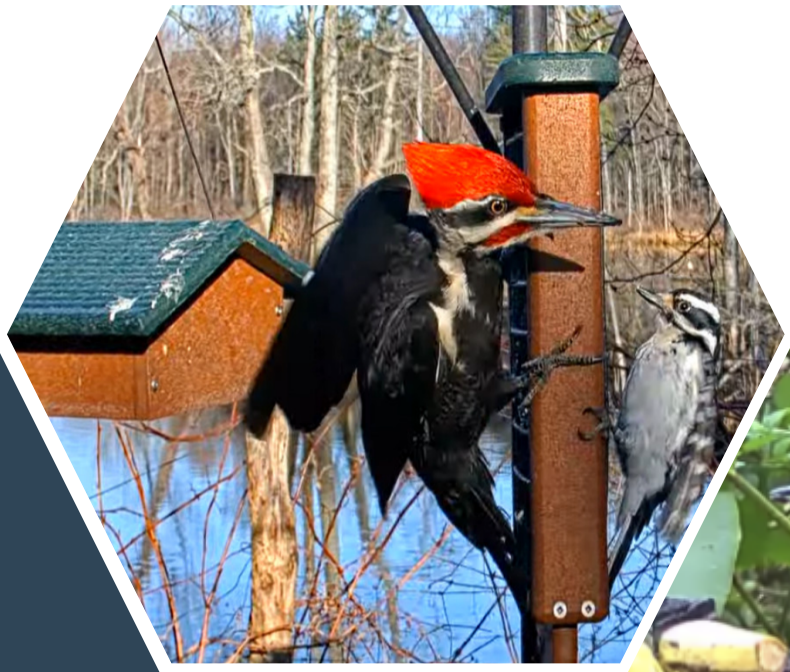

Rockman et al
Research & Evaluation
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FROM BIRD CAMS TO SCIENTIFIC INQUIRY:

Seeking greater understanding of experiences and outcomes that result from co-created scientific investigations

AUGUST 2021

ACKNOWLEDGEMENTS

We thank the thousands of participants who helped make Bird Cams Lab possible.

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EXECUTIVE SUMMARY

Millions of people around the world watch live streaming wildlife cams, but they aren't just watching: they are asking questions, trading information, and witnessing events that may be undocumented in the scientific literature. The goal of Bird Cams Lab was to design a digital space and framework enabling online communities to engage in a co-created scientific inquiry process utilizing wildlife cams to answer bird-related questions of common interest. To achieve this goal, the project engaged participants at every stage of the research process—including observation, generating and selecting research questions, collecting data, reviewing and discussing findings, contributing to data reports, and sharing results with others. In doing so, Bird Cams Lab provided opportunities for bird cam watchers to satisfy their own curiosities, become invested in stages of research that are usually reserved for experts, and bring their own perspectives and experiences to the table in scientific investigations.

Over the four-year grant period, there were a total of six co-created investigations. The first three were part of a formative phase wherein the project team, led by scientists from the Cornell Lab of Ornithology, developed and iteratively tested different formats and strategies for supporting co-created research with lay audiences in an online space. The next three investigations were part of a summative phase where more elements of the co-creation investigation were consistent, which enabled more standardized measurement of outcomes. The investigations focused on live streaming bird feeder and nest cams and a mix of live data tagging and coding of archived video footage. The final three investigations included **Hawk Happenings**: an investigation with live data tagging focused on a Red-tailed Hawk cam on Cornell University's campus, **Battling Birds Panama**: an investigation wherein archived video clips from a feeder cam in Panama were tagged using the Zooniverse platform, and **Cornell Feeders Live**: an investigation with live data tagging of video of a set of feeders outside the Cornell Lab of Ornithology.

The external evaluation team from Rockman Et Al provided timely feedback about participants' experiences and emerging outcomes during the formative stage that were geared toward informing the ongoing design and modification of Bird Cams Lab experiences. This was followed by comprehensive evaluation efforts during the summative stage, wherein the evaluation team collected and analyzed data about participation trends across the three final investigations—including an examination of data about which stages participants engaged in and how extensively they were involved in each stage within each investigation, pre- and post-participation surveys, and post-participation interviews with a sample of participants from each investigation. Ultimately data were collected from more than 16,000 individuals who engaged in some way with the final three Bird Cams Lab investigations—including at least 3,339 participants in Hawk Happenings, 9,026 in Battling Birds Panama and 11,758 from Cornell Feeders Live). While there was limited diversity in race, ethnicity, age, and education level within the participant group, there was noticeable diversity such that hundreds identified as disabled and/or homebound.

Motivations for Participation

Four overarching trends emerged in participants' motivations for engaging in Bird Cams Lab co-created investigation opportunities when prompted in interviews. These included participants who were simply happy to help out, participants who were motivated by the opportunity to contribute to science, participants who were curious about the co-creation process (these were often other STEM professionals, including informal science educators), and those who appreciated being part of a global community collaboratively engaged in these investigations. No matter their reason for participating, there seemed to be a common sense among participants that their contributions had benefited science or that there were personal benefits to participation—and very often, both.

Overall Engagement

About a quarter of tracked participants for each investigation were active contributors i.e., participating in the question design, data collection, data exploration and/or helping to report findings. In contrast, passive involvement in a given investigation was characterized by reading project emails and/or watching the cams but not contributing to question design, data collection, data exploration or reporting activities). While the Bird Cams Lab platform was designed to encourage participation across multiple stages of the investigative process, the vast majority of participants engaged in one stage of the investigation (i.e., across all three investigations, 82% of the active contributors participated in only one stage of an investigation). The data collection stage had the highest percentage of participation, (i.e., across all three investigations 57% of the active contributors tagged data for one or more study). However, due to the high number of participants overall, there were still hundreds of people contributing to most stages within each investigation, and there were dozens of participants within each investigation who participated in every stage of a given investigation.

The Role of Confidence in Engagement

We found that participants were more likely to engage in investigations (and stages of the research process within investigations) when they felt more confident in their knowledge and skills. Survey data for two of the three final investigations suggest that those with more bird and bird behavior knowledge at the outset of an investigation (as measured by a series of knowledge questions on the pre-survey) were more likely to be active contributors to those investigations. Interview findings shed light on instances where participants were more reluctant to participate during the question generation stage when they didn't feel that they had as much relevant knowledge to draw upon, and during the data collection stage when some feared that they might "mess things up." Most active contributors, however, had come to understand the data quality assurances that were in place to ensure that the resulting data sets would be valid even if there was not 100% accuracy in data tagging. Some participants indicated that their comfort engaging more actively in investigations grew over time, as they had opportunities to see the process unfold in its entirety and gained more confidence in their ability to make meaningful contributions.

Learning Outcomes

Not surprisingly, there were different outcomes among participants depending on the number of stages of a given investigation they had participated in and how extensively they had participated within certain stages. Bird knowledge was measured on the pre- and post-participation surveys for each of the final three investigations using a 9-question quiz that was customized for the types of birds and bird behaviors featured in each investigation. In contrast to passive participants, active contributors' bird

knowledge scores from the three final investigations had statistically significant increases from the pre-participation survey to the post-participation survey—and, on average, the more stages a participant engaged in, the greater the increase in bird knowledge scores. Active participants also had statistically significant gains in the average percent of "answerable research questions" they could correctly identify and there was a statistically significant increase from the pre-participation survey to the post-participation survey across the three final investigations among active contributors on self-reported familiarity with birds. More active contributors were also more likely to believe they could make contributions to the scientific study of birds and came to feel greater confidence in their ability to contribute to science.

Behavior Outcomes

Another goal of the Bird Cams Lab project was fostering adoption of certain behaviors related to birds and that help birds and the environment. For behaviors where people weren't already extensively engaged, there were statistically significant increases in the number of people taking actions that help to support and protect birds at their homes and in their communities or people making financial contributions to organizations that support birds, wildlife and environmental causes. Participants also noted greater interest in birdwatching and suggested that the experience of participating in Bird Cams Lab had an impact on their ability to identify and appreciate birds. Similarly, participants came to be more interested and curious about bird behavior, and that led to even greater appreciation of the birds they were seeing in the real world.

The Role of Co-creation

The project team supported co-created investigations as defined by Bonney et al. (2009), with the community of participants contributing to each stage across the scientific process, and at least some public participants involved in most or all phases. However, scientists on the project team were responsible for creating the framework and facilitating the process. Sixty-one percent of survey respondents noted that participants like themselves were supporting a research effort led by a team of scientists at Cornell, whereas 20% felt there was equal ownership and responsibility shared among scientists and lay participants, and 2% of survey respondents felt they had more of a leadership role within the investigations. Despite the fact there were limited numbers of individual participants engaging in every stage of a given investigation, and even though a minority of participants felt they had control or shared control of the investigations with the scientists, these research studies were co-creations of scientists and lay audiences insofar as a community of non-scientists was actively engaged along with scientists in every stage of the process. Furthermore, only 18% of survey respondents preferred a co-created process where community members and scientists decide on research questions together; two-thirds (i.e., 66%) didn't have a preference—either saying as much, or noting equal interest in investigations led by scientists and co-created investigations—and only 16% preferred scientist-led investigations.

Benefits of Co-creation

Among the advantages of co-created research for scientists, participants (including some STEM professionals) noted the fact that a co-created process can improve the quality of scientific research by incorporating different perspectives—including those of a variety of different STEM professionals—and also gives scientists a better sense of the public's interest. For participants, a clear advantage of co-created investigations was a greater sense of buy-in and, therein, engagement with and understanding of the scientific process. Participants noted that co-created projects enabled contributions from those

not traditionally engaged in some aspects of science. Insights such as these provide ample evidence into the benefits of co-created research as well as examples and indicators of best practices for effectively engaging members of the public in co-created research opportunities.

Insights for Practicing Co-Creation

One of the most valuable components of the study was surfacing insights that helped team members understand key factors needed to help make co-creation successful. Perhaps foremost among these findings was the importance of facilitation—specifically facilitation that helps to set a positive and encouraging tone for all participants, that provides timely and effective communication throughout an investigation, that encourages discussion and provides constructive feedback, and that helps to set appropriate constraints for investigations to help ensure that they are both feasible and have scientific merit.

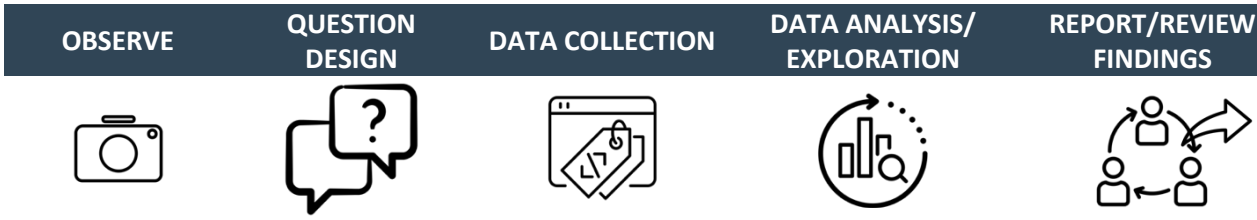
Implications from COVID-19

Even before the pandemic, participants were appreciative of the opportunity to engage in scientific research while doing something that they loved—i.e., observing the natural world. However, during the pandemic, the opportunity to participate in Bird Cams Lab took on even greater importance and seemed to have even greater significance in people's lives. Participants shared an abundance of anecdotes about needing something stimulating to do while they were away from work or experiencing lockdowns or social distancing that precluded their ability to interact more socially with others. A retiree who enjoys traveling noted that she'd missed getting to visit new places during the pandemic, but appreciated the fact she could virtually visit beautiful places like Panama as a result of participating in Bird Cams Lab. A family that wasn't able to get together physically during the pandemic found opportunities to connect with one another in a meaningful way through the common task of tagging data clips and discussing what they were seeing and learning during these investigations—it gave them something to talk about and something that they could still enjoy together. A caregiver who'd taken on the burden of looking after an immune-compromised loved one noted the fact that the Bird Cams Lab experience had equated to a therapeutic release from other daily responsibilities that had filled her life during the pandemic. Similar anecdotes about the powerful impacts of the Bird Cams Lab, and Bird Cams in general, experience pre-date the COVID-19 pandemic, but seemed to become more prevalent in the later years of the project when work and life patterns were disrupted and social-distancing was the norm.

INTRODUCTION

Bird Cams Lab[1] was a four-year project led by the Cornell Lab of Ornithology that sought to engage people from around the world in co-created research projects centered on Bird Cams. Funded by a National Science Foundation: Advancing Informal STEM Learning grant, Bird Cams Lab sought to go beyond the scope of most citizen-science projects by inviting participants to take part in all steps of the scientific process, moving from observation to question generation and refinement, to collecting data, and culminating with the analysis of data and reporting of findings.

Figure 1. Stages of Bird Cams Lab Investigations



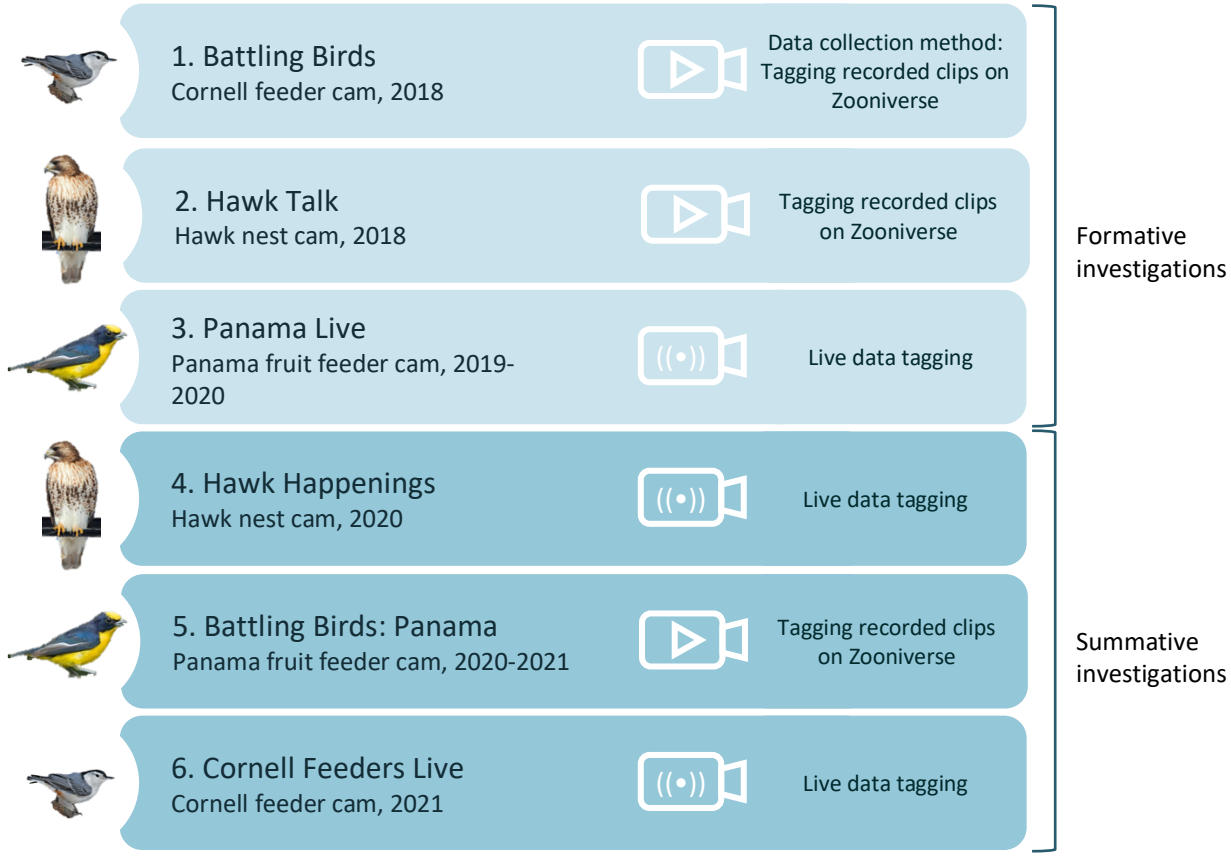
Over the course of this project, thousands of participants engaged alongside scientists in six investigations, each with its own research focus. Along the way, the Bird Cams Lab team developed a wealth of experience and understanding about the best ways to engage informal online learning communities in co-created research, while also investigating how these projects affected participants in terms of bird knowledge, interest and enthusiasm for scientific research, and confidence in their skills related to birds and science.

This report presents findings from the summative evaluation of the project, conducted by external research partners at Rockman et al. While this report will reference the three formative studies during which techniques and tools for effectively engaging lay audiences in the co-created process were developed and refined, its primary focus is the three final investigations that made use of the knowledge gained from the preceding investigations.

The Bird Cams Lab investigations focused on three cams— the Cornell Feeder Cam, Cornell Hawk Cam, and Panama Fruit Feeder Cam. For some investigations, participants watched the cams live and recorded observations through a web platform developed by the project team. For other investigations, participants watched and tagged pre-recorded clips from the cams through Zooniverse – a citizen-science website (see Figure and Figure below).

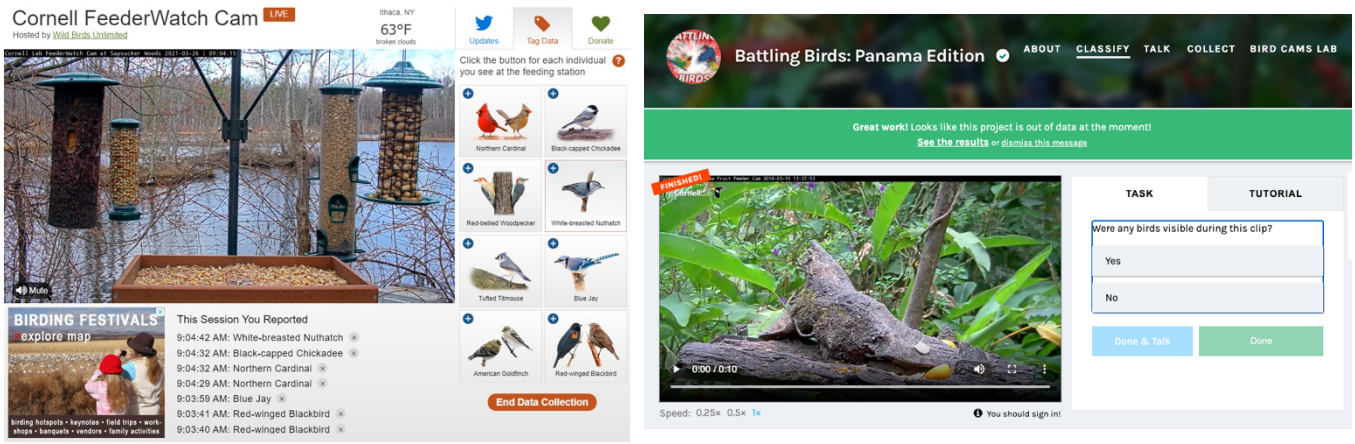
[1] Full grant title: *Co-Created Science and Discovery with Live Bird Cams: Designing an Online Collaboration System for Community Learning*

Figure 2. The Six Investigations of Bird Cams Lab



[2]

Figure 3. Live data tagging on Bird Cams Lab website (left) and recorded clip tagging on Zooniverse website (right)



[2] Image credits: White-breasted Nuthatch by Ryan Schain, Thick-billed Euphonia by Dorian Anderson, Red-tailed Hawk by Alex Lamoreaux, Macaulay Library

Methodology

Formative Evaluation

The formative evaluation included analysis of data on participation. At various stages, participant interviews focused on formative feedback but also enabled exploration of emerging outcomes. Additionally, non-standardized participant surveys sought to measure appeal and emergent outcomes but also fostered iterative design of more standardized surveys that could be used during the summative stage.

