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# Community Science Online: Building Capacity for Native Bee Monitoring

Lauren Vilen

Lisa Mason

Sarah Viders

Jill Zarestky

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**Lauren Vilen**
*Colorado State University - Fort Collins*

**Lisa Mason**
*Colorado State University Extension – Arapahoe County*

**Sarah Viders**
*University of New Hampshire - Concord*

**Jill Zarestky**
*Colorado State University - Fort Collins*

*Native bees are crucial for sustainable productivity in natural, agricultural, and urban ecosystems, but they are losing natural habitat spaces. Extension can facilitate community science programs to collect ecological data on native bee populations and support pollinator conservation. Native Bee Watch, an in-person community science program, transitioned to a hybrid format where volunteers received online training and support for conducting field-based data collection. This article presents the volunteers' perceptions of the program training, support, and bee monitoring based on surveys and data analytics collected from technology tools. Study results indicate redesign successes and challenges and provide insight on how to improve the experience for volunteers participating in community science programs, with implications for Extension education.*

*Keywords:* community science, citizen science, pollinators, online education, native bees, adult education, conservation education, volunteer engagement

Native bees and honey bees are crucial for sustainable productivity in natural, agricultural, and urban ecosystems (Gallai et al., 2009). Yet, Colorado is the seventh fastest-growing state by percentage population growth (U.S. Census Bureau, 2021), and rapid urbanization reduces natural habitats with valuable forage and nesting resources for bees (Goulson et al., 2015). Given the dire situation for bees worldwide, more effort is needed to increase public awareness and generate engagement in constructive ways (National Research Council, 2007). Efforts are underway to develop a national monitoring framework to establish comprehensive and consistent data collection on bee populations (Woodard et al., 2020), and engaging community scientists to collect data can build capacity to address pollinator conservation challenges (Birkin & Goulson et al., 2015; Woodard et al., 2020). Given its history of meeting community needs, managing volunteers, and translating science-based information, Extension is a natural fit for engaging

Colorado residents in bee population monitoring and informal STEM education through community science projects, also known as citizen science (Carr, 2004; Clyde et al., 2018).

Native Bee Watch (NBW), a community science program offered through Colorado State University Extension, enables volunteer community scientists to identify and monitor bees. NBW originated as an in-person program where volunteers collected data in public gardens. When the COVID-19 pandemic hit the United States in 2020, NBW was redesigned as a hybrid program with online training and field data collected at volunteers' residences. The purpose of this paper is to explore volunteers' perception of the online training, bee monitoring experience, and supports in the pandemic-adapted hybrid format. The hybrid format has the potential to increase opportunity and access for volunteers. Our successes and challenges provide a deeper understanding of how volunteers engage with learning resources in this technology-mediated design. Such understanding can benefit community science coordinators and Extension agents and inform the intentional integration of online training and resources with field-based data collection in ways that support volunteers' learning, engagement, retention, and program sustainability.

## Literature Review

Community science, also known as citizen science, broadly describes projects in which "the public participates voluntarily in the scientific process, addressing real-world problems in ways that may include formulating research questions, conducting scientific experiments, collecting and analyzing data, interpreting results, making new discoveries, developing technologies and applications, and solving complex problems" (U.S. General Services Administration, 2020, para. 3). Community science comes in many forms, ranging from large scale, international biodiversity monitoring projects (e.g., Chandler et al., 2017) to localized co-created programs aimed at informing collaborative management decisions among government agencies, individuals, and community groups (e.g., Danielsen et al., 2005; Reid et al., 2016).

Modality varies widely across programs. Some projects operate fully online, such as Galaxy Zoo, where volunteers classify photos of galaxies through a virtual platform (Clery, 2011). Field-based community science is often designed such that all volunteer-involved activities are completed physically in person, including training, data collection, and data submission (e.g., through paper forms; National Academies of Sciences, Engineering, and Medicine [NASEM], 2018). Hybrid programs mix elements of online and in-person formats, meaning online training is provided, but data are collected in the physical world, or conversely, training and data collection are conducted in person, and volunteers submit their data to an online platform. Submitting field-collected data to an online database, such as iNaturalist or a project-specific platform, is becoming more common as it streamlines data processing for analysis.

The extent and nature of how volunteers participate in community science vary depending on each project's design and goals. Common types of participation can be categorized as contributory, collaborative, and co-created (Shirk et al., 2012). Contributory projects include volunteers in data collection activities but do not involve them in other project phases, such as data analysis or defining project goals. Contributory projects often require volunteers to develop specific content knowledge and data collection skills (e.g., insect morphology, data protocols), but some projects ask volunteers to complete relatively simple tasks that require no special training (e.g., photo submission), such as in short-term mass participation projects or BioBlitzes (Pocock et al., 2017). Collaborative projects go beyond solely utilizing volunteers for data collection by offering opportunities to analyze and interpret data and identify potential impacts of the research. Co-created projects invite volunteers to participate in all aspects of the research process, from developing the study's purpose and research questions to generating recommendations based on results (Shirk et al., 2012). Each design has affordances and constraints in terms of purpose, volunteer opportunities, training, and engagement strategies.

While community science has made significant contributions to research activities (e.g., Chandler et al., 2017), the extent to which projects are designed to support participants' learning and engagement varies considerably and is largely unexplored (Bonney et al., 2016; Peter et al., 2021). This deficit is surprising, considering these elements enable volunteers to participate and persist in project activities and support data quality needed for achieving the project's scientific goals (Aristeidou et al., 2021). The historical lack of focus on volunteers' learning and engagement may be attributed to the origins of community science as a method for increasing the capacity of scientific research, resulting in project leaders' low attention to program designs that leverage the learning sciences (Bonney et al., 2016) and consideration of how volunteer characteristics such as project roles, motivation, and prior knowledge impact learning and engagement (Phillips et al., 2019). However, research aimed at understanding the relationship among training, engagement, motivation, retention, and learning outcomes is growing (Follett & Strezov, 2015) as community science is increasingly seen as a way to democratize science (Ottinger, 2010) and foster the general public's understanding of science (Bonney et al., 2016).

### Volunteer Engagement

Engagement is conceptualized differently across disciplines and learning contexts (Lewenstien, 2015). In informal science education, engagement is often described as an interest in science or exhibiting interest-oriented behaviors (Friedman, 2008; McCallie et al., 2009). Community science is one venue for informal science learning, and there is a recognized need to describe the nature of volunteer engagement, particularly in field-based projects (Phillips et al., 2019). Yet, current definitions of engagement primarily rely on measures such as the number of volunteers, retention rates, the quantity of data collected, or how frequently a project website is accessed (Phillips et al., 2012). Describing engagement solely with output measures limits our understanding of the more nuanced ways volunteers experience engagement within community science, including acquiring knowledge and skills, community involvement, use of social media, and communicating with fellow volunteers, program coordinators, and scientists (Phillips et al., 2019).

