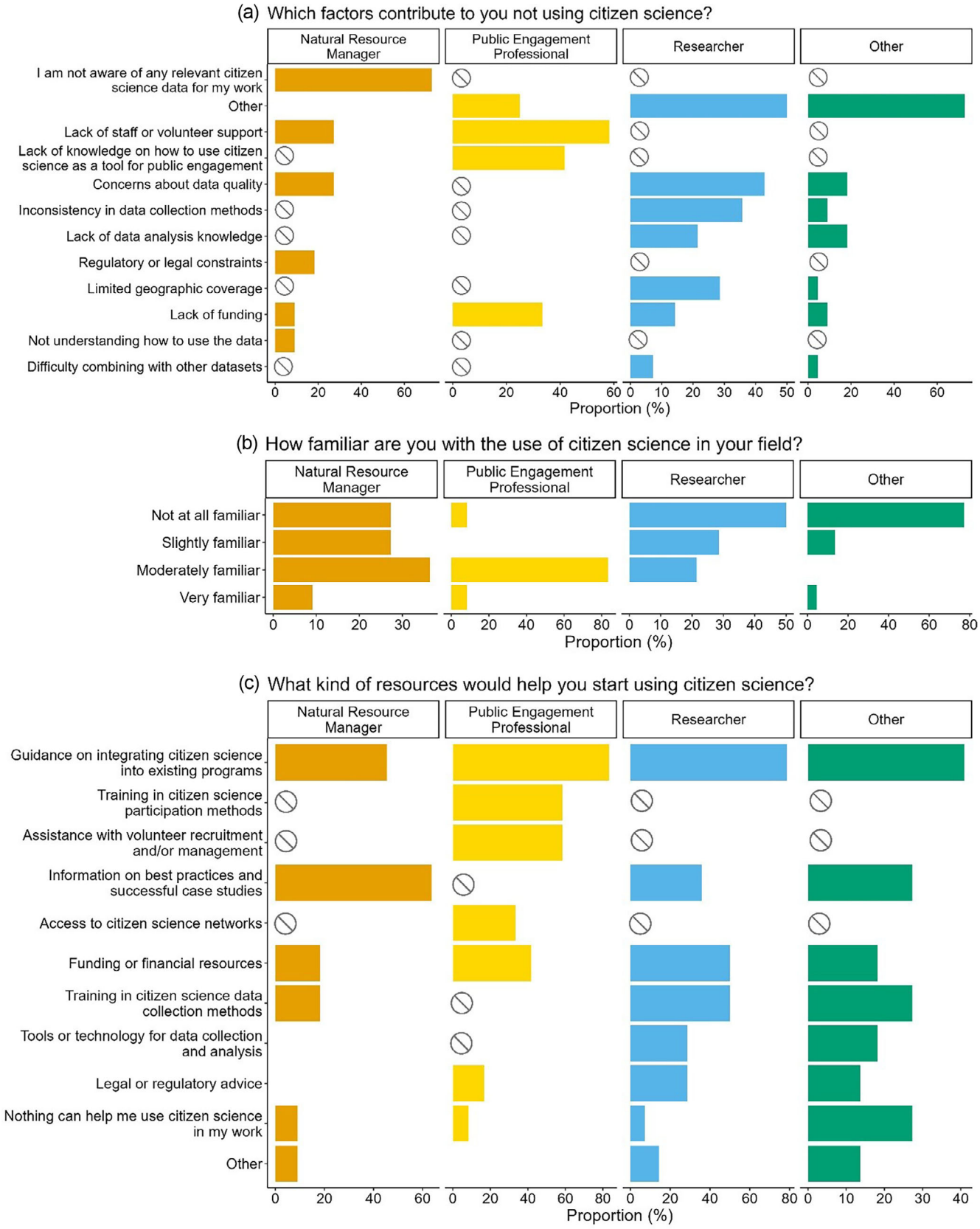

FIGURE 5 Legend on next page.

its use in their work. Our work demonstrates both the potential to expand the role of citizen science in biodiversity conservation as well as barriers that need to be overcome.