Efforts in the first half of the grant to develop, test, and iteratively modify evaluation instruments as well as efforts to iterate on the co-creation facilitation process ultimately resulted in more standardized processes for running co-created investigations as part of Bird Cams Lab, as well as more standardized methods to assess outcomes and impacts. Greater standardization of the co-creation process and the instruments used to measure impacts and outcomes among participants subsequently enabled greater comparison across the final three investigations.

Summative Evaluation

During the summative stage of the project (the three final investigations), a team of evaluators from Rockman et al sought to answer the following evaluative questions:

Summative Evaluation Questions

1. To what extent are the experiences of participants who engage in the research experiences similar to and different from those Bird Cams viewers who do not engage in research experiences?
2. To what extent are the experiences of participants who engage in multiple Bird Cams Lab investigations similar to and different from those who participate in only one investigation?
3. To what extent are the experiences of participants who participate in multiple stages of the scientific process different from those who participate in only one stage?
4. To what extent are the experiences of participants who engage more extensively in one or more stage of a research experience similar to and different from those of participants who participate less extensively?

Participant Surveys

Pre- and post-participation surveys for each summative investigation incorporated a standardized set of questions to facilitate comparison across investigation experiences. These surveys had only slight variations in content-knowledge questions based on the specific birds and bird behaviors being studied in each investigation. They also contained questions that addressed participants' behaviors related to birding and science, their confidence related to knowledge of birds and scientific research, their interest in various stages of a scientific investigation, and their perspective on the co-creation process.

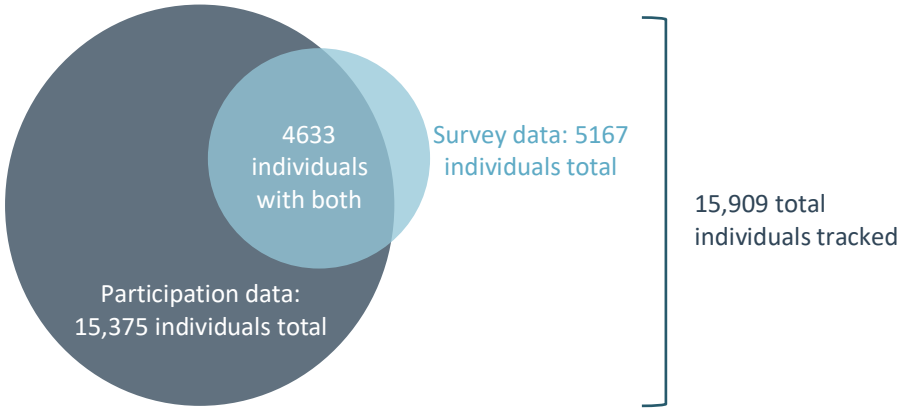
Participation Interviews

Evaluation efforts during the summative stage of the project also included three rounds of participant interviews—one for each of the summative investigations, for a total of 38 interviews—and pre- and post-participation surveys. Interviews were conducted shortly after the conclusion of the Hawk Happenings investigation, as the Battling Birds Panama study was wrapping up and after the data-collection stage had been completed for Cornell Feeders Live.

Participation Data and Analysis

An extensive set of participation data was also compiled. This data set provided greater understanding and fostered insights about when and how participants had engaged with various Bird Cams Lab investigations. The participation data were used to characterize participants' involvement in terms of breadth, intensity, and number of investigations as described above under Research Questions. The data were gathered from a variety of sources, including but not limited to newsletter subscriber lists, webinar registrations, discussion board comments, and website login information. In total, 15,909 individuals were tracked, either via their participation data (available for 15,375 individuals), survey data (available for 5,167 individuals), or both.

Figure 4. Data available on Bird Cams Lab participants



Whenever possible, we used actual participation data as gathered through various platforms rather than self-reported participation from surveys. Information on whether participants watched the cams or shared the research findings was only available through self-report, however.

Participant Profile

Participant Numbers

A key philosophical question for the Bird Cams Lab project was defining participation and characterizing the different ways that individuals chose to engage. A larger discussion of participation trends can be found below (starting on page 17). Here, we present a profile of all Bird Cam Lab participants, including those who were active contributors in the scientific process and those who played a more passive role (See page 18 for additional information on how passive and active participation were defined). As noted above, almost 16,000 individuals took part in the summative investigations in some capacity.

Figure 5. Participant Numbers for Summative Bird Cams Lab Investigations

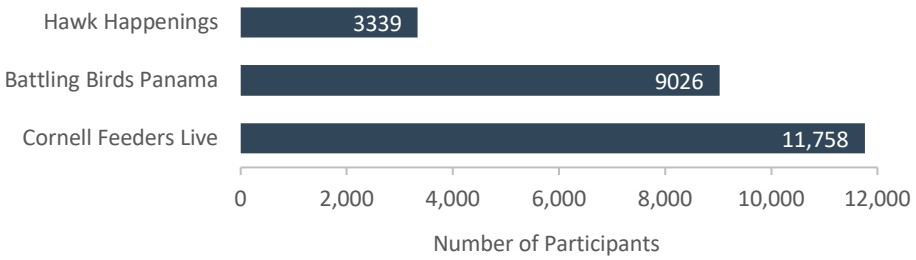
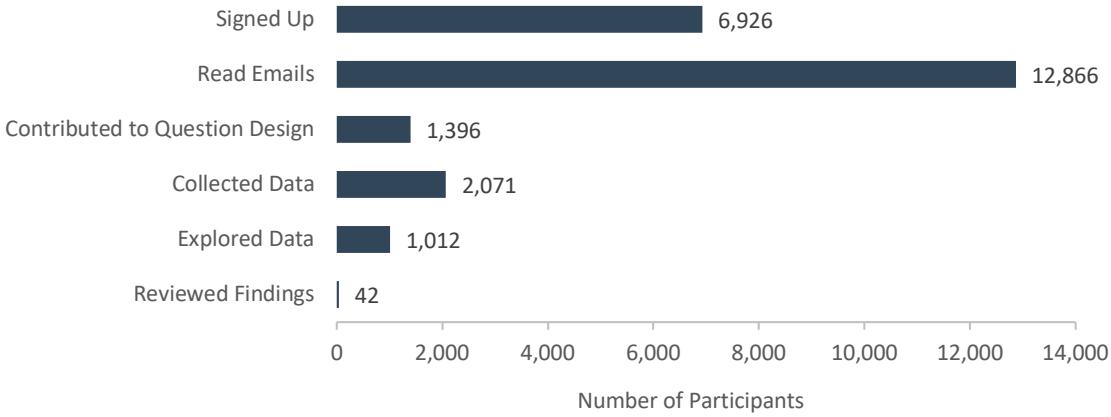


Figure 6. Participation by Investigation Stages



Participants could "sign up" for project investigations via the Bird Cams Lab website or by completing a pre-survey, but they could also contribute to project activities without completing this preliminary step. Data from the Bird Cams Lab messaging software also shows that almost 13,000 subscribers read Bird Cams Lab emails, although most of these individuals did not become active contributors to the investigations.

Recruitment

Bird Cams Lab participants were recruited largely from the Cornell Lab of Ornithology's existing mailing lists. Participants answered demographic questions on pre- and post-surveys, and their earliest demographic responses were used to compile the data shared here, representing approximately 4,000 participants.

Participant Demographics

Among participants who completed surveys and answered demographic questions, 75% were female, 67% were 55 or older, and 89% were white. Participants also tended to be well-educated, with 72% holding a bachelor's degree or higher. These numbers were fairly consistent across investigations through the Bird Cams Lab project.

Figure 7. Participants' Gender (n=4166)

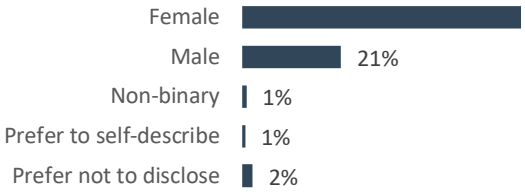


Figure 8. Participants' Ages (n=4007)

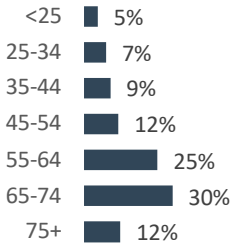


Figure 9. Participants' Race/Ethnicity (n=2419, participants could choose more than one)

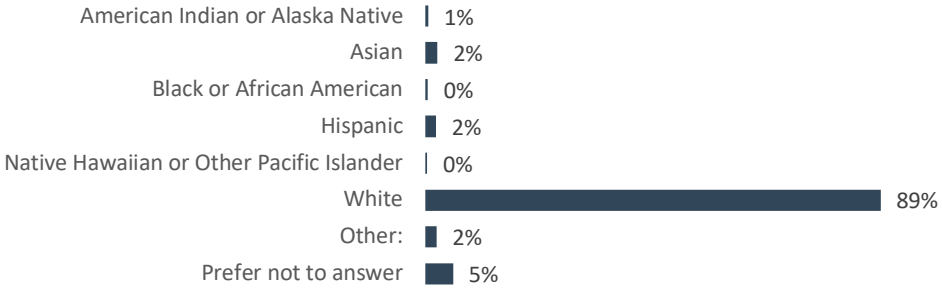
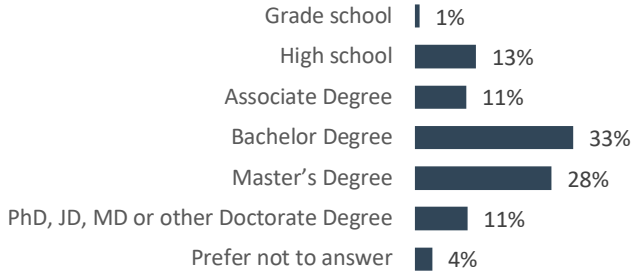


Figure 10. Participants' Education Level (n=4174)



Participants' Professional Backgrounds

Equal percentages of participants were working and retired (45%). We also saw a high percentage of participants report working at home, likely due to the Covid-19 pandemic. While we did not ask participants directly about this in our surveys, many commented on this fact in their open-ended responses, e.g., *"As most everybody else in the planet, working on a reduced shift currently due to COVID,"* and, *"On part time short term due to Covid 19 but generally full time."*

PARTICIPANT INSIGHTS

"Even though I'm a grandma, I can still learn things…I'm just trying to be as helpful as possible and try to learn a little bit more science-wise and bird-wise." (HH11)

Figure 11. Participants' Work Status
(n=4073, participants could select more than one)

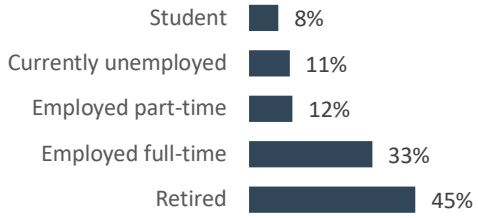
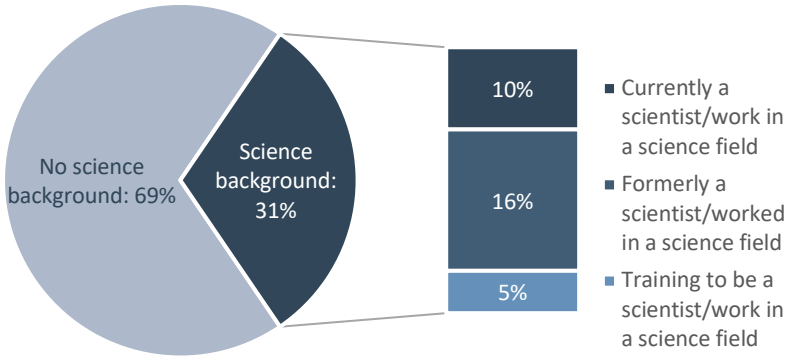


Figure 12. Participants' Work Location
(n=1625)

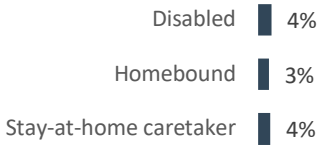
Figure 13. Participants' Science Backgrounds
(n=4137)

Slightly less than a third of participants had a science background—either currently working in a scientific field, having previously worked in a scientific field, or currently training to work in a scientific field.



There were also 435 individuals who reported being disabled, homebound, or stay-at-home caretakers. While these participants make up only about 10% of the overall sample of survey respondents, their experiences underline the importance of citizen-science activities that can be done by a variety of audiences. Interview findings suggest that Bird Cams Lab participation, and bird watching in general, can have special impacts on people who are homebound—including a greater sense of their ability to learn and actively make contributions to science.

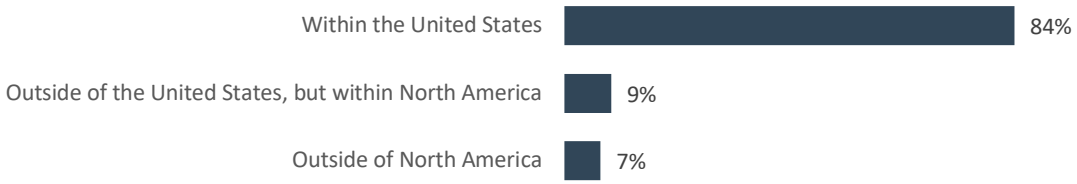
Figure 14. Additional Participant Characteristics
(n=4199)



Participants' Location

There were Bird Cams Lab participants from all over the world. While the vast majority of Bird Cams Lab participants were located within the United States, there were also notable numbers of international participants (16% of participants, n=648). Participants frequently noted that the global nature of the Bird Cams Lab investigations was an appealing element.

Figure 15. Participants' Locations
(n=4169)

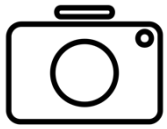
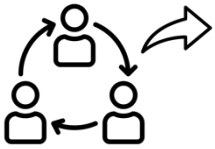


PARTICIPANT TRENDS AND ENGAGEMENT PATTERNS

Participation Stages

While no two Bird Cams Lab investigations were exactly the same, the three final investigations followed the same basic path as illustrated in the diagram below. Participants were invited to take part in co-creation throughout the scientific process, from observing the cams to editing the final report. Individual stages of the investigations often had multiple ways to get involved (e.g., attending a webinar and commenting on a message board). The stages also had different forms of involvement for lay participants and scientists. At times, scientists took a leading role (as in analyzing the data collected). The Bird Cams Lab team, however, invited participant involvement and feedback throughout the entire process.

Figure 16. Outline of Steps and Stages of the Bird Cams Lab Investigative Process

OBSERVE	SIGN UP	QUESTION DESIGN	DATA COLLECTION	DATA ANALYSIS/ EXPLORATION	REPORT/REVIEW FINDINGS
					
Cam Observation Thousands of participants watched Bird Cams before participating. Others joined without prior cam-watching experience. ◎ ◆	**Promote Investigation Opportunity** Scientists reach out to potential lay contributors and invite them to participate. ◆	**Submit Questions** Participants are invited to contribute ideas for research questions that could be answered through observations with Bird Cams. ◎ ◆	**Platform Design** Scientists set up an online data collection platform tailored to the research question. ◆	**Data Analysis** After data tagging is complete, scientists analyze data and produce interactive visualizations. ◆	**Report Creation** A member of the Bird Cams Lab team writes up findings from the investigation. ◆
	Sign Up Cam Watchers and citizen scientists are invited to take part in a scientific investigation around a particular bird cam. ◎	**Discussion** Dialogue about potential questions takes place on Disqus forums and webinars. ◎ ◆	**Data Collection** Participants collect data by "tagging" archived video clips or live streaming Bird Cam feeds to note types of birds and bird behaviors. ◎ ◆	**Data Exploration** Participants are invited to view, interact with, and discuss the visualizations and can ask questions, make comments, and engage in dialogue with scientists and other participants. ◎ ◆	**Report Review** Participants are invited to review the report, providing comments and recommendations. Their feedback helps ensure accessibility for broader audiences. ◎ ◆
KEY: ◎ **Lay Participants** ◆ **Scientists**		**Question Voting** A short list of questions (and/or relevant variables), is presented by scientists for participants to vote on. ◎ ◆		**Data Request** Participants could also request raw data to work with independently. ◎	**Sharing Findings** Participants and scientists spread the word about what they learned through the investigation. ◎ ◆
	PRE-SURVEY		**POST-SURVEY (CFL)**		**POST-SURVEY (BBP/HH)**

Active vs. passive styles of engagement

The Bird Cams Lab team considered everyone who engaged with the project – whether by reading Bird Cams Lab communications, viewing the cams, or taking a more active role in the investigations – to be a project participant. The team posited, however, that engagement in more stages of the scientific process would lead to greater impacts on participants. They also predicted that engagement in multiple investigations and deeper involvement in a single phase of an investigation could lead to greater impacts on individuals' outcomes.

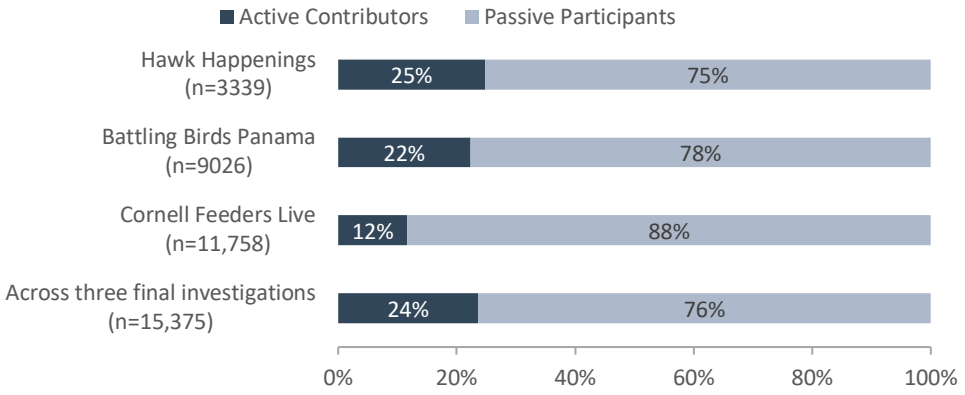
To begin making sense of how nearly 16,000 individuals engaged with the three final Bird Cams Lab investigations, we began by dividing them into "active" and "passive" participation categories. We defined **active contributors** as those who participated in at least one of the four main stages of the scientific process: question design, data collection, data exploration, and reviewing findings. Those who only read emails or self-reported that they only observed the cams were classified as having **passive involvement** and were used to run comparative analyses.