Based on an empirical investigation of how 72 volunteers described their engagement across a variety of field-based environmental monitoring projects (contributory, collaborative, co-created), Phillips et al. (2019) propose a definition of engagement in community science as the "emotional, behavioral, cognitive, and social experiences that initiate and sustain lifelong learning and that are largely influenced by motivational factors" (p. 684). A majority of volunteers reported multiple motivations, the most common being an environmental concern or issue of personal importance, wanting to contribute (e.g., to science, environment, community), interest in the project topic, and issues impacting their community. Other motivations included connection to a specific place, personal enjoyment, learning, social connections, scientific credibility, and being outdoors. Specific to pollinator community science programs, Domroese and Johnson (2017) and Bloom and Crowder (2020) found volunteers were primarily motivated by personal learning interests, such as wanting to learn more about bees, followed by a desire to contribute to scientific research. Furthermore, Domroese and Johnson (2017) found long-term volunteers more frequently reported motivations related to their scientific contributions, suggesting motivations may shift as volunteers participate across multiple years and transition from novice to experienced project members. Understanding shifts in motivation may assist project coordinators in developing strategies to keep experienced volunteers engaged.

Additionally, perceptions of specific activities, people, and resources (e.g., enjoyment, utility, frustration), sense of belonging to the project or group, and individual attributes (e.g., prior knowledge and skills) contribute to volunteer engagement (Phillips et al., 2019). Peter et al. (2021) investigated the connection of project characteristics to volunteers' perceived gains in knowledge (e.g., biodiversity, environmental awareness) and skills (e.g., project-relevant species identification, data collection) among 838 participants in 48 community science projects across 10 countries. Peter et al. found volunteers perceived higher gains when they received interactive or multimedia online training (i.e., quiz, video) or in-person training. Volunteers also reported higher perceived gains when provided with more information about the project's scientific background, goals, and progress, had opportunities to interact (i.e., in-person, social media) with other volunteers, project coordinators, and scientists, and received higher levels of feedback and recognition (Peter et al., 2021).

Research has shown that when community science participants have opportunities to receive individual feedback, it positively impacts their initial and ongoing learning and engagement (NASEM, 2018). In the United Kingdom project BeeWatch, van der Wal et al. (2016) found that providing automated feedback through an online platform enabled volunteers, including novices with little prior knowledge, to rapidly learn and expand their bee identification skills in both the training and data collection phases of the project. Wisniewski et al. (2020) suggest individual feedback can also positively impact motivation, persistence, and self-efficacy with learning tasks, particularly when feedback is information-rich and helps individuals understand why their response was correct or incorrect. This supports Peter et al.'s (2021) findings indicating volunteers who frequently received individual feedback reported higher perceived gains in skills and knowledge compared to volunteers who received less frequent or no feedback. Feedback processes may be one means of helping volunteers feel supported and engaged in community science projects.

Engagement is a combination of personal and project-specific characteristics (Phillips et al., 2019). Frensley et al. (2017) investigated volunteers' engagement in a hybrid co-created community science program utilizing online learning modules with embedded quizzes, web-based concept mapping, and in-person events. Frensley et al. found volunteers felt the self-guided online training modules and embedded quizzes were challenging, time-consuming, and technical issues and unfamiliarity with the online tools created barriers that ultimately overcame their motivation to continue participating. Additionally, some volunteers reported the online training was socially isolating (Frensley et al., 2017). Bloom and Crowder (2020) explored engagement in two pollinator community science projects and found retention was higher when volunteers were asked to collect data on wild bees by observing nest boxes (70%) compared to having volunteers identify and record flower-visiting bees and bee-plant interactions using photography (6%). Bloom and Crowder's findings suggest if volunteers perceive data collection methods as too challenging or complex, it may negatively impact their motivation to persist beyond the training period. Although there is a tremendous amount of variety among community science projects, these studies illuminate how the design, implementation, and perceptions of specific program elements can impact volunteer engagement.

Given the multifaceted nature of engagement, Phillips et al. (2019) emphasize that variations in volunteer engagement are strongly influenced by each project's unique cultural and ecological context and design. Consequently, strategies for supporting engagement are diverse and range from project websites and resource repositories to in-person volunteer appreciation and training events. Although engagement strategies depend on the contextual factors of each project, recent studies show programs that design with the volunteer in mind likely yield a higher quality of work that benefits the research (Crall et al., 2013; Dickinson & Bonney, 2012). Additionally, programs incorporating an online volunteer forum and dedicated website may see higher retention rates and community-building (Clery, 2011). Phillips et al. (2019) recommend a better understanding of how adults engage and learn through community science programs, which can inform science learning in similar experiential contexts and support meaningful engagement among Extension professionals, researchers, community members, and other stakeholders (Desprez et al., 2020).

## Native Bee Watch: Past and Present

Native Bee Watch's (NBW) mission is to engage the people of Colorado in supporting pollinator conservation through research and education. NBW is a contributory project and has four primary goals: (1) learn about bee population and abundance trends in Colorado, (2) understand bees' plant preferences, (3) support education and engagement so volunteers and their communities can make informed decisions regarding landscapes, and (4) support and assess adult learning through community science. All NBW volunteers are individuals who reside in Colorado during the program's annual data collection period, roughly late May through early September.

NBW's data collection protocol is a modified version of the Focal Plant Sampling Procedure (Altmann, 1974; Mason & Arathi, 2019) that groups bees into eight morphospecies categories (e.g., hairy leg bee, bumble bee, tiny dark bee). A monitoring session consists of at least one two-minute observation of an area of flowering plants no larger than two feet squared. Additional two-minute observations in the same session are discretionary and may depend on the availability of flowering plants in the monitoring area. Volunteers record the date, time, weather, and location for each monitoring session. For each two-minute observation within that session, volunteers record the name of the plants in the observation area, the approximate number of flowers on each plant, any pollinating bees observed in the eight morphospecies categories, and pollinating flies observed on the plants.