4.1 | Attitudes and perceptions of citizen science

Across natural resource practitioners that use and do not use citizen science, we generally found agreement that citizen science is an effective way to accomplish public engagement and monitoring, with users having stronger agreement in both categories compared to non-users. Further, both groups were generally in agreement that citizen science is an effective way to create a sense of community, increase public understanding of science, increase scientific literacy, and engage members of underrepresented communities, though non-users had less agreement than citizen science users. There were mixed opinions from users and non-users that citizen science is as reliable as data collected by professional scientists, with no difference in attitude on this topic. These results align with previous research which shows that scientists view public participation as an important part of citizen science, but they question the scientific quality of the data (Golumbic et al., 2017; Riesch et al., 2013). The differences in opinion between citizen science users and non-users may stem from non-users underestimating the role that professionals play in facilitating citizen science data collection, project management, and data quality assurance (Vann-Sander et al., 2016). Nevertheless, citizen science users also had mixed opinions on the reliability of citizen science data, likely representing the varying data needs of respondents. For example, some natural resource practitioners may just need a species list in a specific region, while others may need abundance estimates of key species.

Natural resource practitioners across different job roles generally shared similar objectives for using citizen science, with public engagement and the generation of high-quality data emerging as top priorities. Notably, generating high-quality data was more important to natural resource practitioners than using that data for scientific research, natural resource management, or policy development. The exception was researchers, who also found it important to use the data for research, but not for natural resource management or policy development. However, this is only reflective of respondents who work at a UF Extension Office or for a state agency, not academic researchers more broadly. The limited emphasis on policy development across natural resource, research, and public engagement roles is further discussed in the limitations section. Although previous research suggests that academic researchers place greater importance on using citizen science to educate the public over data collection or classification support (L'Astorina et al., 2023). This emphasis may reflect a lack of knowledge or institutional support for integrating citizen science data into decision-making processes. Alternatively, it may indicate that while some natural resource practitioners do not currently use citizen science data in their roles, they recognize its potential value and aim to improve data quality for future use or for other stakeholders. As expected, using citizen science data for scientific research was most important to researchers. Interestingly, public engagement professionals were the second most likely to use citizen science for scientific research, and had a higher tendency to use citizen science-generated data for policy decisions. This could indicate that public engagement professionals have more trust in citizen science data, especially if they took part in project management (Vann-Sander et al., 2016). Supporting this interpretation, a smaller percentage of public engagement professionals reported data quality as a barrier to using citizen science data compared to natural resource managers and researchers. Public engagement professionals may also feel a stronger obligation to utilize the data, which is a strong motivator of citizen science volunteer participants (Jacobson et al., 2012; Land-Zandstra et al., 2016). Natural resource managers primarily used citizen science to generate high-quality data, more so than for management decisions, scientific research, or policy-making.

4.2 | Barriers and challenges of using citizen science

One of the most commonly reported challenges by natural resource practitioners who use citizen science was a

FIGURE 5 For respondents who do not use citizen science data and define their job role as natural resource manager, public engagement/outreach specialist/environmental educator, researcher/scientists, or other, we asked: (a) what factors contribute to respondents not using citizen science in their job, (b) how familiar respondents are with citizen science in their field, and (c) which resources would help respondents start using citizen science. For panel (a) and (c), not all options were available to every respondent, as some were only relevant to a particular group. Questions that were not available are indicated with a circle with a horizontal line through it. The questions in panel (a) and (c) are select all that apply.