PARTICIPANT INSIGHTS

Do you think you got more out of the experience by having participated in some of those extra steps that probably had fewer participants, than those who are really focused more on some of those early stages exclusively?

"Yeah, I would say, so. I think from being able to be involved from beginning to end if I compare my experience with the Battling Birds to my experience with the Hawk Happenings where I was just there from the data collection onwards, I feel like it was a much more rounded experience, and I feel much more engaged and attached to it, if that makes sense…I definitely felt like it was a fuller experience, and I felt more motivated after being part of this process. I felt a sense of self-obligation, not any pressure from the scientists, but self-obligation to continue forward and going through all the steps, and I felt more motivated…each step of the way." (HH6)

Figure 17. Active Versus Passive Engagement



Although the percentage of active contributors to Bird Cams Lab is lower than that of participants who were more passive, it still translates to more than 3,600 individuals across the three final investigations. The following quote illustrates how one participant perceived the difference between active and passive participants.

PARTICIPANT INSIGHTS

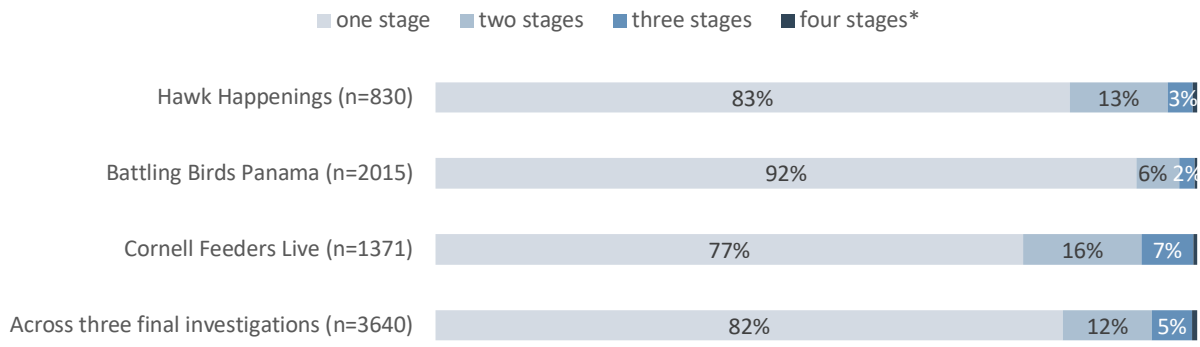
"It felt like there were there were a key group of maybe 20 people…that were talking. Not the same people from investigation to investigation, per se, but that were engaged in the conversations…Then there was sort of another group of people that were less engaged…But overall, I felt that there was a lot of participation on both sides and it was nice to have direct responses from the scientists to questions that maybe weren't going to be directly studied, but that were still valid to think about, and to discuss further…It felt like the people that were engaged were very engaged, and then there was that second subset of people that were just sort of looking around and kind of posing random questions." (HH6)

Breadth of Participation

It is both a distinguishing feature and persistent challenge of informal science learning that participants can opt in or out of experiences based on their availability and interests. With that in mind, the Bird Cams Lab team designed investigations with a modular framework that enabled participants to join in one or more activities, or participate throughout. Participation in every stage of a given investigation was possible, but not required.

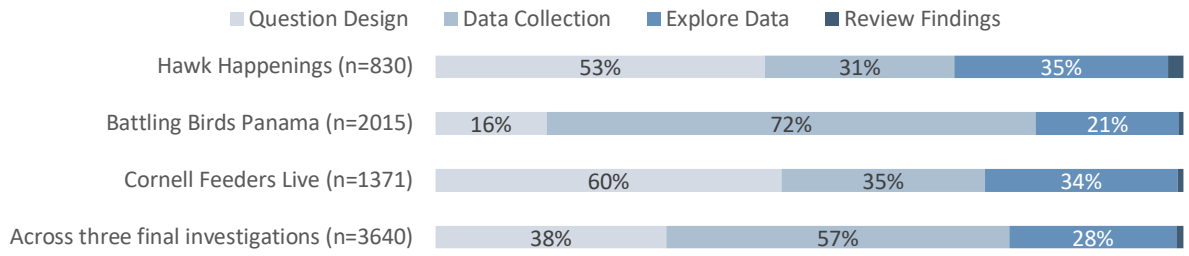
While a few participants were involved in every stage of the scientific process, many more took part only in certain parts of the investigations. Many people opted to follow along the project in a passive way (see Figure 16). Among active contributors to the investigations, the dominant trend was to take part in just one of the four main scientific stages.

Figure 18. Participation Breadth – Number of Stages of the Scientific Process Participants Took Part In (active contributors only)



* Those who participated in all four stages of the scientific process represent 1% or less of active contributors.

Figure 19. Participation in Four Main Stages of the Scientific Process (active contributors only)



* Those who Reviewed Findings represent 3% or less of active contributors.

Participation in the four stages varied by investigation. For example, Battling Birds Panama saw particularly high participation in the Data Collection stage, because this step was hosted through Zooniverse – a citizen-science website that reaches large audiences beyond the usual Bird Cam viewers who follow the Cornell Lab of Ornithology. Overall, 42 individuals took part in the reporting process by reviewing findings and providing feedback on draft manuscripts for publication. While this was a small number in comparison to the thousands who participated across the lifespan of this project, it was an impressively-sized group of uniquely engaged contributors nonetheless.

Given the varied entry points for the participation, it is understandable that some participants may not have fully understood the unique nature of these investigations in that they went beyond having participants contribute by collecting data. There are, of course, subtle but important differences between doing the research together versus *creating* the research together. The Bird Cams Lab team embraced the variety of ways people chose to participate in the project. However, because they felt it important for participants to see how their own effort fit into the co-created process, messaging about the meaning of co-creation and how the community was sharing the "driver's seat" was ultimately emphasized.

Depth or Intensity of Participation

In addition to there being variation across stages of an investigation, there was variation within each stage in terms of the depth or intensity of engagement. Bird Cams Lab participants were given multiple ways to take part in a particular step of the scientific process. For example, a participant could participate in question design by suggesting and discussing questions on a message board, attending a webinar on question design, and/or voting on a set of questions via a survey. Participants were assigned intensity scores for three stages of the scientific process: question design, data collection, and data exploration (see table below for intensity rating criteria).

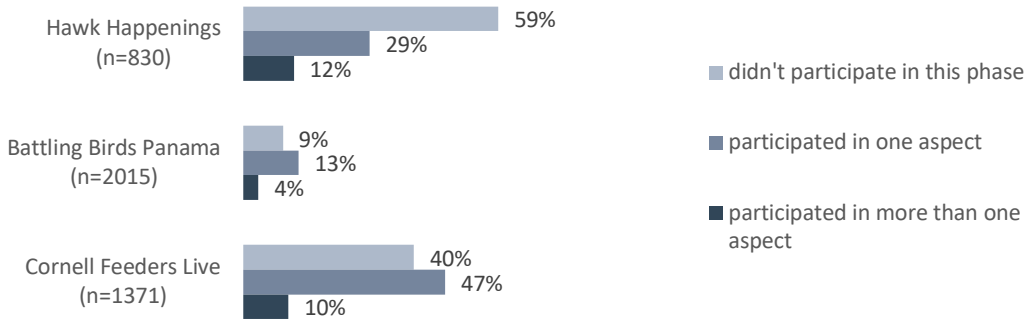
Figure 20. Methods for Characterizing Participant Intensity by Investigation Phase

INVESTIGATION PHASE	METHOD FOR CHARACTERIZING INTENSITY
Question Design	• Participated in one aspect vs. more than one aspect of this stage
Data Collection	• Participants divided into four quartiles based on the number of observations they had made/videos they had tagged
Data Exploration	• Participated in one aspect vs. more than one aspect of this stage

Question Design Phase

Participants could take part in the Question Design phase by contributing comments on the Bird Cams Lab forums, upvoting or downvoting others' comments, attending webinars focused on question design, or voting by survey. Overall, almost half of active contributors took part in at least one aspect of question design, and 14% took part in two or more.

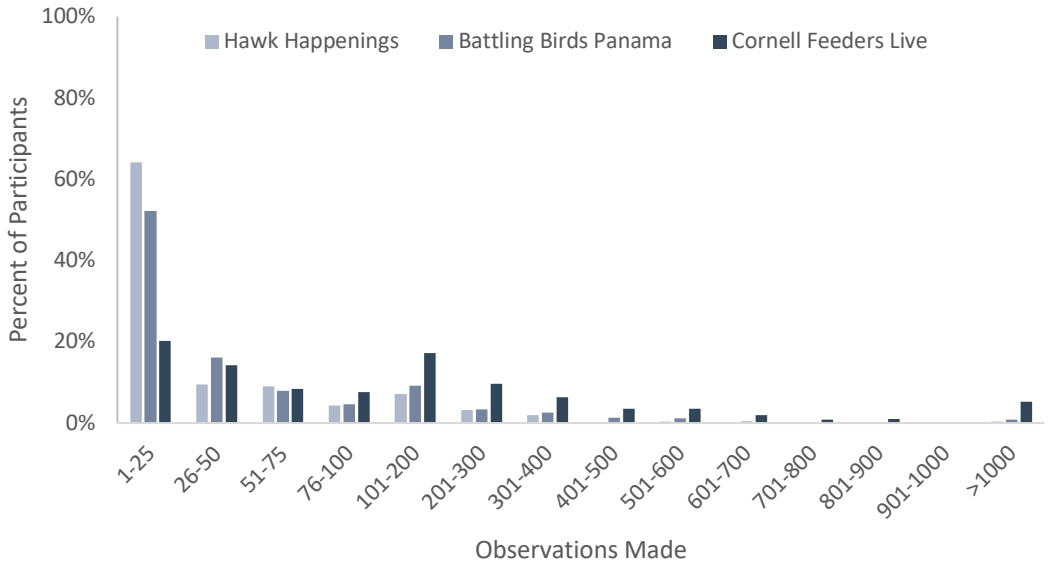
Figure 21. Question Design Participation
(Ns represent active contributors)



Data Collection Phase

Data collection for the three summative investigations looked slightly different from one investigation to the next. In the Hawk Happenings and Cornell Feeders Live investigations, participants recorded observations while watching a live Bird Cam. In the Battling Birds Panama investigation, participants tagged recorded video clips hosted on the Zooniverse website. Compared to the feeder cams, where there are birds visiting frequently throughout the day, participants watching the hawk nest cam for Hawk Happenings experienced larger periods of inactivity due to the more sporadic nature of bird behavior at the nest. As a result of these factors (nest vs. feeder cam, live versus archived data collection), the amounts of data participants contributed in each investigation varied. The quantity of participants' observations/data tags was used to split them into quartiles that represent the intensity of their data collection. For Hawk Happenings and Battling Birds Panama, the majority of participants provided 1–25 observations. Cornell Feeders Live participants tagged far more data, with 50% logging 100 observations or more. The most dedicated Cornell Feeders Live participants collected upwards of 3,000 observations.

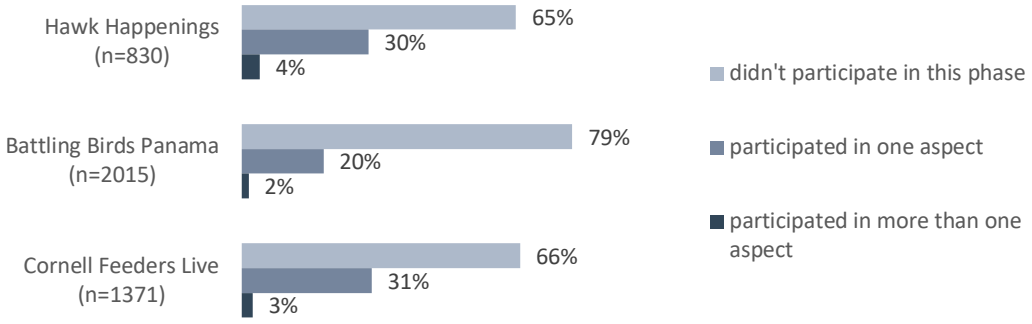
Figure 22. Observations Made During Summative Investigations



Data Exploration Phase

In addition to looking at and commenting on data visualizations and requesting raw data for analysis, participants could also take part in the Data Exploration stage by attending a webinar where preliminary investigation findings were presented. While many participants engaged in one aspect of Data Exploration, very few did so in more than one way.

Figure 23. Data Exploration Participation During Summative Investigations
(Ns represent active contributors)



Factors That Influenced Participation

General interest seemed to be a consistent factor among those who opted to participate in Bird Cams Lab investigations. However, there were also additional factors that seemed to influence the breadth and depth of participation, including:

- Comfort levels resulting, in part, from participants' knowledge about birds and/or science and familiarity with the Bird Cams Lab co-creation process,
- Available time to participate (or lack thereof), and
- Prior science, birding, and bird-related experiences.

Participant knowledge and comfort

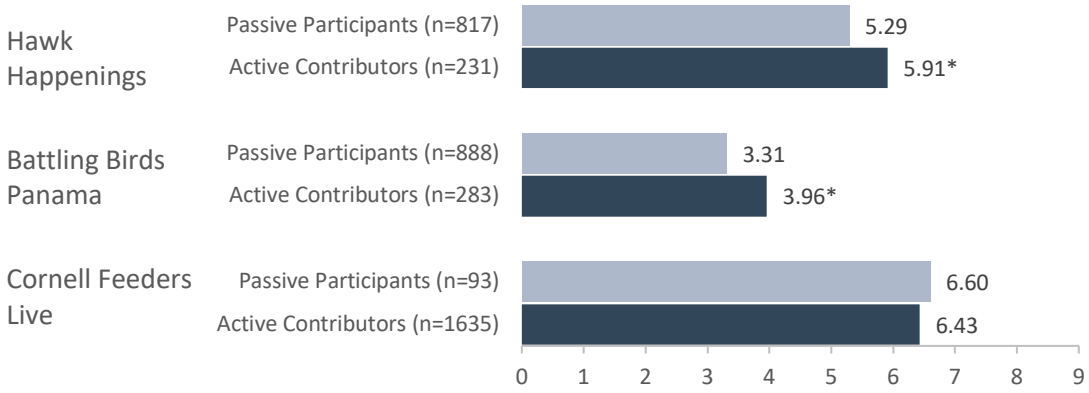
Whether it was general scientific knowledge or knowledge related to a specific cam or type of bird or bird behavior, there were instances where participants' lack of knowledge could inhibit their willingness or ability to participate.

> *"[It is] harder to be as fully engaged in [a] co-creation process when a participant is not as knowledgeable about the cam or birds being targeted." (CFL1)*

Survey data suggests that incoming bird knowledge (or a lack thereof) can sometimes be a barrier to participation. Despite telling participants that those with all levels of knowledge are welcome in Bird Cams Lab, those with lower scores on the bird knowledge quizzes for Hawk Happenings and Battling Birds Panama were less likely to continue on to become active contributors to the investigations.

This was not the case, however, for the Cornell Feeders Live investigation. This investigation was unusual, in that most of the pre-survey respondents went on to become active contributors to the project. The active contributors and passive participants did similarly on their pre-survey bird quizzes, with no significant difference.

Figure 24. Differences in Incoming Bird Knowledge – Active Contributors versus Passive Participants



*indicates statistically significant differences in average correct knowledge scores (out of 9 questions) on pre-survey (*p<0.05*)

Familiarity with certain types of birds or bird behaviors or the scientific process in general was also noted as a factor that influenced participation by interviewees.

> *"I'm not a birdwatcher but I enjoy watching birds. Others were more knowledgeable, so I sat back and went along with it." (CFL3)*

"I do believe some people would be intimidated by scientists, but I have experience enough to not be intimidated." (CFL5 p8)

During the question generation stage

Some participants explained how their lack of knowledge was a factor that limited their participation in the question generation phase insofar as participants sometimes hesitated from contributing questions in instances where they felt their knowledge level was less than that of other participants. When asked what their initial level of comfort was in doing investigations along with scientists, one participant said *"I wasn't too comfortable with that. I was fairly certain that the things that I might have been wondering about might not have been important to the bigger picture." (CFL10)*

Another participant doubted the ability to answer the questions they had: *"Sometimes the questions that would come to my mind, I didn't necessarily feel lend themselves to quantifiable data. So I did not actually put up questions on the Wonder Board but I did read it, and I did once other people had put them up. I did vote on it." (HH7)*

In addition to not thinking that their questions had merit, some participants were afraid of embarrassment.

"[I] don't want to put a question in where people were like 'what was this guy thinking?'" (BBP5)

"I'm someone that can be socially anxious, so sometimes I post my question and then afterwards. I'm like, 'Oh my gosh why did I do that?'…like that's such a stupid question someone else asked that. But as I went along, I realized that there's no real stupid questions, and that I felt reassured as I went along, I would say. It felt like that was a real aim as well, was to make sure that people didn't feel alienated by a lack of experience in that way." (HH6)

During the data collection stage

There was some hesitation stemming from a lack of bird-related knowledge during the data collection phase as well; participants wanted to make sure they were submitting accurate data, but most realized that the collaborative and redundant nature of data collection meant that it wouldn't ruin things if they occasionally tagged something incorrectly. Likewise, the support of Bird Cams Lab facilitators helped to assure participants at all levels of knowledge or experience that their help was welcomed and that they wouldn't mess things up.

"[I had] more trepidation than I had anticipation…wondering if my skill set would allow me to be a good participant. I hesitated several days – sat and watched...I wasn't sure which [woodpecker] was which...I practiced in my head and after a couple days felt I could get in and tag." (CFL10)

"If I didn't think I was able to do it accurately I probably wouldn't have continued participating because I would have felt like it wasn't helping." (BBP1)

"If there wasn't a way to qualify that I was unsure about it, I might not have gone through so many clips, but I think that the fact that there was a way for me to say 'hey I'm not quite sure about this,' it kept me continuing going forward because I knew that there was a sort of a backstop there to make sure that this wasn't being counted as a 100% fact or something." (HH6)

Even though they knew they weren't going to mess up the investigation, some participants noted that they were more comfortable participating when there was a greater familiarity with the cam or the types of birds being investigated.

> *"I think that because I knew the birds, the eight birds we were looking for [in CFL]. I was comfortable with that set of birds. It made it so that I could participate as much as I wanted to." (CFL8)*

One participant noted that they'd been more hesitant to contribute in the Battling Birds Panama investigation because they didn't have as much experience with that cam or knowledge of the birds that come to that feeder. When it came to her confidence to participate in Cornell Feeders Live, they explained that they were: *"more assured of myself...more confident. With [BBP] I was so terrified I'd make a mistake." CFL1 p2*

During the analysis and reporting stages

Interviewees also voiced hesitation to participate in the analysis and reporting stages of the investigation in some instances on account of a lack of knowledge and subsequent lack of comfort in doing so. On the other hand, having more knowledge about the birds being studied, birds and bird behavior in general and/or the scientific process led other participants to feel more comfortable participating in various stages of the investigation.