### In-Person Program Model

From 2016 to 2019, NBW operated as a fully in-person program at four public gardens in Fort Collins and Littleton, CO. Recruitment efforts included advertising through social media, word-of-mouth, and email newsletters leveraging networks within Colorado State University and the City of Fort Collins. Volunteers received a program-specific field guide and attended a two-hour, in-person training focused on how to distinguish bees from other flying insects (e.g., flies and wasps), identifying bees to eight morphospecies categories, data accuracy and collection protocols, and the importance of the plant-pollinator relationship (Mason & Arathi, 2019). Training techniques included lecture, PowerPoint presentations, and examination of insect specimen boxes. Volunteers then spent a significant amount of time in public gardens learning to identify flower-visiting insects and conducted monitoring sessions under the mentorship of a university researcher, program coordinator, or an experienced volunteer. This one-on-one interaction contributed to peer learning and enabled novice volunteers to receive immediate feedback on their bee identification skills, resulting in high engagement from participants (88% average retention from 2016-2018), and a high level of accuracy in the ecological data collected compared to data collected by researchers (Mason & Arathi, 2019). In addition to field mentoring, volunteer support included e-newsletters, email communication, and an annual volunteer appreciation event. During monitoring sessions, volunteers recorded data on a paper form which the program coordinator transferred to a Microsoft Excel spreadsheet.

**Hybrid Program Model**

In the spring of 2020, the COVID-19 pandemic prompted a rapid program redesign so NBW could be implemented virtually to comply with social distancing guidelines. The 2020 pandemic-adapted NBW program design leveraged a combination of technological supports to support field-based data collection. We used the same recruitment strategies for the hybrid model but expanded the reach to statewide audiences instead of concentrating locally. The initial volunteer training was offered twice via synchronous Zoom webinars, which were recorded and posted to YouTube for individuals who could not attend the live sessions. Training webinars covered the same content as prior years' in-person trainings but with greater emphasis on bee identification and data collection protocols. A missing component from the online trainings was the opportunity for volunteers to examine physical bee specimens. Before submitting data to the project, we required new volunteers to attend or view the training webinar and pass an online, open-resource Google Forms photo identification quiz with a score of 85% or better. The 50-question quiz focused on differentiating among bees, wasps, and flies and identifying bees into the eight morphospecies categories. The quality and clarity of the photos varied to represent what volunteers may see while monitoring. Volunteers received no additional feedback beyond whether their answers to questions were correct or incorrect. The quiz could be taken as many times as needed to reach 85% or higher.

After passing the quiz, volunteers monitored bees individually in their home gardens in areas with flowering plants. Given the size and plant variation in home gardens, volunteers determined how much time they wanted to devote to monitoring and how many two-minute observations to include in each monitoring session. For consistency, we asked volunteers to monitor the same plants through the entire bloom period and to monitor every other week at a minimum or once per week maximum. Rather than recording and submitting data through paper forms as in the in-person model, volunteers submitted data using a newly developed data collection form on Survey123, an ArcGIS Online platform, using either the mobile or desktop app. We provided a printable data collection template for volunteers wishing to record data on paper before uploading it to Survey123. Submitting photos from each monitoring session was highly encouraged but not required.

To support volunteers with their at-home monitoring, we created a password-protected resources webpage which provided a central location for volunteer resources such as links to the recorded trainings on YouTube, training presentation slides, identification field guides, and photo flashcards for self-study. Other supports included a monthly e-newsletter and a new Facebook group where volunteers could interact and post photos for identification assistance; to encourage engagement, program staff routinely posted educational content. Two supplemental webinars were offered mid-season; a general Q&A session provided opportunities for volunteers to ask questions, share observations, and learn from other volunteers, and a pollination biology lecture framing the importance of pollinator population data.

Identifying bees is a challenging learning task, even in an in-person setting with the assistance of pollinator experts and ongoing field mentoring. Consequently, we anticipated transitioning to a model utilizing online instruction to teach field-based skills, and introducing a new online data collection tool may present challenges for volunteers. As such, supporting volunteers to feel confident with bee identification and the data collection protocols motivated the development of the one-stop resources webpage. Additionally, we recognized that monitoring at home may be isolating for some volunteers since research has shown that social interactions among community science volunteers, program staff, and scientists can contribute to higher levels of engagement (Peter et al., 2021; Phillips et al., 2019). Therefore, we utilized the Facebook group, email, Zoom, and supplemental webinars to encourage interactions among volunteers and program staff. Volunteer engagement, confidence, and retention were of primary importance for program staff in the transition from the in-person to the hybrid model. Our desire to provide a high-quality volunteer experience led us to conduct the study we present in this paper.

## Purpose and Research Questions

The purpose of this mixed-methods survey-based study is to present the successes and challenges from the redesign of NBW from an in-person to a hybrid model as guided by the research questions:

1. What were new volunteers’ motivations for participation?
2. How did new volunteers perceive the online training?
3. How did new volunteers perceive the bee monitoring experience, resources, and supports?

## Methods

To capture the personal and scientific experiences of NBW new volunteers, this study’s data collection included pre- and post-monitoring surveys, ecological data submitted by volunteers, volunteer participation data (e.g., quantity of participants, monitoring sessions, observations), and analytics from the Facebook group, e-newsletter, and recorded training webinars available on YouTube. All human subjects’ data were collected in accordance with protocols approved by Colorado State University’s Institutional Review Board.