lack of staff or volunteer support. A similar result was found in previous research, where researchers found one of the greatest barrier to running citizen science projects was difficulty in building long-term relationships with the public (L'Astorina et al., 2023). To address this issue, natural resource practitioners might consider leveraging existing citizen science programs and databases to reduce the effort required to engage new participants (e.g., GBIF). However, write-in comments suggest that some users may be unaware of existing resources. For instance, one respondent requested "a simple 'catalog' of citizen-science opportunities," even though such a resource already exists on SciStarter (SciStarter, 2024). Additionally, nearly three quarters of natural resource managers who did not use citizen science were not aware of any citizen science projects relevant to their work. While it is possible their work involves special data collection which is not represented in any current citizen science projects, it is also possible that these respondents are unaware of relevant data, as previous studies have documented limited visibility of citizen science projects to government agents and scientists (Galanos & Vogiatzakis, 2022). While this study did not specifically investigate the types and levels of volunteer support needed, natural resource practitioners emphasized the need for long-term volunteers, in write-in comments, due to the significant training effort required to meet their data collection needs. In such cases, Liñán et al. (2022) recommend adopting an engagement framework that fosters long-term participation by aligning project outcomes with volunteer recognition and cultivating a sense of community. A study on volunteer motivations with the Florida Fish and Wildlife Conservation Commission found that "helping the environment" was the strongest driver of participation (Jacobson et al., 2012). Given this, natural resource practitioners should emphasize volunteers' environmental impact in recruitment efforts and provide ongoing feedback to existing volunteers on their contributions. Interestingly, we found that a lack of personnel was cited as a limitation far more frequently than a lack of funding. This finding suggests there may be a gap in program success related to insufficient training or inadequate communication about available opportunities.

Another commonly reported limitation to using citizen science data was concern about data quality, a challenge more frequently highlighted by natural resource managers and researchers than public engagement specialists or other professionals. This may be due in part to the relatively recent adoption of citizen science among natural resource managers and low stakeholder buy-in (Aceves-Bueno et al., 2015). This concern may also partly stem from colleague perceptions, as one respondent commented, "I would hear people talking about how citizen science data is not as accurate. I think people are cautious because they assume that those collecting the data are not as informed." Such skepticism may be particularly prevalent in government agencies, which often depend on high-quality data for ecological estimation and inference (Brown & Williams, 2019). Additionally, researchers noted that improving the quality of citizen science data can be too time-consuming—either due to the effort required to validate the data or to train the public in accurate data collection (L'Astorina et al., 2023). Moreover, natural resource practitioners not engaged in the project design and management phase are less likely to trust the data, as the issue is often less about who collects the data and more about how it is collected and verified (Brown & Williams, 2019; Vann-Sander et al., 2016). To address these concerns, natural resource practitioners could take a more active role in managing citizen science projects and implementing data quality controls to foster greater trust in the data—both for themselves and within their organizations. To support this process, additional resources could be made available to natural resource practitioners—such as user-friendly websites that guide the design of citizen science projects to ensure data quality (Herodotou et al., 2021). To improve confidence in the reliability of the data, organizations could develop standardized guidelines for data cleaning and validation of popular citizen science platforms in collaboration with citizen science analysts (Brown & Williams, 2019; Downs et al., 2021). With the growing number of published best practices for citizen science, implementing such standards is now more feasible than ever (Johnston et al., 2021; Johnston et al., 2023).

4.3 | Key needs to improve citizen science integration by natural resource practitioners

To help natural resource practitioners better integrate citizen science into their work, our study identified several key needs: tools and technology for data collection and analysis, guidance on incorporating citizen science into existing programs, information on best practices and successful case studies, training in citizen science data collection methods, and additional funding. With the rapid growth of citizen science and the corresponding increase in research on methodology and data validation (Follett & Strezov, 2015), the possibilities of citizen science use by practitioners for natural resource management, public engagement, and research are at an all-time high. However, widespread adoption will likely require the development of more user-friendly tools and technologies for natural resource practitioners who may not have