More information about factors that may have contributed to participants' willingness and perceived ability to participate in different stages of the investigations are included in Appendix B.

Gaining comfort over time

Despite instances where participants felt they lacked the requisite knowledge to participate initially, some noted that their comfort participating more fully in investigations had grown over time. And others indicated that they expected their comfort with participating would grow over time.

> *"So by, you know, 10, 12, 15 clips. I was like okay that's this guy and you know, 'Oh I know that one.' Definitely as my confidence level rose it was a lot easier to, you know, click my response and send it in…knowing that it was pretty accurate." (HH11)*

> *"I was an arson investigator, and you know sometimes we'd have to go in and do a little bit more, you know, digging around and more specific stuff but it was pretty cut and dry. But with this, there was so many other facets, because yeah there was a displacement, but what were the birds that were involved in displacement, you know, time of day, and stuff like that…so it was interesting because the first couple of ones…I probably took me 15 minutes to get everything, and then the more I did the better I got [at] it." (BBP5)*

> *"I was definitely more comfortable doing Cornell Feeders Live after doing Battling Birds Panama and getting my feet wet on that project...[I] understood what they were looking for...understood the process the second time around." (CFL10)*

> *"I gained confidence participating over time because...I came to understand that ...nothing was all on my shoulders. If I couldn't ID something, the project wasn't going to fail...the bird wasn't going to die." (CFL2)*

"I think if I was doing one again…some of the things about coming up with the questions and stuff I might feel more confident. I guess that's the part that made me feel afraid the phrasing of how to make the scientific question about, you know, coming up with the way to. I mean, that's my science [background] that got in the way of letting me just say what I was thinking. I didn't want to sound foolish, which is dumb because nobody would have made me feel foolish. But that was the beginning, you know, so it's when the whole thing started….'we're looking for people to come up with the question,' I wasn't 100% sure what they really meant." (BBP9)

Timing and availability of time

Participants noted that their participation was influenced more by the availability of time (or lack thereof) than any other factors. Most noted that they would have participated more if more time had been available and some noted that they had participated more because they happened to have more time on their hands. (Note: we'll talk more about the impacts of the pandemic on people's participation experience in a later section).

"I will say I was a little bit more distracted with other things like in my life going on so I didn't participate as heavily in that one as I did with, like the Hawk Talk or the Battling Birds." (HH5)

Participants also appreciated the fact that they could often squeeze participation into short periods of time or use participation as an opportunity to take a break from other tasks.

"One of the things that appealed to me is that it was very flexible. I could just sign on at any point, and spend 15 minutes. Like, for lunch break, whenever I had time I wanted to take off from working on my other stuff…it became a relaxing thing to do during the day so kind of this break especially during the last year, it became very nice whether I was counting birds, or just watching the cams, you know, it was kind of a ritual to disconnect from doing what I usually do to give something completely different." (CFL6)

"Totally gets my mind off of school...I'm going home and I'm going to stare at some birds. It's something that I like to do that I think has value. I'm happy to be a part of it." (BBP3)

"[You] can do it for 1 min or 30 minutes, no time requirement. There were months where I had it up on computer—when stopping to fix coffee I would do 2 clips and then move on." (BBP1)

Time of year was a related factor insofar as some participants were more inclined to participate during times when weather was not conducive to doing things outdoors.

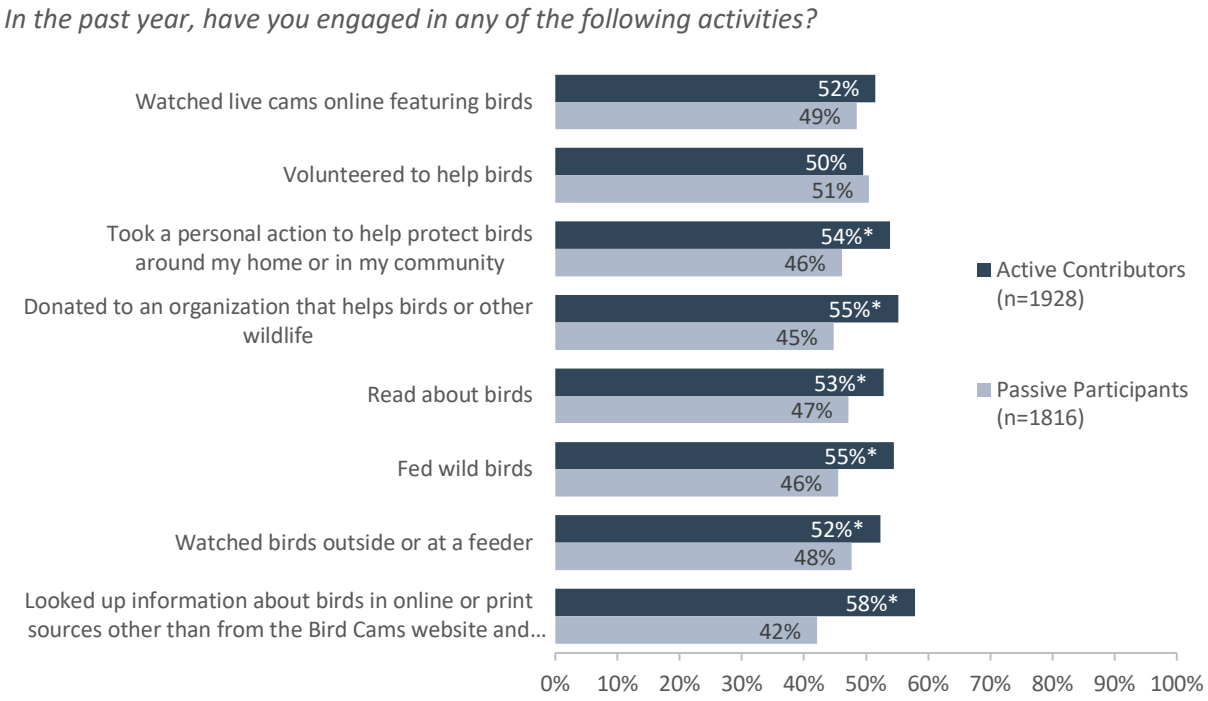
"So for me the winter indoor thing is…it's a huge thing and I was really looking forward to it." (HH12)

Timing was also a factor in when participants started to participate. In some instances, participants got started after the question generation stage simply because they didn't learn about the investigation until after that stage had been completed.

Prior science and bird-related experiences

Since Bird Cams Lab participants were largely drawn from the existing watchers of Cornell's Bird Cams, it is therefore not surprising that many were already enthusiastic birders or engaged in a variety of other bird-related activities. Those who went on to be active contributors to the Bird Cams Lab investigations reported having taken part in a wide range of birding activities on their pre-surveys. These prior experiences and activities ranged from watching live cams, to feeding birds, to donating to organizations that help birds or other wildlife. Those who went on to become active contributors in investigations were more likely to report having engaged in a variety of activities involving birds in the past year in comparison to those who engaged in more passive ways.

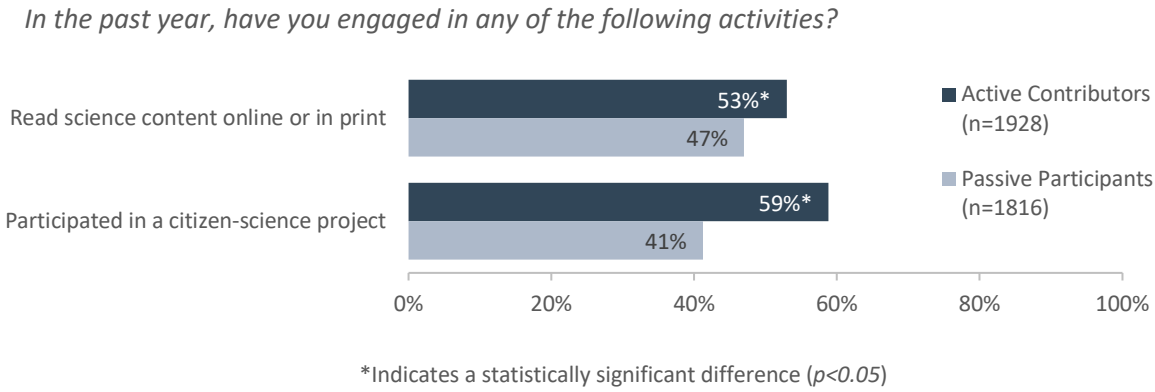
Figure 25. Birding Behaviors Reported on Pre-Survey – Active Contributors versus Passive Participants



*Indicates a statistically significant difference ($p<0.05$)

Survey respondents who went on to become active contributors in investigations were also more likely to report having read science content in the past year and having participated in a citizen-science project, suggesting those that are slightly more science-minded may be more comfortable or more motivated to take part in this type of co-created research project. Interestingly, participants' engagement did not seem to be related to whether or not they work(ed) in a scientific field.

Figure 26. Science Behaviors Reported on Pre-Survey – Active Contributors versus Passive Participants



*Indicates a statistically significant difference ($p<0.05$)

Patterns of Participation

In addition to measurable knowledge and behaviors that influenced participation, interviews enabled us to explore unique motivations for participating in Bird Cams Lab investigations. Participants' responses to questions about their motivations for participating resulted in four main categories of participation styles and preferences:

- **Participants who were simply happy to help:** This category included individuals who were eager to do whatever they could in whatever time they had available to help scientists. This happiness, for some, stemmed from having something intellectually stimulating to do—especially during the pandemic.

- **Participants who were motivated by the ability to contribute to science:** People in this category had a strong passion for science and were attracted by the opportunity to do scientific research and contribute to science. Some had trained to be scientists or had once been scientists—so their participation offered opportunities for fulfillment or continuation of what they considered to be a calling.

- **Participants who were curious about co-creation:** This category includes participants who were intrigued about the co-created nature of Bird Cams Lab investigations. The opportunity to do scientific research alongside scientists was a motivating factor for participants in this category. There were also several individuals who indicated that their curiosity stemmed from specific professional or volunteer interests (including people in various STEM and STEM-ED careers, e.g., zoo or park-based educators, and various types of scientists).

- **Participants who appreciated the sense of community:** This category includes participants who enjoyed the sense of community that they got from participating in Bird Cams Lab.

Note: There were many instances where participants fell into two or more categories, and a few expressed comments that were related to all four patterns of participation. As such, these categories serve less utility from an analysis perspective, and function more as constructs for understanding the range of factors driving participation for various participants. Additional examples of the types of comments given by participants within each category are shared in Appendix D.

Bird Cams Lab Vision for Co-creation

Most citizen-science projects enlist members of the general public to collect data (Schäfer and Kieslinger 2016, Shirk et al. 2012), while co-creation seeks to involve participants in all steps of scientific research, as partners and idea generators. Bird Cams Lab was envisioned as a way for Bird Cam watchers to satisfy their own curiosities, become invested in stages of research that are usually reserved for experts, and bring their own perspectives and experiences to the table.

In the initial project proposal, the Bird Cam Labs team described their vision for co-created research:

> *"The objective is to engage participants with each other and with scientists in activities spanning the entire scientific process: asking questions, deciding what data are needed, generating data, looking for patterns, making interpretations, reviewing results, and sharing findings."*

From the start, the Bird Cams Lab team recognized the possibility that participants may experience outcomes no matter the breadth or depth of their participation, but also posited that greater breadth or depth of participation may result in greater outcomes. Some individuals experienced the co-creation process more fully. However, even in instances where participants did not engage fully over the complete lifespan of an investigation, the three summative investigations were co-created in the sense that a community of participants was actively engaged at every stage in a collective fashion, and that at least some participants contributed to most or all phases. Allowing and encouraging fluid participation in any phase led to co-creation in various and somewhat organic forms.

Participants' Views related to Co-creation

In the final survey, we asked participants how they define co-creation, in order to compare how the public's view might align or depart from that of the project team's. Roughly 45% of respondents talked about co-creation as a collaborative process between scientists and lay people. In some of these responses, participants described public participants as contributing to the design of the study and analysis of data on a more even footing with the scientist experts, but in other responses it was less clear how participants viewed the scientist/public relationship.

> *"Co-created research involves both scientists and community members who are interested in the research topic. It's different from other scientific research because it uses data gathered and possibly interpreted by a wide number of people." (Survey Respondent)*

> *"Co-created research provides the opportunity for interested people (lay people or "citizens," although citizenship is not a requirement) to work alongside scientists in the development of scientific studies, and to contribute to the analysis of data collected during the study. Participants do not need to have prior experience." (Survey Respondent)*

Different participants also referred to different stages of the scientific processes. Some participants talked only about the question generation stage, while others focused on data collection. It seems likely that a participant's view of co-creation was largely dependent on which stages of the project they had

participated in. Furthermore, 11% described co-created research as a collaborative process, but didn't refer explicitly to the collaboration as occurring between scientists/experts and the general public.

Interview responses related to co-creation also emphasized the fact that the participants saw co-creation as lay people working alongside professional scientists to achieve a common goal."

> *"You have an idea, I have an idea...the scientific community wants answers….and all together...a little bit of everybody...Everybody thinking in similar ways...different ways...exchange ideas...give and take, but eventually sift down to a workable question we can try to answer." (BBP3)*

> *"This is meant to be something that brings the community and the civilian community and the scientific community together to achieve these common goals." (HH6)*

> *"Allows community citizen scientists to fully engage in the research process from the beginning...Working together with community to design a research project from beginning to end that's participatory from the initial discussion and creation of research question all the way to data sharing. Scientists and researchers and community [together] throughout the whole project." (HH10)*

Co-creation Style

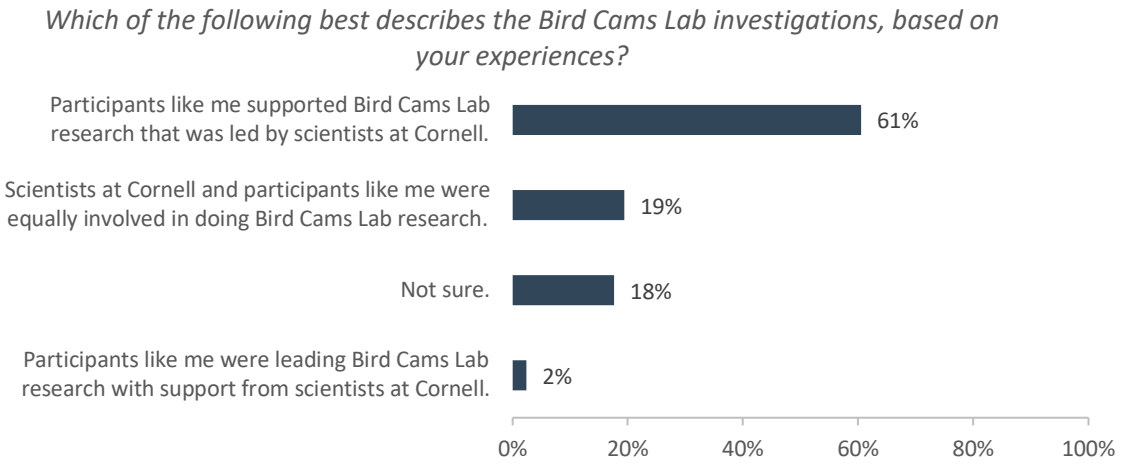
Co-created projects have historically been seen as those in which the community is driving the study as much as the scientists—or at least have equal agency to make decisions related to the investigation. They have also tended to be place-based, i.e., focused on a particular location. However, other scholars have suggested that lay audiences don't have to drive the study, but that at least some of the public participants should be involved in most or all aspects of the scientific process (Bonney et al. 2009, Shirk et al. 2012). From the outset of Bird Cams Lab, facilitators did just that—i.e., by inviting participants to contribute at every stage, they sought to create opportunities for co-creation that enabled participants to collaborate in meaningful ways with scientists and each other. While stages of the investigation process did not attract equal numbers of contributors, lay audiences were nonetheless involved at every stage in meaningful ways.

> *"To me [co-creation] really means that everyone is engaged, it's not necessarily that everyone is engaged equally, but that everyone has an opportunity to engage at all stages. So that's, that's what co-created means to me." (HH2)*

> *"It's important to look at it also from the perspective of having a seat at the table with the scientists, which to me is very important, and so, just by virtue of the fact that we were part of the process that fulfilled the expectations." (HH9)*

While participants' preferences surrounding co-creation had considerable variation, their characterization of the Bird Cams Lab investigations was more consistent. Survey findings suggest that over 60% felt that the Bird Cams Lab investigations were **led by scientists with the support of public participants.** However, roughly **a fifth** described the relationship as a **more equal partnership**. And only 2% thought that public participants **led the projects** with the support of scientists.

Figure 27. Participants' Characterization of the Bird Cams Lab Investigations (n=618)



Interviewees were asked to elaborate on the co-creation experience and, similar to findings from the survey, a few noted that they'd felt fully in control:

> *"[I] thought it was a positive thing that from the scientist end of it they weren't pushing or moving to a particular thing...to an outcome they were hoping for. It seemed as though it was really coming from the citizens who were participating." (CFL10)*

> *"I thought that that the citizens were creating the questions and involved in the whole process, and was that a good thing" (CFL4)*

Other interviewees felt there was a balance between scientists and lay-audiences:

> *"People came up with questions. There was enough interaction with the scientists to help you answer your questions and proceed, but there wasn't a lot of interference. It was the lay people who were driving it. I thought it was a good balance." (CFL4).*

> *"I think everybody was very much involved in participating...I think they definitely opened it up for everybody to have a chance to...speak what they wanted to speak and share and ask and contribute." (CFL12)*

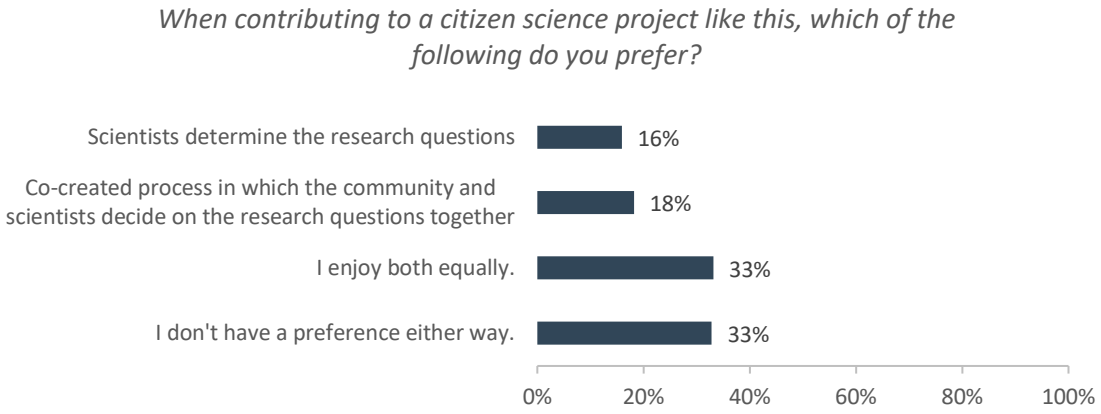
And lastly, there were participants who felt they played a supportive role to scientists. Most in this group made sure to note that a scientist-led approach to co-creation was preferable to a style of co-creation that was more evenly distributed between scientists and lay audiences.