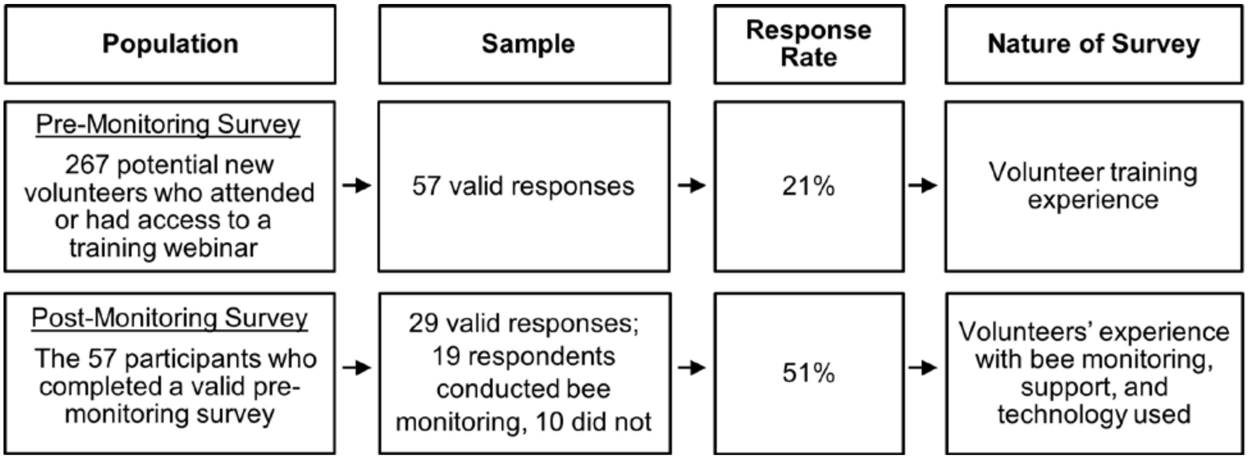
### Participants and Data Collection

For the 2020 NBW season, we recruited new volunteers through Colorado State University Extension, the statewide Master Gardener program, and social media. Two 3-hour virtual trainings were offered in late May 2020; 51 people attended the first training, and 159 people attended the second training. Sixty-nine people could attend neither and requested access to the recording for a total of 279 attending or viewing the training. Our goal was to assess the hybrid program design on new volunteers who had no prior experience in NBW's in-person model, so we considered participants to be eligible for this study if they (a) attended or viewed the 2020 online training webinar and (b) had not participated in NBW anytime from 2016–2019. Given these criteria, we removed 12 prior participants, leaving 267 potential new volunteers eligible to participate in this study.

After attending the training webinars in May 2020 and before the field monitoring season began in June 2020, we invited all 267 potential study participants to complete a pre-monitoring survey. The pre-monitoring survey addressed volunteer demographics, prior knowledge and skills, STEM content learned, possible associated conservation behaviors, and initial perceptions of the training process. Post-monitoring surveys were conducted in August and September 2020 at the end of the monitoring season. Only volunteers who completed the pre-monitoring survey were eligible to take the post-monitoring survey because we wanted to capture any differences in perception before and after the monitoring experience. The post-monitoring survey addressed volunteers' experience during the training and field monitoring, STEM content learned, possible associated conservation behaviors, motivation to volunteer and to return if applicable, and for respondents who never conducted bee monitoring, reasons why they dropped out after attending training.

In developing the surveys in Qualtrics, a secure online survey platform, we drew from a validated survey in environmental education (Vaske & Kobrin, 2001) to inform questions on environmentally responsible behaviors. The STEM topics list and qualities specific to NBW were collaboratively generated by education researchers and the program coordinator based on training content, knowledge, and skills necessary for conducting monitoring. Questions about motivation to participate and engagement supports were informed by prior studies on engagement (e.g., Domroese & Johnson, 2017; Phillips et al., 2019) and the program coordinator's interactions with volunteers in the prior in-person model. We pilot-tested the pre- and-post monitoring surveys with two summer interns who were new to NBW in 2020, attended the online training, and conducted monitoring. Figure 1 summarizes the data collection processes.

***Figure 1. Participant Sampling and Data Collection Procedures***




## Data Analysis

We used descriptive statistics to analyze the frequency distributions of all variables from closed-ended questions on the pre-and-post monitoring surveys. For questions asking participants to rank items from most to least helpful (e.g., training components and field resources), we calculated and ordered the mean rank for each item from highest to lowest rank (1 = *highest possible rank*, 10 = *lowest possible rank*). On the pre-monitoring survey question asking participants to rank elements of the volunteer training, four respondents experienced a browser glitch prohibiting them from using the drag-and-drop feature, lowering this question's responses from 57 to 53. We used Likert-scale questions to ask participants about technology and program communications. For example, the question "How easy was it to use the Survey123 app on my mobile or tablet?" included the response options of *didn't use*, *very challenging*, *moderately challenging*, *moderately easy*, and *very easy*. For analysis, we coded Likert responses from one to five, corresponding to the choices *didn't use* and *very easy*.

We analyzed open-ended survey questions about the training, program resources and communication, and monitoring experience using a qualitative content analysis process (Merriam & Tisdell, 2016). We sorted and grouped responses based on the key content to build categories. In September 2020, we downloaded data analytics from the Facebook group, YouTube, and Constant Contact e-newsletter, survey data from Qualtrics, and monitoring session data from Survey123. We analyzed the YouTube data to assess engagement with the recorded trainings using guidance from YouTube Help (n.d.). Constant Contact analytics presented the number of individuals who received the e-newsletter, the percentage that opened the e-newsletter, and the percentage that clicked included links. Facebook data included the number of group participants and the frequency, time of day, reactions to (e.g., likes), and views of postings. We conducted descriptive analyses, including frequency distribution and mean, of the Facebook and monitoring sessions data in Excel and survey data in SPSS 26.

## Results

We report results regarding new volunteers' experiences in the trainings, bee monitoring activities, and perceptions of program support. We focus on results that inform programmatic elements and volunteer engagement.

Of the 267 potential volunteers that participated in the live training or had access to the recording, 68 new volunteers followed through on data collection and were considered active volunteers. Additionally, 12 volunteers from prior years conducted monitoring for a total of 80 active volunteers in 2020, an increase of over 200% from the program's historic high of 25 volunteers in 2017. Monitoring locations expanded geographically from three or four public gardens to backyard gardens statewide, as shown in Figure 2, with a majority located in urban and heavily-populated areas. Figure 3 depicts volunteers' monitoring activity.