extensive research backgrounds. While frameworks and case studies on citizen science in natural resource management (Chase & Levine, 2016), public engagement (Dickinson et al., 2012), and research (Aceves-Bueno et al., 2015) exist, more specific use cases may be needed, current resources may not be effectively reaching natural resource practitioners, or both. Establishing more associations and networks focused on citizen science for natural resource practitioners—similar to successful models such as the Citizen Science Africa Association, CitizenScience.Asia, and the Iberoamericana Network of Participatory Science (Fraisl et al., 2022)—could help strengthen the integration of citizen science into professional practice. Some respondents commented that they want to incorporate more citizen science in their program, but "one of the hardest things [they] found was finding data that someone actually wanted to use." Therefore, a framework for connecting public engagement professionals with researchers and natural resource managers could encourage more uptake of citizen science by natural resource practitioners. Organizational guidelines on citizen science usage could help encourage collaborations and make these resources more accessible. Additionally, sharing successful case studies within organizations can provide natural resource practitioners with examples that are directly relevant to their contexts. Given that organizational learning practices can enhance innovative performance (Sung & Choi, 2014), organization-provided or -sponsored citizen science data collection training could equip natural resource practitioners with the necessary skills to lead effective programs. Nevertheless, increasing funding for citizen science programs remains critical. This could involve shifting attitudes of decision-makers within organizations, expanding grant opportunities, or encouraging partnerships with other institutions and agencies to secure more diverse and consistent funding sources (Latimore & Steen, 2014).

4.4 | Limitations

This study was exploratory in nature and did not seek to capture a generalizable sample of all current and potential citizen science users in Florida. While our sampling strategy purposefully selected a wide range of practitioners with the potential to use citizen science from major natural resource-affiliated organizations in Florida, it likely still suffered from coverage bias and may have missed some population segments. For example, we focused on researchers affiliated with government agencies or university extension offices, as they are most likely to be involved in decision-making. However, academic researchers also contribute to natural resource management, policy decisions, and public outreach, and their perspectives could be explored in future studies. Additionally, while we surveyed natural resource practitioners who may engage in policy-related work, policy development is likely not a primary component of their roles, and our sample did not include policymakers such as legislators or elected officials. Given the potential for these individuals to rely on citizen science—and the possibility that increased exposure could enhance their use of such data (Turbé et al., 2019)—future research should specifically examine policymakers' engagement with and perceptions of citizen science. In addition, response bias likely influenced the overall positive attitudes of our respondents towards citizen science, as individuals with more neutral attitudes may have been less inclined to take the survey. Though effort was made to encourage non-users to take the survey, the sample size of non-users was small and is likely not representative of all potential citizen science users in the state of Florida. A follow-up survey could be conducted with an incentive to further encourage non-users to participate.

Additionally, we aimed to capture general attitudes towards citizen science; however, the field is diverse and encompasses a range of initiatives—from small-scale projects designed by natural resource practitioners to global platforms like iNaturalist or eBird. Natural resource practitioners' attitudes may vary depending on the type of platform they engage with. Future research could focus on natural resource practitioners' perspectives on specific platforms or explore whether attitudes and perceptions differ by the nature of the initiative.

5 | CONCLUSION

We highlight positive perceptions of citizen science among diverse natural resource practitioners in Florida, with strong theoretical support for its role in public engagement and natural resource management. However, despite this support, fewer practitioners reported actively incorporating citizen science into their own work, suggesting a gap between perceived value and practical application. Overall, we found that respondents tended to use citizen science in ways that aligned with their job roles. Natural resource practitioners often use citizen science to engage the public and collect quality data, but natural resource managers and public engagement professionals place less importance on using the data for research, management, or policy decisions. Researchers prioritize using the data for research but see less value in its application to natural resource or policy decisions. Opportunities exist to expand the application

of citizen science in these areas through enhanced organizational support, targeted training, and collaboration. Natural resource practitioners held concerns about data quality and limited resources to support the use of citizen science in their role. Addressing these barriers could improve the integration of citizen science into natural resource management, leading to better-informed decision-making and conservation strategies. Future research should explore natural resource practitioner perspectives across diverse regions and organizational contexts, as well as further investigate non-users' perspectives to better understand and address their needs. With appropriate tools, guidance, and funding, citizen science can be further leveraged to strengthen public engagement and support current and future conservation efforts effectively.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

R scripts and data are made anonymously available in Zenodo: https://doi.org/10.5281/zenodo.16942213.

ETHICS STATEMENT

The survey used in this study was approved by the Institutional Review Board of the University of Florida (ET00024319).

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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