> *"[I] feel like what the participants contributed was listened to and made part of the choices…Felt like contributions were heard…[and] taken seriously. That was good. (BBP12)*

Participants Thoughts About Who Should Lead Co-created Investigations

The survey asked participants about their preferences regarding co-creation—in particular, who should take part in deciding the research questions. In response to a close-ended survey question, only about a third of respondents stated a firm preference. These individuals were more or less evenly split between having the scientist choose the research question versus having a more equal co-created process. The remaining two thirds of respondents said they enjoyed both equally or did not have a preference.

Figure 28. Participant Preferences Related to Co-Creation (n=661)



Participants elaborated on their responses in an open-ended format. Some who selected "no preference" actually seemed to be expressing a preference for either co-created or scientist-generated questions but overall, the preferences for those two approaches remained roughly equivalent. The open-ended responses also provided insight into why participants leaned one way or the other or had no preference.

Survey responses show that scientist input and leadership is highly valued. Forty-two percent of survey responses about co-creation referenced the importance of scientists' expert knowledge, particularly in identifying what topics to study and what questions to ask. In other words, participants readily saw the value of scientists to help ensure that the resulting investigations would be impactful. Participants felt that scientists have more insights on what contributions will be most valuable and therefore best able to move the collective understanding forward.

Echoing the survey responses, many interviewees noted that they felt the team of scientists at Cornell were leading the investigations, but their doing so was essential to ensuring that each investigation had scientific merit.

Scientists brought in expertise on how to frame questions so that they were answerable

Participants acknowledged the important role that scientists played in helping to frame questions so that they were answerable.

"It could not have been done without the researchers. They were good leaders of people...teaching how to ask a question and when asked, if that question could be answered. They did a good job of directing them the right way. It was a good balance between the researcher and the people" (CFL5)

"While I have enjoyed the co-creative process very much, I would also be equally interested in exploring a project determined by only scientists...as they have information and a point of view that a non-scientist would not know...the biggest challenge was coming up with a question that could be answered through with cam observations. I could think of many questions I'd like addressed, but most were not amenable to investigation using cam info." (BBP1)

"You know, I'm not sure how much these methods really come from the community, and again, that's where as scientists we can really make this better...That's where the expertise as a scientist can really help, because the community says 'I want to answer this question...I'm interested in this thing...and then it's the role of the scientist to say 'this is how we measure that thing,' and then that also is an opportunity to teach the community about method." (HH2)

PARTICIPANT INSIGHTS

Does the fact that it was a co-created scientific process make the experience more or less appealing?

"More appealing, but there are downsides...If you have these two goals of getting the best science, and engaging with your community...to get the really most interesting possible thing that I would want to learn as a behavioral ecologist from these cameras is probably not what the community is going to decide. Because that comes from years and years [of study], it's very specific knowledge and skills in terms of being able to collect that data. So that's the cost to co-creation, but the benefit is that really all these people can learn all of these things about how everything works in the ecosystem and really become engaged and have a better understanding of science in general and a better appreciation of birds and wildlife….so those are really highly beneficial [outcomes] from doing this co-creation method...versus the ivory tower method of 'we went and we figured this out and this is the truth...so I am telling you this as an expert and you should listen to me.' There's some conflict there, but I think it's worthwhile. (HH2)

Scientists have more knowledge about topics in need of investigation

Some participants expressed a desire for their contributions to help advance science. As such, they acknowledged the important role that scientists play in helping to ensure that Bird Cams Lab investigations were able to do so. Participants felt that scientists had valuable insights about what to investigate based on gaps within the literature base or pressing needs for greater understanding.

> *"I feel that the scientists have more experience with what has been and what has not been studied. That should lead to more valuable research." (CFL8)*
>
> *"I like the idea of contributing to the question, but I also think researchers are in a better position to identify the most important questions to be answered." (CFL16)*
>
> *"Scientists may be aware of more important questions to be asking. For example, if there is a specific concern that may benefit from the research results of an investigation, the scientists leading and forming the questions could directly help yield results that inform those working on said specific concern." (HH6)*

PARTICIPANT INSIGHTS

"There are probably certain points in time where the community is pushing forward with a question. The participants are pushing forward with a question that's already been explored forever, and there are definite answers to these questions already and in that case…time and resources would be better spent on questions that, yes, the community can help create and can help collect data for, but that actually also do play a role in the broader scientific agenda and in terms of learning and questions that still need to be answered, as opposed to, you know, a food preference for example might be something that is very well known and very well documented. In that case, the community driving and choosing that question wouldn't be necessarily as helpful as maybe a mix of that, which helps the community stay engaged, and something that the scientists might want to explore more because it's of importance, conservation-wise or towards, it's a question that hasn't been answered yet." (HH6)

For many of the reasons outlined above, some participants thought that scientists should always take the lead:

> *"Scientists should always take the lead; you can ask other people for input but experts know more." (BBP4)*

> *"I think I would like to see a little more guidance on the scientific end in setting up the study...Scientists should be leading it." (BBP10)*

Others thought it was good for scientists to guide the process but not necessarily be the ones to lead all aspects of an investigation:

> *"Everybody's got their own idea of what's important...Sometimes separating important from trivial is a challenge. I think people are looking for more guidance. Like a moderator or instructor in a college class...doesn't direct everything, but keep everyone going down right path." (BBP10)*

Despite wanting scientists to be involved in guiding the investigations, many participants also felt their contributions to the investigations had value as well:

> *"I would say that generating the research questions...I was thinking that would be better left to the experts, but I think that was incorrect because people came up with a lot of questions and then there was feedback and discussion. I was surprised that, you know, as non-experts we could all participate in that. I think I still believe that those people with expertise probably could design the best questions. But I think it gives something to those of us who are participating. I mean, the idea of curiosity and that what we're curious about matters, and that perhaps what we're curious about even could be unique, or something, others haven't thought about... that's important." (CFL8)*

"Having both scientists and community members participate in creating a scientific project helps to create a more inclusive, accessible project—something that both career scientists and lay people can find useful." (BBP7)

"I believe that scientific researchers and citizen-scientists approach research from a different perspective. If the intent of the research is to educate the general public then having a combination is the best approach." (HH9)

Benefits of Co-creation

During interviews, participants explained the benefits of co-creation as they had come to understand them through their involvement in Bird Cams Lab investigations.

Furthering scientific understanding

Participants felt one of the primary advantages of co-creation, not unlike other types of research, was the fact that they could lead to more scientific understanding in general—and in relation to birds, wildlife, conservation efforts and environmental factors that affect the natural world in particular.

"We can do together as a group that has a much larger effect and it can accomplish much more, I guess that'd be a benefit...and I think it's important to protect our environment or be considerate of our environment and being...together like this I think is a great way to accomplish that." (BBP13)

Time and cost-savings in working with large data sets

Participants noted that another advantage of contributing to research is that scientists get assistance gathering data to facilitate scientific investigations that would otherwise be impossible—or at the very least, lengthy or costly based on the amount of time it would take a smaller number of people or an individual to do.

"I guess you could collect these kinds of data without involving people, it would take a lot of undergrads and a lot of money right to pay undergrads to just sit in front of the camera for 12 hours a day or whatever. And so that's the thing that I think is really exciting, is that we're getting to a point where co-creation is becoming...integral to the scientific process...that we're getting to do things that were not previously possible by getting hundreds of people to log in hundreds of man hours into a study...It expands the realm of what's possible in scientific inquiry." (CFL6)

"I learned that...sometimes it takes two to tango...that the scientists need us lay people...you folks don't have the time to sit and watch all the birds like we might have. I'm sure you have lots of other things to do so. I think that in that respect, it's a two-way street. It's definitely something that, you...should take more advantage of, people that have the time." (CFL3)

"I definitely think that my participation is important to scientists. My singular participation is a small piece, but if there are many, it creates a resource that is not easily accessible by one researcher...it's incredible how much data Cornell has on birds, because of participants like me." (BBP2)

"With the advent of digital camera and understanding that...we have more and more data that we need to have other eyes looking and sharing. And so, it's a way of learning to use the other people's interests." (BBP9)

"We are living in a world with enormous amount of data...computers can process [some] data, but the public can also collect and process all of these data that that cannot be done if a single person, or single scientist or a group of scientists starts to work with these large amounts of data..." This participant, who happened to be an ornithologist working in Hungary, went on to give an example about the types of projects that could be aided by citizen scientists who can mobilize quickly to analyze large data sets, about the spread of insect-borne viruses for example. These projects, he explained, allow us to *"act effectively or [respond] more quickly to our changing world." (CFL7)*

Equal or higher quality science

Participants felt that co-created research was of equal, or perhaps even higher quality than other types of research. This was due, at least in part, to a belief that more people helping to collect and analyze data could ultimately lead to better quality results, but also because of the benefits of including different strengths or perspectives.

"I went from thinking, you know, maybe the data won't be as accurate when you've got Joe anybody... doing the data collection... but I think they've done a really good job of thinking through that to make sure that they're collecting it in a way with they have enough repetitive data collection... they had enough people watching the same clip...they knew how many people had to watch it... I kind of feel like maybe it's even more accurate than if they're doing it by themselves because you've got all these people… It seems very robust to me." (CFL11)

"Well my personal bias would be that it's more valid... because I think it's important to get as many different [people] contributing and thinking about something. I think it's easy if it's just one or two of us, developing a project... the focus of study for us to be kind of producing something it's a little bit more limited scope… you're sort of trapped in your own mind, you need to have other people. And in a variety of folks that bring, different strengths, different ways of seeing any sort of a project." (BBP7)

"If it were done just that way instead of engaging participation from across... the community, you might lose something that turns out to be very valuable... so I don't know that I would say what's better or worse, but I would say you probably gain more than, than you think you would by engaging citizen scientist participation." (CFL1)

Most participants understood that there were protections in place to ensure data would be useful even if people occasionally made mistakes in their data-tagging:

"You feel like you can't do anything wrong, which I think is very encouraging because I think otherwise I might be anxious like what if I get the sound wrong...because you're doing it with this community at large...if they get 10 evaluations from people like me, if eight of them say this...Okay they feel comfortable with those 8 that that was an accurate measure...If you're in the outlier, not to worry, because you know they're going to wait until they get 10 looks before they feel like they can make a scientific judgment, so there's no pressure." (BBP1)

"It wasn't just one person tagging that video...10 people tagged a video, and then have to be a confidence factor of...7 out of 10 said it was this before they would accept it as an answer. I think that makes it acceptable. If you were...just trusting random people in the community to say, 'Oh, that's what they said it must be true' that obviously would be a problem. I don't think it should be judged as any less valid... as long as you have the right protections in place...I don't know that having non-scientists makes a scientific evaluation more likely to be accurate, but I think it certainly doesn't hurt the accuracy given the protections they put in place." (BBP4)

Different perspectives

Sometimes thinking outside of a given scientific "box" can provide different perspectives on the behaviors being observed. Twenty percent of survey respondents stated that scientific research could actually be improved by public involvement. These responses described the value of having different perspectives on a project and how non-scientists may sometimes notice or pay attention to things that scientists overlook.

Interviewees and survey respondents shared similar opinions about the value of having input and involvement from non-scientists—especially in terms of contributions during the question generation phase of the investigations.

"I think having the people not thinking like scientists is the benefit because I can get so many brains focusing on something that I miss all the other elements that are going on around it. Have you ever held a roll of toilet paper up to your eye and looked through it? You can only see what's going on there [gestures in front], you miss what's going on here [gestures around his side]. And that was the scientists. They get so narrowly focused that they miss the ancillary things that are going on around us. And the common people don't look at it through that tube they look at it as a whole. The benefit is bringing that broad range of viewing into a group of people that have a narrow range of view." (HH4)

"The scientists…have a certain way of thinking and those of us who participated as citizens, or as bird lovers, I think we look at it differently, and maybe in a more concrete way than a scientist might. And I think that the suggestions that were made by the bird lovers are more based on what they experienced and what information they would like to have, as opposed to what a scientist might be looking at as information that they would like to have, and hopefully that those two things can come together." (HH9)

"I'm a scientist, in fact, an ornithologist, living in Brazil, and I like to keep up on what's happening in my homeland. And, I know often lay people don't really know what scientific questions are interesting, yet at the same time, lay people often have questions that show considerable insight and imagination, and that often stimulate scientists to think a bit more broadly. Also, the exercise of explaining to a layperson why a question is interesting often teaches the scientist to be more understanding." (Survey Respondent)

"I think if you have participated in something from the beginning of the creation, you have ownership in it, and you're I think more dedicated to it, and more committed to continuing to be a part of it and giving of your time… it's a way to create a connection with your audience, which I think is important, because the more people that can participate, the better your data is going to be and I understand that from a scientific perspective... I think these partnerships are very

important because we can learn from the scientists, and they can learn from us because our perspectives are different." (HH9)

Enhanced ability for scientists to engage with public audiences

In their open-ended survey responses, respondents described co-creation as having educational value. Most of the time they referred to participants learning about the research process, but a few participants also noted that scientists can learn from their work with the public. Interviewees also believed that co-creation could help scientists gain a better understanding of what lay audiences are interested in and therefore be better equipped to do research that has broader public appeal.

"I like exploring the interests of non-scientists because it gives a baseline of what the public understands and is curious about." (HH5)

"We may find more interesting questions that scientists have overlooked. The public can add more questions or more viewpoints into scientific research because, for example, they would like to know something that is interesting for the public or more beneficial for the public than scientists." (CFL7)

"I think I still believe that those people with expertise probably could design the best questions. But I think it gives something to those of us who are participating. I mean, the idea of curiosity...and that what we're curious about matters...and that perhaps what we're curious about even could be unique, or something others haven't thought about….that's important." (CFL8)

"If you want to solicit engagement outside the university...you have to be open to what [is of] interest to other folks outside." (CFL11)

"I think it's pretty easy for scientists involved with their data to be so comfortable with it but they sometimes forget that those of us who haven't been immersed in that data might find the jargon a little confusing, so just being able to get the jargon out and write more in plain English so that a larger community can use the report...We really are looking at the text and is it really saying what we what we want it to say the end product then becomes something that you feel is more accessible to lay audiences than maybe other types of academic research….what is really intriguing is just how so many different people can have suggestions and how that coalesces into a much more refined product, much more understandable and accessible." (BBP7)

"As a scientist and science educator, I have seen myself evolve over time in my understanding of scientific method and how to make it usable by novices; I will admit to early naivete followed by impatience with novices followed by tolerance of novices followed by desire to educate novices into more clear understandings of what science is about." (HH16)

Greater public engagement with science

Another obvious benefit of co-created research is the actual public engagement that can result from the research experiences themselves. For example, when asked to indicate if she thought the project had fully engaged members of the general public, one participant who happened to be an oceanographer, agreed and stated, *"I know a little bit about the National Science Foundation, and I would think that it might be one of their goals to educate citizens, about how science proceeds and that it's fun to do." (CFL4)*

"I got the sense that they get more engagement from people because it was stuff that you know people think about on their own, you know like, well, how come this bird only comes through this part of the day or why did these birds only come and it's raining you know so those kind of comments from people, even though I didn't really participate too much in the question forming...I was reading the chats every night, and it was just cool to see what people were saying, you know about what they were thinking about, what they'd like to see us capture, you could tell it was stuff that...everyday people think about when they're watching birds in their yards." (CFL11)

"Because it feels more inclusive. It feels as though what I do as a 'non-scientist' participant has value…I think anytime you have engagement from anybody it's going to be more interactive...it's going to be more engaging...If it wasn't co-created, [if you] just put out a list and said, 'I want everybody to look at this and share your thoughts on this' ...I'm not sure you would have had the participation that you did...Engagement of people in any part of that process definitely... increases the outcome...the overall knowledge that y'all put together for the bird world." (CFL1)

"So I think being a participant in Bird Cams Lab, really, it's the whole new level of engagement, you know many people are interested in kind of a passive way but then you can really get involved, by being a participant in terms of now you're collecting data to learn a little bit about how we collect data and the kinds of things that are interesting. So it's really another level of engagement. As a Bird Cams Lab participant versus just a bird cam watcher." (HH2)

"When you can engage the public as much as possible, then they're going to support your project, so that the more people you have that are viewing then, the more data you'll have, the better data, you will have. So it makes sense to me to involve the public, and for them to feel that they were a part of this creative aspect of it." (HH9)

More lay-audience buy-in to the scientific process through co-ownership of the experience

Through co-ownership of the research experience, participants came to feel greater buy-in to the scientific process.

"It really gives you agency. You decided you wanted to know this...then you get to decide how you're going to...answer that question and then you get to learn, the answer the question that you asked… If it's someone else's question, that can also be very interesting... but there's not as much agency from the individual." (HH2)

"I had never really thought about public participation….[It's] really a great way to get the public to be more invested in science." (BBP2)

"People don't believe in climate change...because they're isolated from being involved in it at all....So if you give people the opportunity to have input and their input is recorded and used. I think they're... going to have a stake in the outcome. So, I think, in that sense, a co-created project is valuable. Maybe not for a scientific reason but for political reasons or for social reasons. In order to get things accomplished, you need people to buy and they need to have a stake in the outcome. So, the more you can get people involved in hands-on, the more success you're going to have." (BBP10)

"It seems like, especially today... having more people involved...having citizen scientists involved...is what we need. Because I think scientists have maybe seemed to a lot of people...as these unapproachable people...doing things I could never understand and that's just not true. So I think it's for the benefit of everybody to have as many people involved as possible and actually having some ownership in these sorts of things. And, you know maybe that will help give what scientists say more credence you know instead of things seeming so separate, I guess, you know from lay people... to have people invested in these kinds of things and conservation in general. So I think the more people that can be involved, the better." (BBP12)

Providing a greater sense of connection among participants

This type of co-created research also led participants to feel more connected to each other as well as scientists. The sense of connection to others doing science was therefore another way that participants came to feel more connected to the scientific process in general.