***Figure 2. Monitoring Locations in 2020***

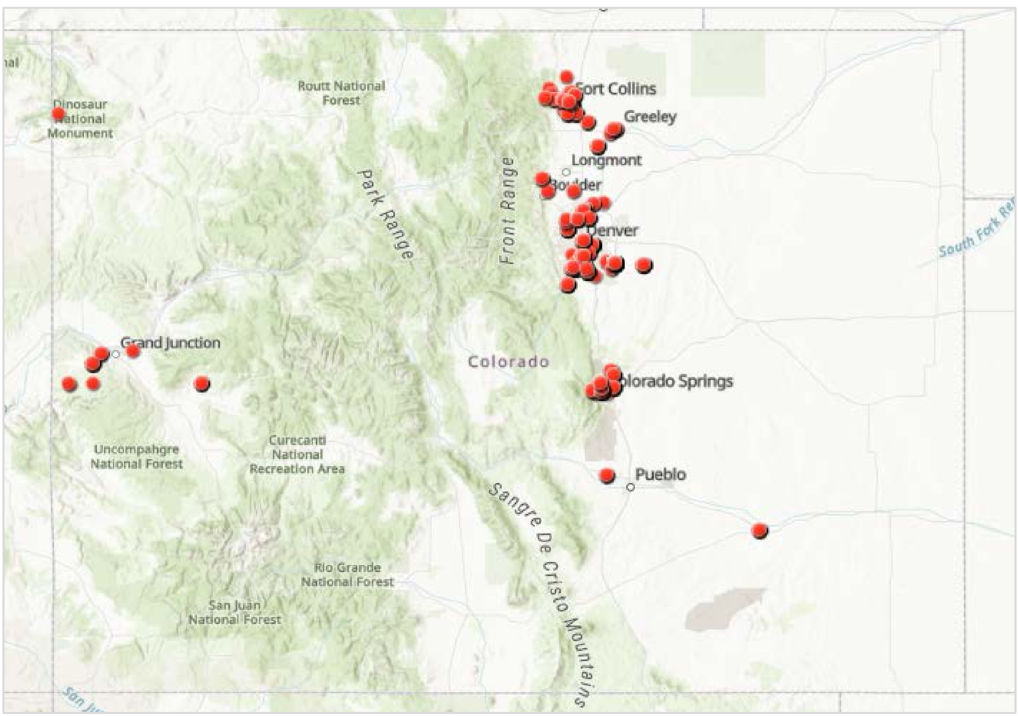
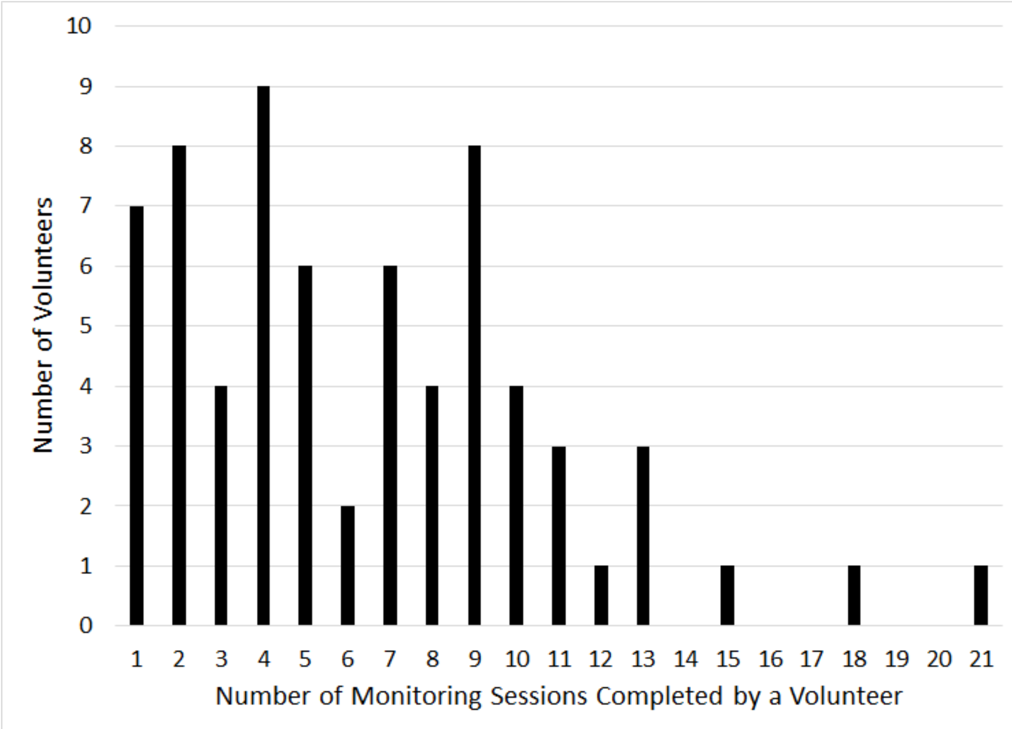


*Figure 3. Number of Monitoring Sessions Completed by New Volunteers*




*Note. N* = 68. The monitoring season was 12 weeks, from June through August; volunteers were asked to monitor approximately every other week. The mean number of completed sessions was 6.4.

**Demographics and Motivation to Participate**

In this section, we present results pertaining to the first research question and the characteristics of study participants. Most pre-monitoring respondents identified as female, white, 55 years or older, and possessing at least a bachelor's degree. Of those who reported annual household income, approximately 50% of respondents earn $80,000 or more. Table 1 shows the respondents' demographics.

***Table 1. Demographics of Pre-Monitoring Survey Respondents (N = 57)***

| Variable | Category | *n* | % |
|---|---|---|---|
| Gender | Female | 48 | 84.2 |
| | Male | 9 | 15.8 |
| Age | | | |
| | 25-34 | 5 | 8.8 |
| | 35-44 | 5 | 8.8 |
| | 45-54 | 6 | 10.5 |
| | 55-64 | 17 | 29.8 |
| | 65-74 | 21 | 36.8 |
| | 75 or older | 3 | 5.3 |

| Variable | Category | *n* | % |
|---|---|---|---|
| Race/ethnicity | | | |
| | White | 54 | 96.5 |
| | Black/African American | 1 | 1.8 |
| | Asian/Pacific Islander | 1 | 1.8 |
| | Two or more | 1 | 1.8 |
| Household Income | | | |
| | $30,000 to $59,999 | 9 | 15.8 |
| | $60,000 to $79,000 | 7 | 12.3 |
| | $80,000 to $99,000 | 13 | 22.8 |
| | $100,000 or more | 16 | 28.1 |
| | Prefer not to specify | 12 | 21.1 |
| Highest education level completed | | | |
| | Some college credit, no degree | 5 | 8.8 |
| | Trade/vocational training | 1 | 1.8 |
| | Associates degree | 1 | 1.8 |
| | Bachelor's degree | 19 | 33.3 |
| | Master's degree | 20 | 35.1 |
| | Professional degree | 4 | 7.0 |
| | Doctorate degree | 7 | 12.3 |

Table 2 presents the distribution of respondents' background attributes. Over 75% of participants reported prior knowledge or skills in gardening, plant identification, and identifying plants that attract bees. Write-in responses included membership in the Master Gardener program ($n$ = 4) and prior exposure to beekeeping through family or neighbors ($n$ = 4).

***Table 2. Attributes of Pre-Monitoring Survey Respondents: Prior Knowledge or Skills (N = 57)***

| Variable | *n* | % |
|---|---|---|
| Gardening experience | 51 | 89.5 |
| Plant identification skills | 44 | 77.2 |
| Identifying plants that attract bees | 43 | 75.4 |
| Professional data collection experience | 27 | 47.4 |
| Pollinator habitat or related experience | 25 | 43.9 |
| Professional experience in science | 24 | 42.1 |
| Distinguishing bees from other flying insects | 20 | 35.1 |
| Other (write in) | 14 | 24.6 |
| Teaching background in science | 13 | 22.8 |
| Bee keeping experience | 12 | 21.1 |
| Participated in other citizen science projects | 11 | 19.3 |

*Note.* Respondents were able to multi-select. Frequencies and percentages reflect respondents who answered *yes* to this question.

Post-monitoring survey respondents who conducted monitoring indicated their motivations for participation reflected a desire to learn something new, concern for bee populations, and a desire to participate in bee conservation and scientific endeavors (Table 3). Write-in responses included earning Master Gardener hours (*n* = 3) and wanting to observe which home-garden plants bees prefer (*n* = 2).

***Table 3. Motivation for Participation in NBW (N = 19)***

| Motivation | *n* | % |
|---|---|---|
| To learn something new | 19 | 100 |
| I enjoy participating in science | 15 | 78.9 |
| I like contributing to bee conservation efforts | 14 | 68.9 |
| I'm concerned about the bee population decline | 13 | 68.4 |
| I love bees | 6 | 31.6 |
| Other (write-in) | 6 | 32.6 |
| I wanted to spend time outdoors | 4 | 21.1 |
| To get out of the house | 4 | 21.1 |
| To connect with other people in my community | 2 | 10.5 |

*Note*. Post-monitoring respondents. Respondents were able to multi-select.

For the 10 post-monitoring survey respondents who dropped out of the project after attending the training, the most reported reasons for non-participation were (a) low comfort or difficulties with using Survey123 to submit data (*n* = 3), (b) low confidence in their identification skills (*n* = 3), and (c) inability to pass the required training quiz (*n* = 2). Of the 19 post-monitoring survey respondents who conducted bee monitoring, 89.9% reported they plan to volunteer in 2021. When given the option to write in factors potentially influencing their decision to volunteer in the future, responses included available free time and whether the program will be offered in-person or in the current hybrid format. However, preference for either program format was not indicated. While one respondent reported they would like to monitor with fellow volunteers, several others stated they hope to continue monitoring in their home gardens because being required to monitor in designated public gardens may present a barrier, depending on the garden's location.

## Perceptions of the Online Training

In this section, we present results pertaining to the second research question. The recorded volunteer training available on YouTube had 124 views. The most-viewed sections were distinguishing a bee from a fly or wasp and identifying categories of bees. The second most-viewed section was on submitting data using Survey123.

Both pre-and post-monitoring survey respondents were asked to rank discrete elements of the volunteer training from most helpful to least helpful in preparing them to monitor bees, shown in Table 4. Volunteers reported the most helpful training components were those designed to provide and assess knowledge on bee and insect identification; the least helpful aspects were unrelated to the monitoring process but provided background information on pollinators and the program. Interestingly, the video monitoring demonstration was ranked as less helpful post-monitoring compared to pre-monitoring.

The pre-monitoring survey included an open-ended question asking volunteers to offer suggestions for future trainings. The most common themes were (a) incorporating more information and practice time on bee and insect identification (e.g., practice quizzes, having an expert model bee identification), (b) increased diversity and quality of visual materials (i.e., bee photos or videos), (c) an in-person mentor, and (d) breaking the training into smaller modules (e.g., multiple shorter sessions). In general, pre-monitoring respondents provided positive feedback about their training experience. For example, one volunteer wrote, “I’ve already enjoyed being able to identify different kinds of bees that I didn’t know existed before.” Another participant related,

> The training was great! Going into the training, I knew very little about native bees and how to distinguish them from honey bees, wasps and flies. I came out of the training feeling pretty confident that I will be able to apply what I’ve learned during my observation sessions and identify what I see correctly.

Although these responses were submitted prior to conducting bee monitoring, they demonstrate participants felt the training supported their learning and preparation for monitoring.

***Table 4. Most and Least Helpful Elements of Volunteer Training***

| Element | Pre-Monitoring Mean Rank | Post-Monitoring Mean Rank |
|---|---|---|
| Lecture on identifying bees and other similar insects | 1.45 | 1.26 |
| Practicing identification using photos in the PPT | 3.68 | 3.58 |
| Studying the *NBW Citizen Science Field Guide* | 4.30 | 3.42 |
| Practice quiz | 4.57 | 4.37 |
| Lecture on data collection tools/procedures | 5.89 | 5.89 |
| Outdoor demo of monitoring session by facilitator | 5.91 | 7.26 |
| Lecture on pollination | 6.30 | 6.47 |
| Lecture on reasons for pollinator decline | 7.13 | 7.21 |
| Update on how the data has been used and the future direction of NBW | 7.55 | 7.89 |
| Structured Q&A through the chat box | 8.23 | 7.63 |

*Note.* Pre-monitoring respondents, *N* = 53. Post-monitoring respondents, *N* = 19. 1 = *most helpful*, 10 = *least helpful*.

After the initial volunteer training, participants were required to pass an online quiz before monitoring. All 19 post-monitoring respondents who were active volunteers reported they successfully passed the quiz, with the majority (52.6%) needing two attempts. All volunteers responded “yes” when asked if the quiz was helpful in learning to identify insects.

### Perceptions of the Bee Monitoring Experience, Resources, and Supports

In this section, we present results from the post-monitoring survey pertaining to the third research question. Several questions to capture the experiences of volunteers who conducted monitoring inquired how volunteers used and perceived field and technology resources, communication channels with NBW, and volunteers. As shown in Table 5, volunteers perceived the field guide (Mason et al., 2018) and a camera as being the most useful field resources. Write-in responses for the *other* category included binoculars and asking questions via email.

A variety of resources were available on the NBW website to support volunteers. Volunteers reported the website and volunteer resource webpage were either *moderately easy* (42.1%) or *very easy* (52.6%) to use (*N* = 19; one respondent indicated they used neither resource). Additionally, NBW utilized several technology applications during the trainings and for data collection. The majority of volunteers indicated using Zoom to attend the volunteer training webinars was *very easy* (84.2%), with only 5.3% of volunteers reporting it was either *moderately easy* or *moderately challenging*, respectively (*N* = 19, with one respondent indicating they did not use Zoom). Volunteers reported using Survey123 to submit monitoring data was mostly *very easy*, with slightly higher ease of use on the computer desktop (42%) compared to a mobile device (32%). Of those volunteers who found using Survey123 *moderately challenging*, most reported using the application on their mobile device (16%) instead of a desktop computer (5%; *N* = 19).