"I had made some observations on my own, of course, of watching you know the birds every morning, but to hear other people's opinions and see what they thought was important, I thought was very interesting." (CFL3)

"So I really liked that they opened up these discussion boards for people to like spitball their ideas of what they want to get out of the project and some things that they want to use...I think that's really important because it makes science more accessible to people who don't...who think that science is beyond them and beyond the scope of their understanding or their ability." (HH5)

Scientists more open to input from others

One participant, who was a recently retired scientist, advanced the following thought about one of the unique benefits of co-created scientific investigations: *"I'm sure it would make you more open to suggestions by lay audiences." (CFL4)* Another participant, who had a background in agriculture R&D and bioengineering, stated, *"We have a really traditional view of science in the science world... work getting done between experts, but with wildlife, nature and environmental science, one person can't be an observer of everything that happens. Involving the public in science can make them more excited about science but also create a better resource for science. That's a really unique perspective." (BBP2)*

"It seems as though there's really a wide range of that community as far as, you know, just like to watch birds to, you know, folks who have a background in science where they, probably are involved in other projects where they're working deeply with data and such. And I'm learning a lot about how you would work with such a diverse community. (BBP7)

Input and Insights from other STEM professionals

Another advantage of the co-creation process is that it ultimately attracted other STEM professionals to participate and contribute their own insights, knowledge, and skills. For example, an ornithologist from Hungary explained how he exchanged several email messages with Bird Cams Lab facilitators at Cornell: *"I was interested in the methods they used so far to determine the dominance hierarchy and [they were] interested in the methods I use in this context...and [we] started to discuss all of these things together." (CFL7)* Others with STEM backgrounds asserted that there was a benefit to learning about different methodological approaches from other STEM professionals.

Challenges of Co-creation

Skill/expertise is necessary for some parts of the process

In addition to the perceived skill and knowledge required by participants, there were also specific skills and types of expertise that actually were required on the part of a project team (in this case, scientist-facilitators) to create and implement an effective co-created research project. Considerable amounts of effort went into the process of setting up investigations, facilitating the entire investigation process (including moderation of discussion and answering questions that come up during the data collection stage), analyzing results, preparing interactive data visualizations, and preparing reports that had scientific merit. Therefore, one of the challenges of this type of co-created investigation is that it would not be possible without time-intensive contributions of highly skilled scientists who are able to effectively facilitate the process.

> *"Do you want tight analysis? Or loose analysis? ...If I want a loose analysis I would go with a different group of people than if I wanted a tight analysis." (HH4*)

This wasn't just co-creation, it was a highly collaborative co-creation process (i.e., managing a democratic process that involves hundreds of people potentially). As such, the skill necessary to effectively facilitate an engaging participation process with hundreds of lay participants cannot be over-emphasized.

Balancing people's interest with desire to advance science

Interviewees indicated that another challenge of co-created research was the need to limit the complexity of the question being investigated in order for it to be something that lay audiences were interested in and capable of making accurate observations for in a timely way or without more considerable training.

> *"The question is maybe more simplistic than something a scientist could design...maybe it's not the most rigorous most interesting science question you could ask with this data." (HH2)*

> *"People have their own agenda…people who aren't scientifically inclined...I think that there's maybe a lot of time, not wasted, but it takes longer to narrow scope of study when lot of different inputs. The message board discussion got a little out of control for a while...people were going off on tangents or suggesting data that was not practical to be gathered…On the one hand there's value to getting everyday people involved in this kind of thing because it gives them a stake in the outcome. But science is not really a democracy." (BBP10)*

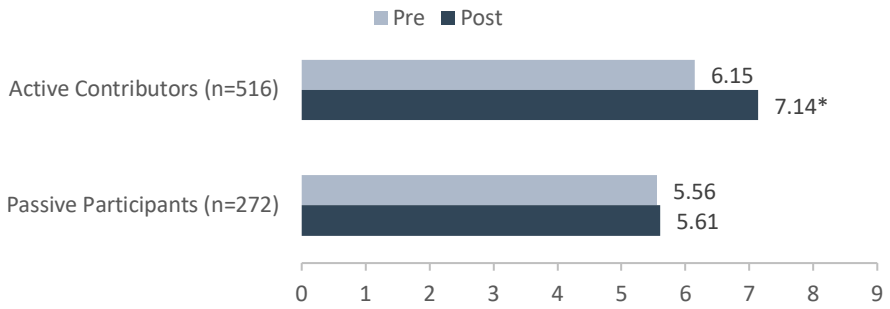
Gains in Bird Knowledge

Knowledge Gains for Active Contributors Versus Passive Participants

A key research question of the Bird Cams Lab project was whether participation—and more active modes of engagement—in the scientific process would lead to stronger learning outcomes for participants both in terms of their bird knowledge as well as their understanding of the scientific process and their scientific thinking skills.

A nine-question bird quiz was presented to participants on each pre- and post-survey as a means to measure knowledge of the birds that feature on the cams specific to each investigation. Those who were active contributors to the investigations showed a significant improvement in their bird quiz scores from pre-survey to post-survey, while those who were passively engaged showed no statistically significant gains in their bird knowledge.

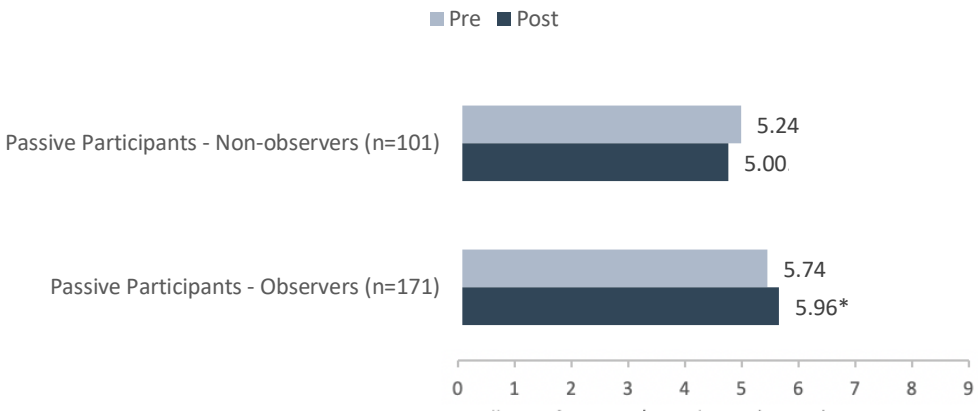
Figure 29. Bird Knowledge Gains – Active Contributors versus Passive Participants



*Indicates statistically significant pre/post change ($p<0.05$)

Among the more passive contributors to the Bird Cams Lab investigations, we also found that observing the cams seemed to give those individuals a slight advantage where bird-related knowledge is concerned. Cam viewers, or "observers," had a slight but statistically significant gain in their bird knowledge scores from pre to post as well, although their gains were smaller than those who were more active.

Figure 30. Bird Knowledge Gains for Passive Participants – Those who observed the cams versus those who did not



*Indicates significant pre/post change ($p<0.05$)

Observation Ability

In addition to the bird knowledge quiz, each pre- and post-survey contained a video question which asked participants to describe what they saw in a short video clip taken from the particular cam of that investigation. This question was intended as a way to explore participants' observation skills and the extent to which their qualitative descriptions might change through their involvement. These video questions presented certain logistical challenges—for example, some participants said they could not view the videos, and others could not figure out how to replay the videos a second time before typing up their observation. Still, the descriptions we received painted an interesting picture of how participants view, interpret, and describe the activity on the Bird Cams.

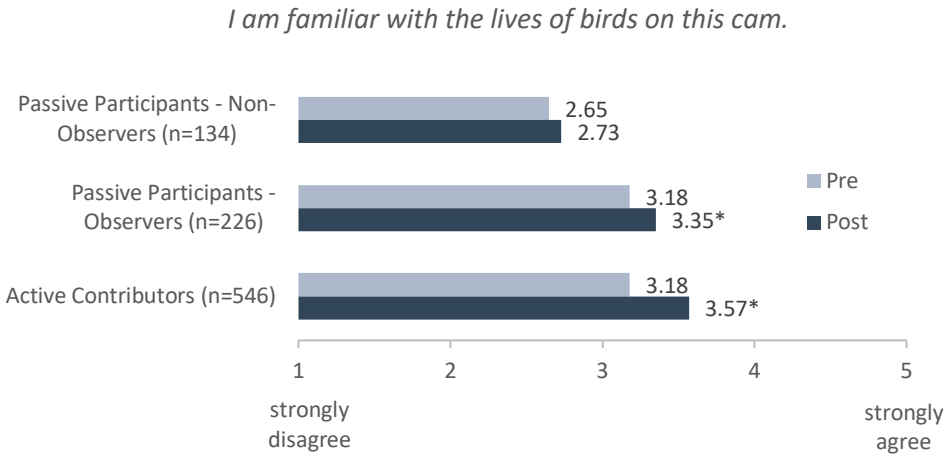
Responses to the video questions were coded for their completeness, accuracy, use of scientific terms, and use of anthropomorphic terms. We gave participants a composite video score—completeness, accuracy, and scientific terms all being additive, and anthropomorphic terms counting against their score. Individual elements of their responses were examined in addition to overall scores.

We found that active contributors to the investigations were more thorough in their video descriptions, more accurate, and used scientific terms more frequently on their post-surveys compared to their pre-surveys, while passive participants did not show statistically significant improvement. Interestingly, passive participants showed a statistically significant drop in their use of anthropomorphic terms from pre to post, but active contributors did not. Overall, however, the composite scores for active contributors went up, while for passive participants they stayed relatively unchanged.

Confidence in Bird Knowledge

There were significant gains in participants' confidence in their bird knowledge for active contributors and the more passive contributors who were cam-viewers. There were small, but not statistically significant, gains among passive contributors who did not watch Bird Cams.

Figure 31. Participants' Confidence in Their Bird Knowledge

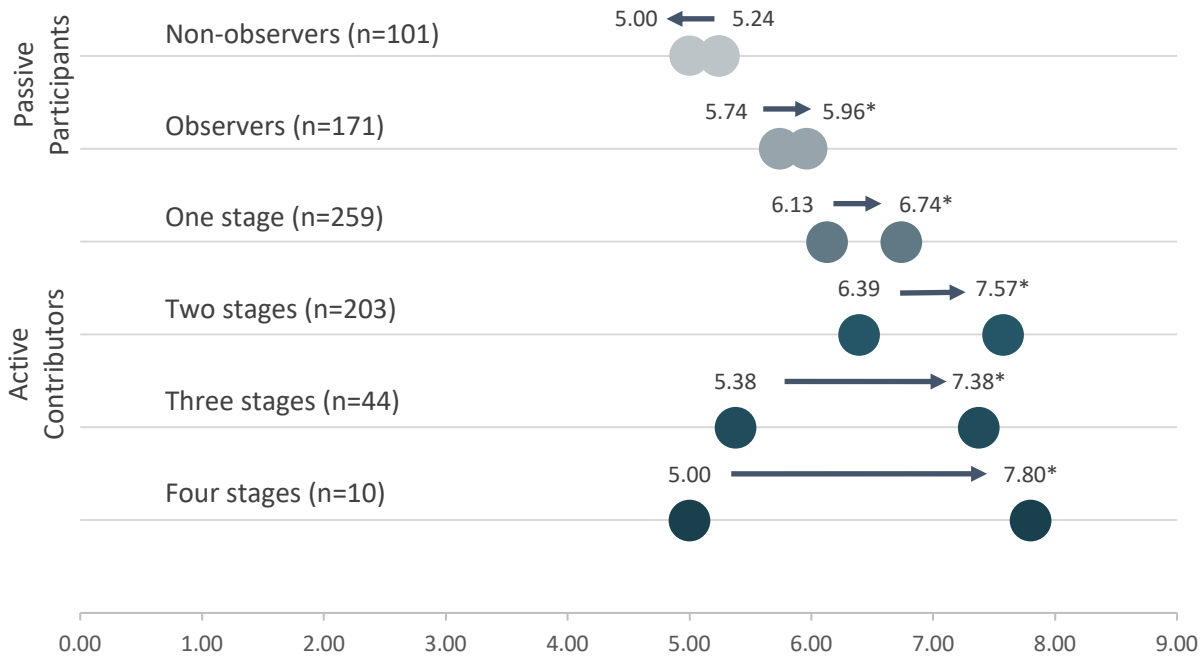


*indicates statistically significant pre/post change ($p<0.05$)

Bird Knowledge Gains Related to Breadth of Involvement in the Investigation

The breadth of an individual's involvement in a given investigation, (i.e., number of stages participated in), was also found to be related to changes in participants' bird knowledge scores. Generally, the more stages of the investigation a participant took part in, the greater their bird knowledge gains were from pre to post. The number of *previous* investigations an individual had taken part in was not found to have an effect on their bird knowledge change.

Figure 32. Bird Knowledge Gains as Related to Participation Breadth



*Indicates significant pre/post change (*p<0.05*)

Non-observers showed a decrease in their bird knowledge scores from pre to post—the only group to show a backwards slide. Those who only observed the Bird Cams fared similarly to those who participated in just one stage of the investigation. They both showed significant improvement from pre to post, but the gains were small, and there was no significant difference between these two groups. Those who participated in two or three stages, however, had significantly larger gains in their bird quiz scores than the other participants. Finally, only 10 individuals with pre/post data had participated in four stages of any investigation—too small a group to run meaningful analyses.

Overall, data suggest that the biggest differences in knowledge-related gains occurred at two points: 1) between passive contributors who observed cams in contrast to those who didn't and, 2) between active participants who participated in only one stage of the investigation versus those who participated in more than one stage of the investigation.

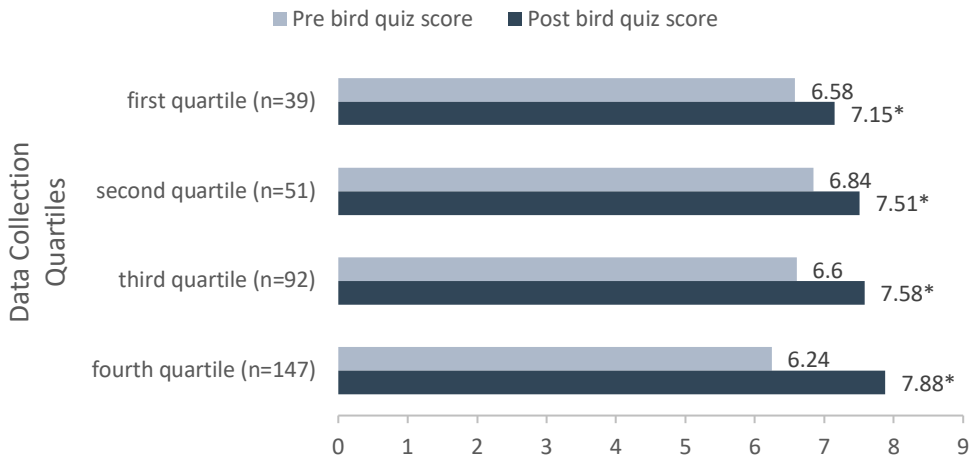
Bird Knowledge Gains Related to Intensity of Involvement

There was great variability among participants in terms of their intensity of participation. Within the question design and data exploration stages, intensity of participants' involvement was not related to pre-post differences in performance on bird knowledge quizzes. However, within the data collection stage, intensity of involvement was related to pre-post differences.

In a given investigation, some participants tagged only one or two observations and others tagged hundreds, whether it was tagging data in real time or on recorded video clips. Not surprisingly, the intensity of a participant's involvement in the data collection stage was found to be correlated with bird

knowledge gains. The more data a participant collected, the more their bird quiz scores improved from pre to post. Those who fell in the uppermost quartile of data collection intensity had significantly different change scores from pre to post than the other participants.

Figure 33. Data Collection Intensity as Related to Change in Bird Knowledge



*indicates significant pre/post change ($p<0.05$)

How and Why Bird Knowledge Gains May Have Occurred

Interview data provided additional insights into how and why participants—especially participants who engaged in more steps and in more active ways—came to have knowledge gains as a result of their participation experience. These data suggest that participation in the data collection stage was particularly important in terms of generating knowledge and confidence in knowledge related to bird identification and identification of bird behaviors.

How the data collection stage contributed to knowledge gains

Some participants felt that their Bird Cams Lab experience—especially during the data collection stage of each investigation—provided opportunities to develop and hone bird identification skills. For example, a participant who contributed to the Battling Birds Panama investigation said the experience gave her an opportunity to "sharpen tropical bird identification skills." (BBP11) Other participants shared similar anecdotes about how they came to be more skilled in their ability to identify the birds they were asked to tag as part of a given investigation.

Participation in Bird Cams Lab investigations also enabled participants to gain new understanding of bird behaviors and increased their ability to identify those behaviors. The following quotes illustrate participants' self-reported knowledge gain related to understanding and identification of bird behavior.

> *"You really can learn a lot just by…observing those behaviors…To actually see that behavior or see that interaction, again, instead of reading it and that to me, experiencing something is something that I will remember." (HH9)*

"I gained a lot of knowledge about different species and about displacement and...what types of foods that will bring different types of species, and...learning about the whole process of observation and things to look for...what types of birds are more aggressive and the dominance hierarchy." (CFL12)

"I didn't know any terminology [and] I didn't know what a lot of the behavior meant, so I learned it, in order to be able to…enter the data." (HH8)

How the analysis stage contributed to knowledge gains

The analysis stage provided opportunities for participants to reflect on what they had observed during the data collection stage, and/or during previous Bird Cam viewing experiences. Being able to see the data that resulted from Bird Cams Lab investigations validated assumptions and beliefs about birds and bird behavior that were either formed during the data collection phase or based on previous observations.

Some participants were happy to see findings that matched what they'd observed:

"I enjoyed looking at the data because it affirmed what I was watching...and what I had watched other times." (CFL10)

"Thought data was very interesting...exactly what I thought it was going to be having watched every day." (CFL3)

"Sometimes you wonder, am I getting the full picture. One of the reasons I wanted to get the Panama data was that I thought I was only seeing one bird all the time...the Clay-colored Thrush…[I wondered] is this what's going on all day long ...and it was."(BBP3)

"I learned stuff...because I'm focused so much on this cam, it validated a lot of what my assumptions were about, you know, some of the some of the categories like the time of who attends when...who comes in what weather. So that kind of validated what I normally see so that was interesting to me." (CFL1)

Participants also learned from instances where outcomes of the investigations went against assumptions based on their prior observations:

"I was actually surprised at how from beginning of the day to the end of the day, how many birds...we're seeing almost from beginning to end, I kind of expected there to be a steeper drop off... Most of the birds that we were counting were at the feeder most of the time." (CFL11)

"I also found it a little bit interesting...with it being the 'Battling Birds' I thought you'd be looking at a lot of interactions between different species and when I was doing it I felt like most of the interactions were between birds of the same species so that was something that I learned...that a lot of times...maybe [it's] a territorial thing between two birds of the same species rather than one between another one that's smaller, or that kind of thing." (BBP15)

"It's always interesting to see what you think might be happening versus what the data actually shows...I know that just looking at it, I'd be like, 'Oh, that's interesting to me' that when I look at it I see it from my point of view, but as a researcher the data might show something different because I'm not looking at it 24-7 when it's available. So maybe I get the times when I look at something it's always one bird visiting the feeder or more than the others and I'm not I'm not looking at it at noon when more different birds might be active." (BBP14)

Participants came to be more interested in bird behaviors

There was also an interesting pattern of responses that emerged during all three rounds of interviews that suggests participants came to be more interested in bird behavior as a result of their participation in Bird Cams Lab. This included thinking more deeply about the types of behaviors they were seeing, rather than simply being interested in looking at or merely identifying birds.