***Table 5. Most and Least Helpful Field Resources (N = 19)***

| Resource | Mean Rank |
|---|---|
| *NBW Citizen Science Field Guide* | 1.63 |
| Camera to take pictures | 2.89 |
| Bee size comparison guide | 5.00 |
| Recorded webinars | 5.32 |
| NBW Facebook group | 5.79 |
| Internet | 5.84 |
| The book *Bees in Your Backyard* | 6.16 |
| Magnifying glass | 6.16 |
| Working one-on-one with partner | 7.74 |
| Other | 8.47 |

*Note.* Post-monitoring respondents. 1 = *most helpful*, 10 = *least helpful*.

NBW sent a monthly e-newsletter to all volunteers during the active monitoring season (June through August), which included reminders, monitoring tips, and educational information. The majority of volunteers reported not receiving the e-newsletter (26%) or finding it *very* (16%) or *moderately unhelpful* (31%, *N* = 19).

When asked if they received enough communication and support from program leaders, 63% of volunteers indicated *yes*, and 37% responded *no* ($N$ = 19). Write-in suggestions for improving communication and volunteer support included immediate and direct feedback on volunteers' data submissions, more information posted in the Facebook group, and facilitated weekly Q&A Zoom meetings during the first several weeks of monitoring.

In general, volunteers who completed the post-monitoring survey indicated a positive overall experience. Table 6 presents representative participant quotes.

***Table 6. Write-in Responses from NBW Volunteers on Overall Experience (N = 19)***

| Category | Example Quote |
| --- | --- |
| Knowledge | What an enriching learning experience this has been! My awareness, and appreciation of the role of pollinators in the food chain, has increased ten-fold. |
| Meaningful contribution | I really liked doing this, it was super helpful and I felt like I was contributing in a meaningful way. |
| Nature appreciation | It has enhanced my pleasure at being able to see the diversity of bees and other pollinators as I walk or sit among the plant life they touch. I am in awe. |
| Master Gardener | I'm an CMG. … A native bee presentation should be a class for CMG's and apprentices. For me, learning about bees made my work as a gardener complete. |

*Note*. Post-monitoring respondents.

## Discussion

Based on this study's results, the rapid transition from an in-person to a hybrid program model was successful in retaining and engaging volunteers. Insight into volunteers' perceptions and experiences in the hybrid format contextualizes our successes and challenges, provide a baseline for program development, and contributes to scholarship on engagement in community science.

### Successes and Opportunities

Key successes and opportunities created by the hybrid model included reaching a broader spatial (statewide) scale as opposed to the localized monitoring previously and retaining a greater number of active volunteers (80) than in prior years' in-person model. Among the 68 new active volunteers, the majority completed four or more monitoring sessions over 12 weeks, suggesting that most volunteers were able to overcome initial challenges with learning to identify and monitor bees. This was a major success since the level of challenge and complexity in pollinator species identification and data collection can contribute to low volunteer retention (Bloom & Crowder, 2020; Klienke et al., 2018), and volunteers did not have the benefit of in-person mentoring to assist with initial difficulties.

The online training was available at no cost to potential volunteers and was offered in a live and recorded format, resulting in a high number of interested participants. Although many attendees opted not to become active volunteers after the training, the high level of participation in the online training suggests there is great interest in learning about bees and pollinator conservation among Colorado residents and aligns with volunteers' motivations for participating in NBW and similar pollinator community science projects (e.g., Bloom & Crowder, 2020; Domroese & Johnson, 2017). In future years, training attendees who never conduct monitoring should be surveyed so program staff can assess barriers to participation and develop appropriate strategies.

Research indicates that volunteers' prior knowledge, skills, and experiences contribute to engagement in community science (Phillips et al., 2019) and informal science learning (Falk & Dierking, 2019). NBW was able to successfully leverage existing networks to recruit volunteers with established interests or experience in project-relevant activities. Additionally, the demographics and locations of NBW volunteers reflect broader trends in community science participation, namely that volunteers are primarily white, well-educated, older in age, and middle to upper class (NASEM, 2018). Furthermore, pollinator community science programs skew heavily towards urban centers where participants tend to be highly educated (Mason & Arathi, 2019), and the locations of NBW monitoring sessions lend support to this trend. The hybrid format afforded greater accessibility for volunteer participation, yet opportunities exist to expand recruitment efforts to non-urban areas and groups underrepresented in community science.

Survey results indicated new volunteers found the trainings valuable and interesting. For future trainings, instead of a 2-hour webinar, breaking the content into shorter pre-recorded videos may be beneficial and would enable volunteers to access specific information throughout the project. Providing short, on-demand, just-in-time training can support volunteers' species identification skills and data accuracy (Katrak-Adefowara et al., 2020). Furthermore, educational videos of ten minutes or less align with Extension best practices (Dev et al., 2018), and recent research indicates recordings of one-hour webinars are, on average, rewatched for only 12 minutes (Barnes et al., 2021), suggesting viewers are navigating to segments most relevant to their immediate needs. Since analytics of the recorded NBW training showed volunteers primarily viewed sections on bee identification and data entry, creating short stand-alone videos to address these specific skills and making them available on the project website may support volunteers' initial and ongoing engagement.

The availability and format of program information and resources can impact volunteer engagement (Peter et al., 2021), and the hybrid model provided the impetus to build a single repository for all the NBW community science resources on the project website. This wealth of resources, and the ability to revisit information that had previously only been available in person, was a success and reduced the number of routine questions directed to staff. As a result, volunteers may have had less interactions with program staff through email or other means. This highlights the need to incorporate opportunities for interactions among volunteers and program staff as an engagement strategy to build comradery and confidence in project-related skills (Peter et al., 2021; Phillips et al., 2019). For example, facilitating weekly Zoom sessions was a write-in suggestion for improved communication and support from program staff. Since the primary motivations of NBW volunteers are to learn something new and participate in science, prioritizing continuing education may be an effective strategy for volunteer engagement and retention. In future iterations of the hybrid model, NBW staff should consider using recorded webinars and resources from related Extension programming to supplement continuing education needs. Making available in-person training, hands-on identification workshops, and peer-mentoring between new and experienced volunteers to improve identification accuracy (Freitag et al., 2016)) could also supplement online learning and support volunteer engagement (Frensley et al., 2017; Peter et al., 2021; Phillips et al., 2019).

For active volunteers, the most useful resources were the pre-monitoring quiz and the field guide. Although the quiz was designed to assess insect identification skills prior to submitting data to the project, research shows that quizzing is also a powerful learning tool (Roediger et al., 2011). Opportunities exist to leverage research from the learning sciences to support volunteers' identification skills (e.g., Wahlheim et al., 2011) in hybrid programs where species identification is initially learned through photos and then transferred to a field setting. Wahlheim et al. (2011) suggest that using photo training can support volunteers' ability to distinguish among the key characteristics of species, which aligns with the data protocols of NBW and other pollinator community science programs (e.g., Bloom & Crowder, 2020; Domroese & Johnson, 2017). While volunteers reported the quiz was helpful, findings from the open-ended survey questions indicate volunteers desire more information and practice time with bee identification. Utilizing an online platform that can provide immediate detailed feedback on quiz responses and creating more opportunities for identification practice with feedback may further enhance volunteer engagement (Peter et al., 2021).

Finally, volunteers expressed enjoyment in learning about their own yards and natural spaces, as opposed to the public gardens in previous years. They perceived this project helped them feel more connected to their own yards and take positive advantage of pandemic-imposed restrictions. Research exploring the role of place in community science volunteers' motivation and engagement is growing (e.g., Newman et al., 2017; Phillips et al., 2019), and future research should investigate how project activities utilizing public and private place connections impact engagement.

**Challenges and Recommendations for Future Programs**

Technology was an advantage, but it also presented a barrier for some volunteers. Training required videoconferencing software, data submission required a mobile app or desktop computer, and engagement with program personnel or other volunteers required email or Facebook access. Yet, similar to the findings of Frensley et al. (2017), volunteers' technology skills were highly varied, and not everyone was comfortable with technology-mediated project activities. Technology is becoming increasingly integrated into community science, and future work should address accessibility by considering internet access and technology skills.

The amount and type of information available to volunteers can impact engagement (Peter et al., 2021), and e-newsletters can be an effective tool to communicate with volunteers (Erikson & Hansen, 2012). However, survey results indicated most volunteers did not receive the newsletter or did not find it helpful, suggesting a mismatch between the intent of the newsletter and its perceived utility to volunteers. An ongoing challenge for NBW is staff capacity for generating project communications. Newsletters can be time-consuming to create, and volunteers and staff may rate the relevancy of included information differently (Peter et al., 2021). Further investigation is needed to understand what newsletter content would be helpful to active volunteers versus individuals with a general interest in NBW, such as individuals who attended a volunteer training but never conducted bee monitoring.

Lastly, although the challenge of learning to identify bees and collect observational data resulted in some volunteers leaving the program, NBW fills a much-needed gap in pollinator population monitoring research. Traditionally, research on bee populations entails collecting specimens to fully understand species-level populations and health. However, there are several challenges associated with this method, including a lack of personnel with the required taxonomic expertise, overcoming sampling biases from current capture methods (e.g., pan traps, vane traps, netting), securing the needed funding and resources to process and store specimens, running the risk of over-collecting, and abiding by collecting restrictions for endangered or at-risk species (Portman et al., 2020; Woodward et al., 2020).

Observational data collected through community science volunteers can build capacity and provide additional data about bee populations without the challenges associated with specimen collecting (Birkin & Goulson, 2015). Furthermore, popular online community science platforms such as iNaturalist are experiencing data backlogs since only 7% of users participate as identifiers (i.e., volunteers with the skills and ability to make informed identifications from photos) compared to the 92% of users who only upload photo observations without providing an identification (Callaghan et al., 2022). This backlog highlights the importance and need for programs like NBW that train and support volunteers to collect pollinator population data through observational methods. Although it can be challenging for non-scientists to grasp the larger picture of population monitoring research, clearly communicating the importance of observational data and the scientific niche it fills could support engagement (Peter et al., 2021) for new and long-term community science volunteers who have strong scientific motivations. NBW should consider developing data visualizations for the project website as a way to recognize volunteers and contextualize their scientific contributions.

## Implications for Extension Programming

Extension strives to stay relevant and increase engagement with local communities (Reed et al., 2015). Community science can be one method for Extension to connect with their constituents on locally-relevant issues (Desprez et al., 2020). The successes and challenges presented here can be applicable to other issues Extension aims to address, including climate change, water quality, invasive species detection, food systems, and agriculture (Cooper et al., 2014; Ryan et al., 2018).

The recent Colorado Community Needs Assessment conducted by Extension indicated that sustainable landscapes, outdoor education, and yard/garden management continue to be high-priority needs in the state (L. Mason, personal communication, December 2021). With decreasing budgets in Extension and university resources, community science projects can leverage capacity through existing Extension infrastructure, such as volunteer management systems for administration, website and communication tools, and education resources. Like NBW, utilizing current volunteer programs as recruitment networks, such as Master Gardener, Master Naturalists, and 4-H, is an opportunity for any Extension community science project because volunteers are already connected through Extension networks and have exposure to science-based learning (Clyde et al. 2018). Extension can also leverage its history of collaborating with established partnerships, community members, and research faculty to provide a strong foundation for community science programs (Clyde et al., 2018). Additionally, because of its presence in each county, Extension can help community science programs connect with volunteers in non-urban areas where there is an established need for pollinator community science programs (Mason & Arathi, 2019). This study's results regarding program design and volunteer engagement can inform Extension and community science programs elsewhere.

## Conclusion

Volunteers are the heart of community science. While the pandemic was disruptive in countless ways, the opportunity to move NBW to a hybrid format enabled greater participation from a wider range of Colorado locations. The transition to a hybrid program was partially successful because NBW was housed within Extension and leveraged Extension resources and recruitment networks. Our study informs the development of NBWand similar community science and Extension programs. It illuminates ways staff can better support volunteers with field-based tasks through online training, resources, and engagement strategies. By focusing on engagement, we aim to recruit, retain, and better position volunteers to make informed decisions about their own landscape and advocate for bee conservation in their communities.

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*Lauren Vilen*, M.Ed., is a Ph.D. candidate in the Colorado State University School of Education. Her research interests include adult learning, environmental adult education, and community-based education. Lauren's professional background includes non-profit program management, where she provided young adults with training and education for environmental stewardship and job readiness.

*Lisa Mason* is the Horticulture Specialist for Colorado State University Extension in Arapahoe County. She is the founder and leads Native Bee Watch, a community science program that monitors native bees in urban areas in Colorado. Her professional interests include Extension education and programming, community science, horticulture, entomology, and pollinator conservation.

*Jill Zarestky*, PhD, is an associate professor of Adult Education and Training in the Colorado State University School of Education. Her research interests focus on adult and STEM education and issues of conservation, sustainability, and globalization.

*Sarah Viders* is a J.D. candidate at the University of New Hampshire Franklin Pierce School of Law with an interest in environmental law. Sarah’s professional background includes internships with the New Hampshire Department of Justice's Environmental Protection Bureau and, during her time at Colorado State University, Native Bee Watch where she learned to identify Colorado's native bees and worked with community scientists.