One participant, who described herself as being slightly reluctant to participate at first because she felt that others had greater knowledge about birds than she did, explains how she'd hoped to learn more about birds, but was pleased that she came away with a greater understanding of their behavior in addition to a greater ability to identify different birds: *"Personally, I've learned to be more observant, rather than just enjoying the color and watching the activity. I was paying attention to more attention to what was happening so that was a positive thing for me. And of course I learned a little bit more about each of those birds." (CFL10)*

"I went from barely being able to identify all the birds...to noticing behavior." (CFL6)

"I have watched birds from afar for a long time but…didn't look at them as something…that I wanted to learn more about rather than something to just look at and say 'that's pretty' or 'look at that bird.' I wanted to learn more about how they lived and how they interacted with each other and the environment." (CFL2)

"It made me think about the behaviors more...what time of day birds were coming or if different food was being put out...It made me think more about the timing of birds' arrival to feeder and thinking more about displacements." (BBP2)

"Started looking at it from a different perspective....[e.g.,] hierarchies and displacements…'Was it a time of day, were there bananas?'...taking a deeper look and referencing things that were brought in by [Dr. Miller]. I would have never thought about that...I got to wondering how much influence the humans had on birds coming to feeders. [There were] lot of questions going through my mind…[wanted to] keep watching to see if there were different correlations/connections." (BBP3)

"I think it helped develop critical thinking...better critical thinking as opposed to just observations." (HH1)

In addition to having an impact on their experiences observing birds during the investigations, there is ample interview-based evidence to suggest this new-found interest in bird behavior was spilling over into observations they were doing at home.

"I have tons of bird feeders at my house—have looked at some of the birds there and sort of look for some of the same behaviors, displacement and stuff, that I never really focused on or thought about before. Now I seem to notice it more when I'm looking at the birds here…You see birds interact all the time, but then when you see them in a short span of time on the camera you get to see a lot more about how they how they interact and how...different birds can get along with each other versus similar birds kind of fight with each of those, those kind of things you don't necessarily always think about." (BBP4)

"I am more interested in the whole idea of the dominance hierarchies and so I've been trying to learn a little bit more about that on my own...and then as far as behaviors...every time I'm outside I'm sort of looking at these things that I've been involved in on the screen." (BBP7)

"Thinking about the birds and the interaction, that really was the mental stimulus that made me really think about it…we studied the birds in our backyard at our feeders and were they having displacement activity?" (BBP9)

PARTICIPANT INSIGHTS

"[It] kind of helps you to try to look at the bigger picture of birds. I think sometimes as a birder you kind of get into [mindset] - 'I want to see as many species of birds, every day,' but you don't really get learn to appreciate the birds as much…Instead of just observing birds you're seeing the interaction of the birds and then how they interact…Now I'll see a bird and say, 'oh there's a displacement!' Think it's made me a better observer in my regular birding." (BBP5)

"Going out into nature and observing the behavior and witnessing the displacement or not…There's an area where there's a fruit tree which draws many songbirds and I would just go there to observe to see what kind of birds are attracted to the food…and what kind of interaction. I'm like, 'Oh, that's…an unsuccessful displacement'...You just learn more by doing...Then I started to see nests, as they're being built... so just being curious. Increasing my curiosity to go outside and understand more of my own world and the more you learn and know some behavior of birds. (HH12)

"I did genuinely learn about displacements and micro-aggressions and things like that and so when I'm watching the bananaquit over here and the this other one over here…I'm now thinking in terms of what I learned in that project. I think that I'm actively seeking kind of replicating the kind of investigation and curiosity in my everyday life." (HH6)

On the whole, data suggest that participation in Bird Cams Lab investigations was sufficient to generate gains in participant knowledge. Furthermore, the findings suggest different knowledge-related outcomes based on different styles of participation.

Gains in Science Knowledge and Skill

Bird Cams Lab taught participants to identify specific bird species and bird behaviors – skills they needed in order to contribute to the project as data collectors. Bird Cams Lab also sought to teach participants the skills needed to be involved as co-creators in other stages of the research process, including framing research questions and interpreting data. Two additional survey questions addressed these skills. One of these questions asked participants to determine whether a list of research questions was answerable or not using footage from the bird cams. The other question asked the participants to interpret a chart and verify whether or not a list of statements was supported by the data presented. Participants could receive partial credit, depending on how many of the questions and statements they evaluated correctly.

Science Knowledge and Skill Gains for Active Contributors versus Passive Participants

Active contributors did not do significantly better on the chart interpretation question, but they did do significantly better identifying which research questions could be answered using cam observation data. The increase, however, was very small, due to a high score on the pre-survey. Passive participants did not show any significant gains from pre to post on these science skill questions.

"If you watch for just a few minutes or half an hour I don't think you're seeing patterns or learning as much as you would if you're there to see the interactions over a longer period of time." (HH9)

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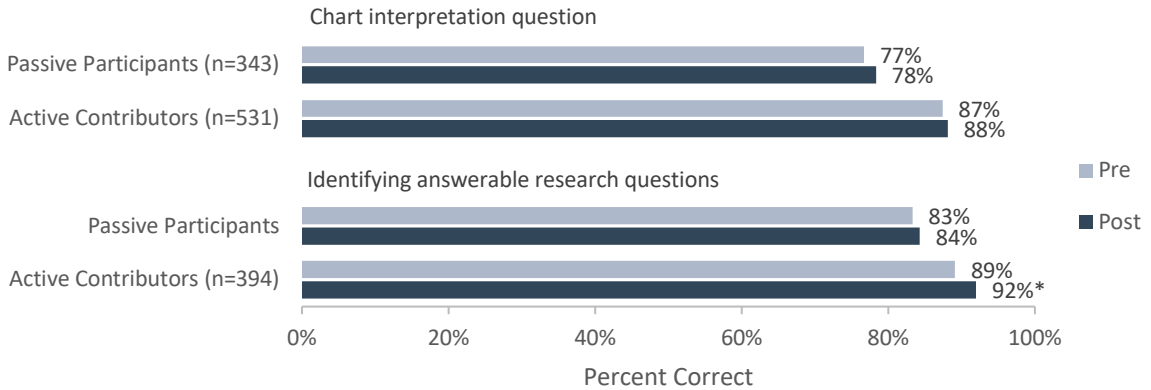
Did your experiences provide any opportunities for learning about science or how scientific research is done?

"Yes…sharing the results and the outcomes of those [studies]…and putting that data together. It's one thing to have anecdotal information by watching the cam or just even tagging this, that, [and] the other, but to correlate the tagging within…seeing the output and [doing] your part of it. Yeah, it does increase your knowledge on a higher level of just, I like to watch birds. It does, it makes you grow a little bit in your head…makes you see a much bigger picture. (CFL1)

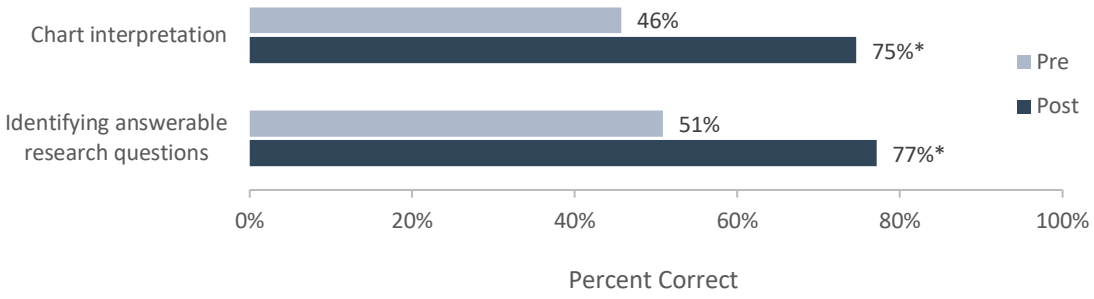
Figure 34. Performance on Science Skill Questions – Active Contributors versus Passive Participants



*indicates significant pre/post change ($p<0.05$)

When separating those with higher and lower pre-survey scores on the question that asked them to select cam-observable research questions, the gains from pre to post are much more discernible. When we focused on those who did less well on these questions on their pre-surveys (those who scored 60% or less), we found significant improvement on both of these science skill questions.

Figure 35. Performance on Science Skill Questions – Active contributors who scored a 60% or less on pre-survey



*indicates significant pre/post change ($p<0.05$)

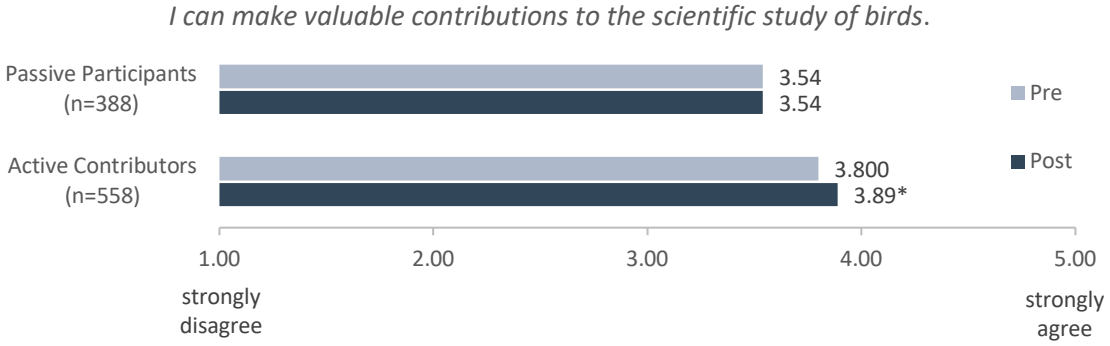
Science Knowledge and Skill Gains Based on Breadth and Intensity of Participation

Performance on these two science skills questions was not found to be linked to the breadth of a participants' experience (i.e., how many stages of the investigation they had contributed to), the number of investigations they had taken part in, or the intensity of their involvement in the related research stages. For example, those who had taken part in multiple aspects of the question design process did no better on the question identifying answerable research questions that those who had taken part in just one aspect of question design.

Lay Audiences' Beliefs About Their Ability to Contribute to Science

In addition to showing some slight gains in the science skills, active contributors to the Bird Cam Lab projects showed some slight but statistically significant increases in their science confidence. When asked to rate their agreement with the statement, "I can make valuable contributions to the scientific study of birds," active contributors showed increased agreement from pre to post, while passive participants' scores did not change.

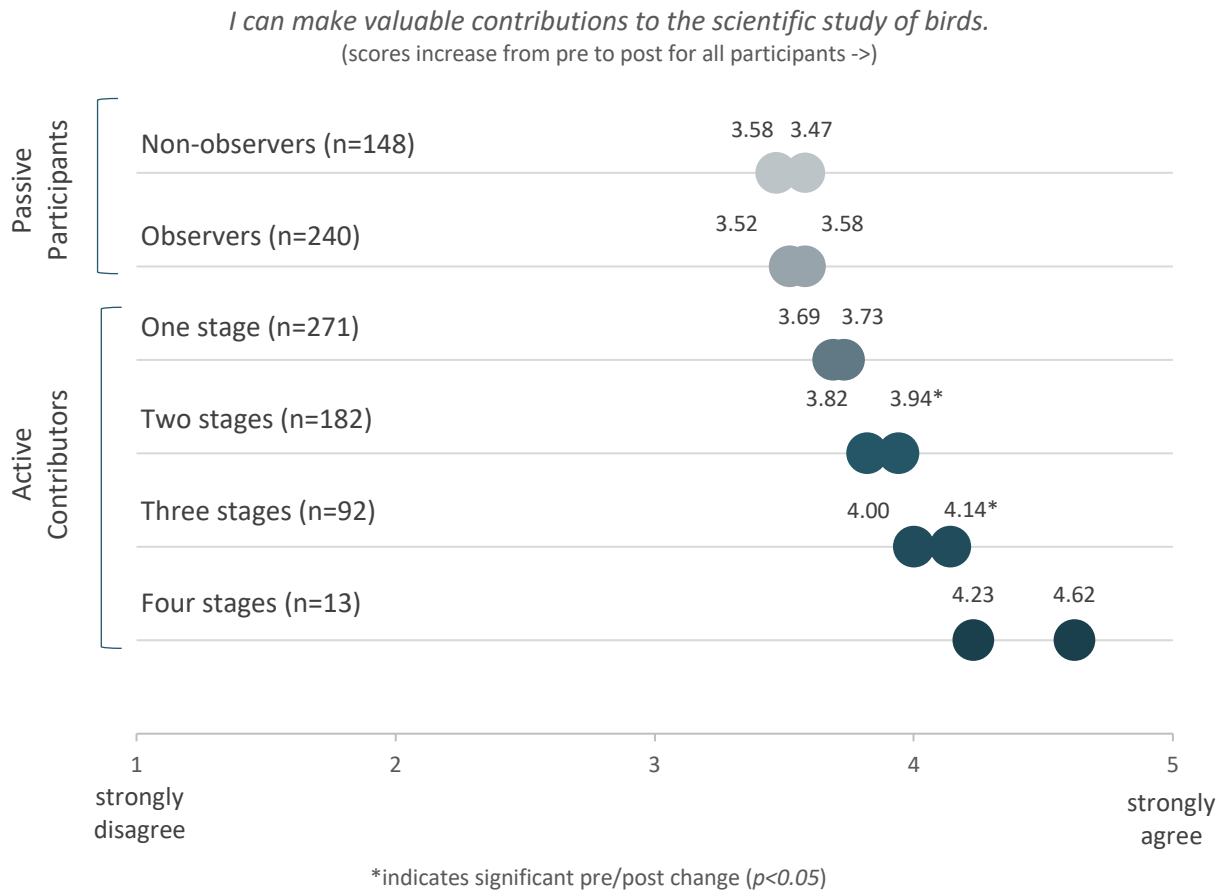
Figure 36. Participants' Confidence in Science Contributions – Active Contributors versus Passive Participants



*indicates significant pre/post change ($p<0.05$)

Looking at the changes in agreement with this statement as a related to a participants' breadth of involvement in the investigations showed that those who participated in more stages of an investigation were more confident to begin but also showed greater increases on their post-survey.

Figure 37. Science Confidence as Related to Breadth of Participation

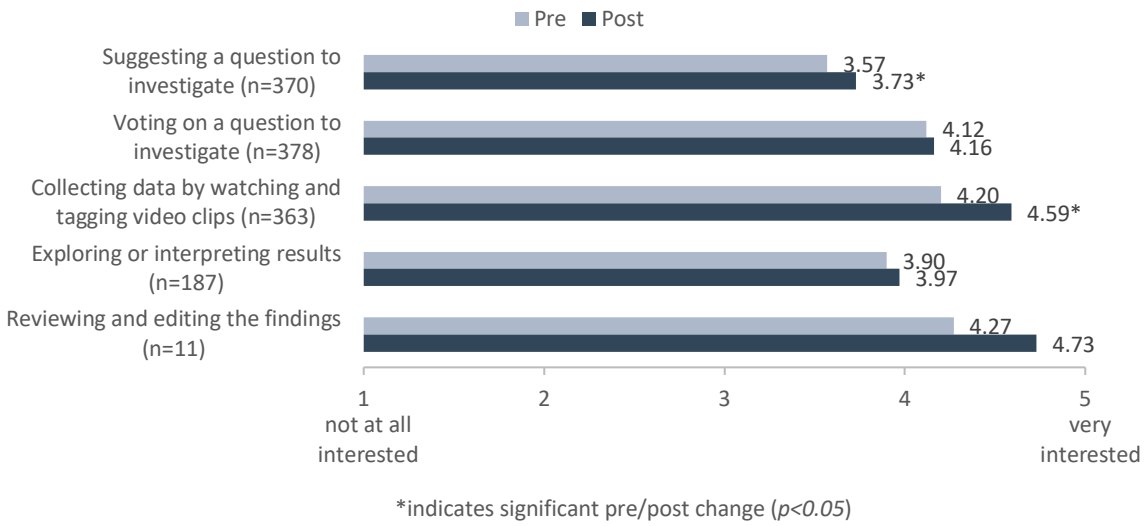


Gains in Science Interest

Additional questions on the pre and post-surveys asked participants about their interest and confidence related to science. We were interested to know, does participating in Bird Cams Lab investigations increase participants' interest in the scientific process? Do participants feel more comfortable contributing to science after taking part in a co-created investigation?

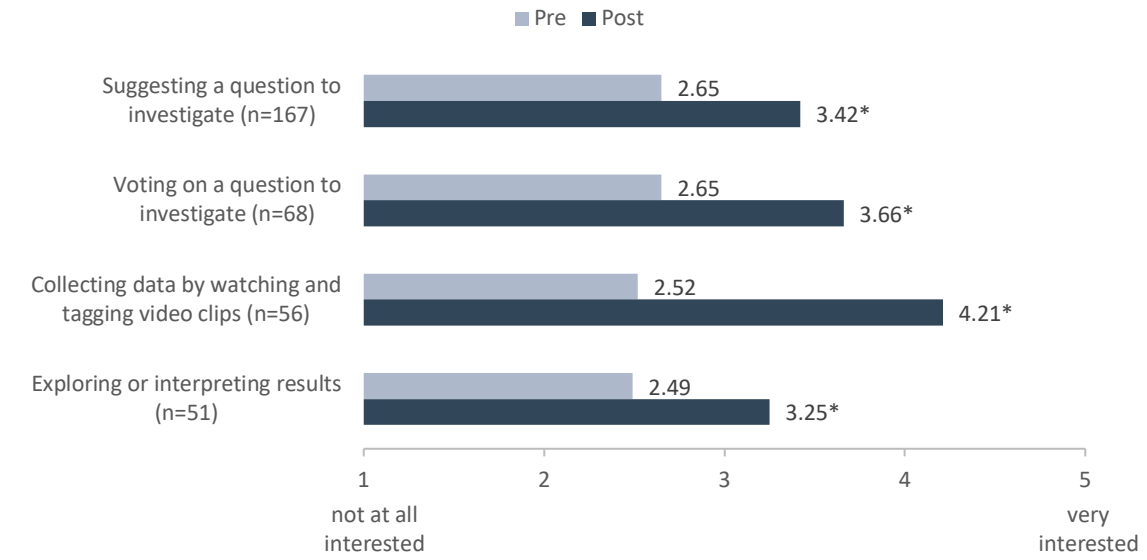
Our findings regarding participants' science interests were similar to our findings on birding behaviors—many participants had fairly high interest to begin, again, leaving little room for growth. Nonetheless, those who took part in the question design stage of the investigations showed a small but statistically significant increase in their interest in suggesting a question to investigate. The same is true of those who took part in data collection.

Figure 38. Changing Interest in Steps of the Scientific Process



When we looked at those who had a low initial interest (not at all interested, not very interested, or neutral), we saw significant increases across the board.

Figure 39. Changing Interest in Steps of the Scientific Process – Focus on individuals with low initial interest



(Interest in "Reviewing Findings" is not depicted in the above chart, as the sample size for this group was too small to detect significant differences.)

How and Why Science Knowledge, Skill and Interest Changes May Have Occurred

Interviews with participants provided insights into the ways in which the Bird Cams Lab experience had impacts on participants' science knowledge, skills, and interests.

> *"I get pleasure in learning things, and especially about birds. I've actually learned a lot since I've been doing this because...observing birds online has led me to observe birds in person, and I'm getting a lot better at it, and understanding a lot more about my own environment." (BBP10)*

Participants' understanding of the scientific method

Some participants gained understanding of the scientific method, whereas others felt that the Bird Cams Lab experience was a good refresher for something they already felt well-versed in.

> *"I know instinctively that people can do science, but it's just really refreshing to see that all the way from beginning to end….[I] gained a stronger appreciation for this whole process and that anybody really can do it." (HH5)*

> *"It was all about the scientific process. You know, I didn't know anything about how these projects, got started but then after watching the webinar and then participating in parts of the Panama Battling Birds and then the Cornell one…t's such a good 'give and take' of really great ideas and how to go about studying it, what to study and then how to go about studying, what ended up being you know the focus of the project...it was all about how the research is born. I mean having been in the medical field all my life I understand how important science is. But this has given me, I guess, a higher respect and regard for how much thought and processes have to be gone through before the science is even able to start. There's a lot more background from the beginning that I think guess I never even really gave it a thought, until these projects came up." (HH11)*

> *"It made me feel very glad to know that I still sort of understand the scientific method…[It] was fun to see how science is moving to include technology and video. I just enjoyed watching the different birds and that but as far as the scientific method thing I felt like all along I understood what was going on." (BBP9)*

A key area of growth in science knowledge and skill was related to strategies and considerations for generating effective and answerable research questions. Participants also gained an appreciation for the complexities that are sometimes inherent in crafting a good research question.

> *"I learned how to craft a question...like what questions to ask...which…is a skill that I've taken into the rest of my life...how to talk to people in a way that engenders engagement...I have become more practiced in being more aware that other people see things from a totally different perspective...so when I talked to other people just in general I listened differently. I listened to their responses, I consider what they find interesting." (BBP1)*

> *"I feel like you learn a little bit just thinking about the questions and how they're designed and...how to design a study that you can get meaningful data out of. I think you don't really think about that too much until you actually participate in one…it's like how the scientific process works because you have to come up with...some kind of a theory that can then be tested and checked on. So that was interesting." (BBP15)*

"It helped me to understand the power and the limits of the process of developing a question that could be answered using quantifiable data." HH8

"The more time you spend doing something, the more you learn about it. But I also think that I learned a lot more about the process of it. I learned more about how to approach and how an investigation like this might be approached, where I might not have thought at all about, okay, 'here's a question about bird aggression at the bird feeder, what do we want to look at?' and I wouldn't have thought before about what is possible to look at given this format. And that's a huge part of constructing an investigation or an experiment...that got me thinking in a different way and I liked that I felt like I had learned something more about the scientific process." (HH6)

"I still wouldn't say I'm comfortable with trying to come up with the questions or how to start a study, but at least, watching the Panama one and now the Cornell bird feeder one kind of… It gives me a little better footing on how the science starts. I guess how a project gets started and how much thought goes into it. I didn't realize how, like every time somebody came up with a question, they had almost like...there were 10 more questions that were born out of one, one thing that somebody asked so it was fascinating to me and I look forward to being able to do more projects like this." (HH11)

Participants also learned the importance of setting aside preconceived notions and beliefs. When asked if they had learned anything new about the nature of scientific investigation, one participant explained*, "I think you have to be open...Sometimes I get a little closed...I'm more aware of trying to look at all the possibilities and not just my predetermined thoughts" (BBP3)*

"I've learned to change my expectation, and even maybe not to have an expectation, because I had no idea. Some of the things we're very surprising to me that I found out. So I think that must be crucial from a scientific point of view, which is, you know, not to color what you're looking at because it could take a whole different format that's unexpected so you need to be open to it and that's easier said than done….Neil deGrasse Tyson has a quote that I'm sure I'm misquoting that I love; He says 'you know the thrilling thing about science is to know just enough to know that you don't know anything'...I think that's such a great scientific way to think...we want to be confident in what we're doing and expressing our opinion and moving forward…but we have to always be open to the fact that we just don't know. And we need to be open to learning and discovering….You know the discovery is thrilling...that I can be this age and at home and in my computer and be a part of this community, the scientific community that is discovering things. I just I can't say enough about how profoundly impactful that is just for me individually." (BBP1)

Lastly, in addition to the examples above that illustrate <u>how</u> participants had gained science-related knowledge and skill, many expressed their beliefs about <u>why</u> this was important.

"An understanding of science is really important...because I feel like it feeds these other things where you can make the world better if more people understand science." (HH2)

Changes in Participant Behaviors

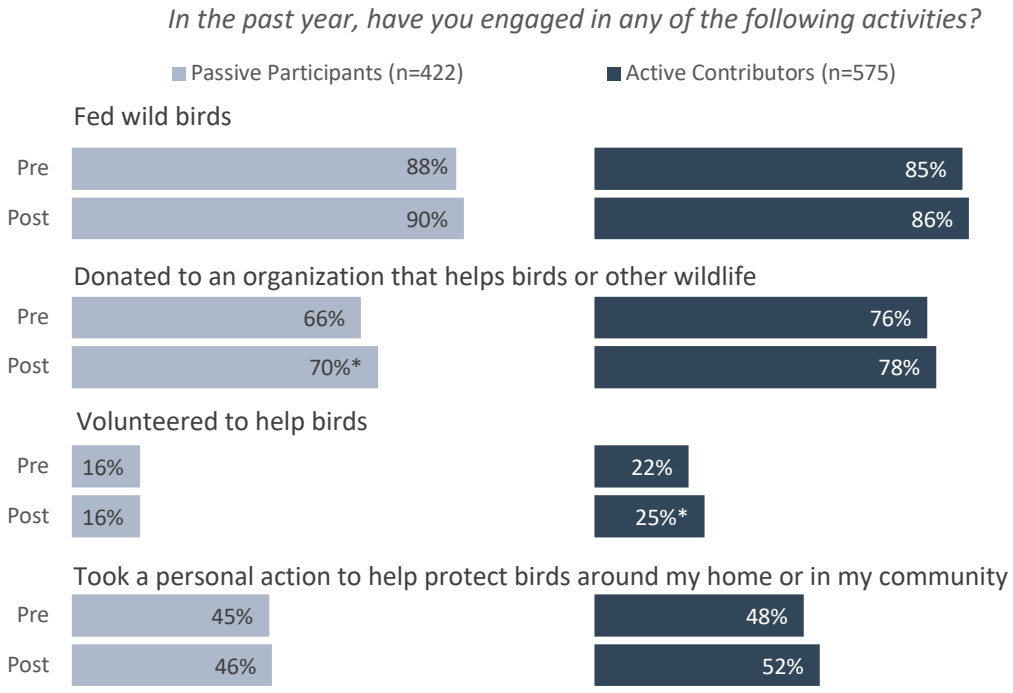
In addition to looking at gains in participants' knowledge and skill related to birds and science, the Bird Cams Lab team was also interested in changes in participants' behavior—including both bird-related and environment-related behaviors.

Bird-Related Behaviors

Most Bird Cams Lab participants were already interested in birds prior to their involvement in the project, and as such, we did not see great changes in bird-related behaviors between their pre- and post-surveys. Certain behaviors—such as feeding wild birds—were already common among survey respondents in the pre-survey, leaving little room for growth. Others were low but still did not show much shift. The one exception was volunteering to help birds. The number of participants who engaged in this activity was significantly higher on the post, but the increase was still just three percentage points. There were some differences in birding behaviors reported by active contributors and passive participants, however. On the whole, active contributors reported a higher number of bird-related behaviors on their pre-survey than passive participants; however it was the passive participants who showed an uptick in donating to organizations that help birds or other wildlife.

We also found little correlation between these outcomes and the breadth of a participants' involvement in a single investigation, the breadth of their involvement across multiple investigations, or the intensity of their involvement in a single investigation phase.

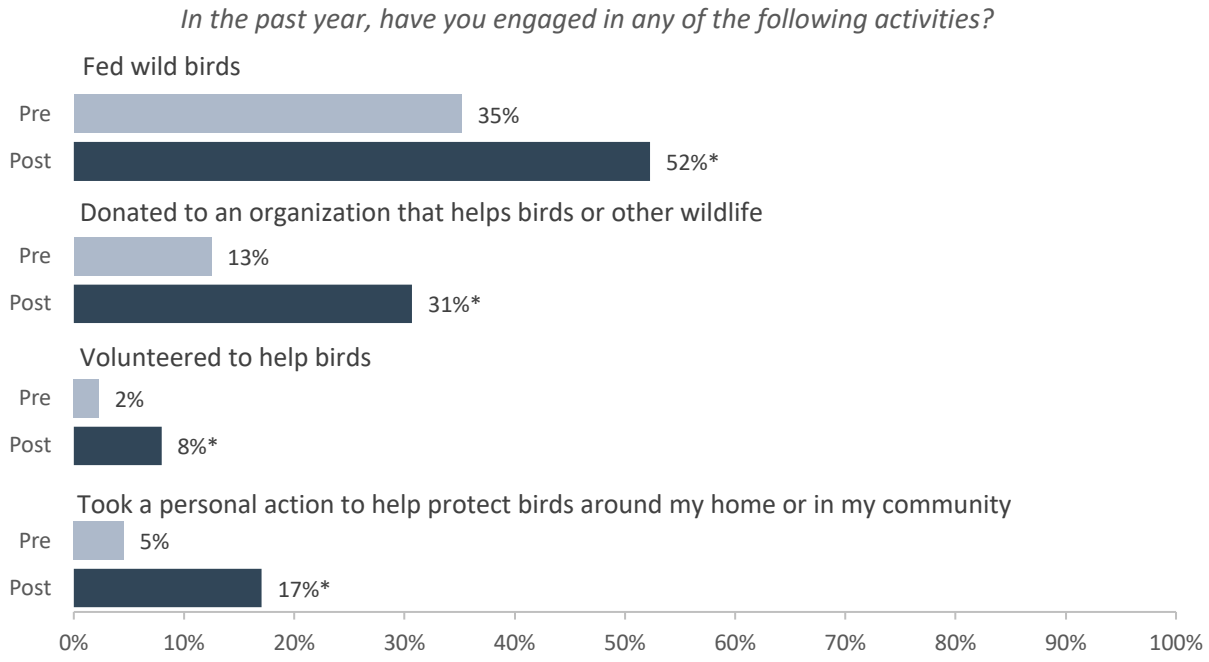
Figure 40. Change in Birding Behaviors – Active Contributors versus Passive Participants



*indicates significant pre/post change ($p<0.05$)

However, those who came into Bird Cams Lab with less bird-related experience did seem to show a shift in their behaviors. We divided participants into "low" and "high" groups based on how many bird-related activities they selected on their pre-survey in response to the question, "Which of the following activities did you engage in during the past year?" Those who selected three or less activities were placed in the low group, which represented just 9% of participants (88 individuals, N=995). Ninety-one percent of participants had done four or more activities on the list, and were placed in the high group. When we focused on just the low group, we found that these individuals did show a statistically significant increase in their birding activities from pre to post, including feeding wild birds, donating to an organization that helps birds or other wildlife, and taking a personal action to protect birds.

Figure 41. Change in Bird-Related Behaviors – Focus on those with fewer initial bird-related activities (N=995)



*indicates significant pre/post change ($p<0.05$)

Impacts on Other Bird-Related Behaviors

During interviews, participants talked about a wide variety of different activities they had done related to birds, ranging from looking up more information about birds, to doing more birdwatching. At least one participant noted that she had also installed more bird feeders at her home.

Looking up more information about birds

Interviewees shared examples of things that they had done to learn more about birds—either in response to things they were doing for a specific investigation (e.g., tagging data) or simply because they were curious.

"I probably looked up some things about the birds, I was curious about the goldfinches and whether they migrate or not and look that up and, you know, things like that." (CFL4)

"I definitely did a lot of research to try to figure out the different birds and learn more about the different birds—to make sure I was identifying them correctly. [I] did quite a bit of reading or research." (CFL8)

"As questions came up—I found myself researching more…doing online searches and trying to become more familiar with topics." (BBP7)

Birdwatching

The experience of participating in Bird Cams Lab also motivated participants to do more birdwatching out in the real world. Some felt that the skills they'd gained in identifying birds a part of the investigations transferred to the birds they were seeing in their local environments.

"I'm doing a little bit more birdwatching on my own, and then I was getting a little more successful." (HH7)

"I found a pair of binoculars…The case was dusty, nobody had used these in a while. They were…tucked behind a piece of furniture, so I took them out and I've been using them when I go out for a walk…I'm looking at the birds more." (HH8)

Impacts on Environment-related Behaviors

The Bird Cams Lab experience led some participants to take additional actions related to environmental conservation and activism.

"[I] got more interested in things in my community. I have gotten more involved politically...it moved me to be more aware and then to take action." (BBP1: Note: she went on to explain that she'd called her senator to comment about the Migratory Bird Act)

"It's getting people, overall, interested in the birds...and the environment...and the climate and larger picture." (BBP3)

"It makes me want to get outdoors and look at birds in real life...I think it's made me more conscious of like some of the waterways in my area are just not pleasant looking and I am curious about the relationship between the health of those waterways and the birds." (CFL2)

"Trying to educate the public more on birds and increase interest in birds...and increase empathy for birds because of all the issues birds are having right now. Letting people volunteer and participate is great because they feel like they are a part of it...Education is one goal, and increasing interest and empathy in birds and their plight and maybe...getting people involved… makes them feel more personally responsible for birds." (CFL5)

"The more people that participate in that project...the more knowledge there is about birds...the more it becomes a global issue...It's not just one person who likes birds, it's watching the camera or watching their own feeder, I think the more people that get engaged in this process, learn

more and share more. So it you know it makes a big difference in the overall information that's published about birds." (CFL1)

"I think that the knowledge that will lead to the improved conservation of habitat of how human beings, interact with wildlife out there." (BBP10)

Some participants noted direct impacts that the experience had had or would have on their work-related or volunteer activities related to birds and environmental stewardship.

"It would help me directly in my work as a land steward...I do a lot of outreach with what we call 'Walks and Talks'...so it allows me to disseminate better information to those participants." (HH1)

Other Lasting Impacts

Fostered a sense that contributions to science can be made by lay audiences:

"I think I'm actually more hopeful now than I was going into it that there can be these types of projects that are able to be done at distance on a big scale with a lot of people participating from all over the world and that it's not just you have to be an accredited, you know, you have to have your PhD and all this other stuff to be able to participate. My own personal journey took me to a place in a different direction, this is a way of me sort of recapturing that where I ultimately want it to be. I'm going to start crying a little bit, but I really, really did it made me feel really good... It made my day brighter. I guess every day...It felt like I was contributing to something greater than myself." (HH6)

Fostering bird and science engagement in next generation:

"I am trying to get my two granddaughters who are six and seven to get involved in birding because I'm so excited about it. And whenever they come, you know, the feeders are always filled with birds. So, you know, I've given them journals and provided them with materials they use my binoculars and there have been age now where they're more interested you know when I tried when they were younger, it did, you know, it really, it didn't interest them, but I'm trying to pass on that experience to them, because it's it gives me a great deal of pleasure." (HH9)

PARTICIPANT INSIGHTS

EVOLUTION FROM READER TO LEADER

"I live here in New Braunfels, Texas, and there's a place called Landa Park, which has a lot of variety of bird species there. And I had noticed that we're getting just a variety of different birds coming in. And so I started doing research on like what's going on with all this bird activity that we're having. And so then I said, I'm going to really start getting into learning more about birds I want to find out about their activities and is there, because we're getting really large birds here, like we got the Great Blue Heron that we've never had before and then we're been a lot of parents that we haven't had and, and the white cranes and just things that are I've never seen ...And I was noticing the change in the bird environment here and I'm going like is there something going on with the ecosystem that... I wanted to research and so I started like watching them their observations ...So then I saw the Battling Birds thing and I was going like, 'maybe I should like look into this and learn as much as I can about what's going on with the bird system.'"

"I'm definitely an advocate...and I am sharing the information about...all the webcams that are available. Also Zooniverse, and then sharing the data with a lot of people, especially the senior citizens' community. I work at a adult senior living place...they have an activities director there and so I've shared with him, what I'm doing...he's asked me to actually come and like share what I've learned and share the Merlin app and show you know show the different birds and we were going to do a bird walk around the whole premise and see what kind of birds we can identify. And so just bringing in the senior citizens into getting more involved and seeing if they would like to be interested in getting involved with live cams, and just sharing with as many people as I can, who might be interested in in growing their knowledge of the different birds that there are here in the area...And so yeah, I'm trying to be a local advocate of what we have here and connect it to you guys there and see if we can get more and more people involved." (CFL12)

PARTICIPANT INSIGHTS

SPREADING THE WORD

"Not only am I totally hooked, but I've gotten all of these other people hooked. I told a friend who's a teacher who teaches Environmental Science at a local high school and she now has a bird unit. It was fun for me to have shared the thrill and inspired others….I was hearing from teacher friends how challenging its been to be a teacher [due to the pandemic], so much shifted to online." ...so she offered ideas about how to incorporate Bird Cams Lab, "I called every teacher I know in every discipline...its a great way to enter the world through birds, through investigation...understanding our responsibility to protecting our world. I'm also active in my community...exposing people to opportunities at Cornell and on Zooniverse...I even had my grown up kids doing it….I've gotten more assertive in wanting to share the information because... it has enriched my world so profoundly." (BBP1)

RECOMMENDATIONS AND BEST PRACTICES

Over the lifetime of the Bird Cams Lab project, the team sought to develop and test various strategies for effectively facilitating co-created research. Techniques and tools were honed during the formative stages of the project and implemented more consistently during the final three investigations. In this section, we present a summary of findings related to participants' recommendations and knowledge gained in regards to best practices for co-created research.

Good Facilitation Skills Are Essential

Participants shared many comments during interviews that suggest the great importance of facilitation. They readily acknowledged the care taken and efforts made by the team of scientists from Cornell to help ensure that Bird Cams Lab investigations were both a positive experience and also capable of generating positive scientific outcomes.

Setting the right tone

Participants appreciated the fact that the Bird Cams Lab facilitators kept things positive, fun and educational.

> *"You have to be open to what you know kind of interest to other folks outside...I thought they did a good job of trying to...balance what would be a good valid scientific question to research with...Some comments you could tell it just wasn't something that we could measure I thought the bird cam contributors did a really good job of...encouraging people to say whatever they wanted to talk about...throw whatever ideas they had and they really did a really nice job I thought of saying, well, that might be hard to measure in a certain way but...they kind of helped steer people...rather than just say, 'Well, we're not going to do that' they tried to find ways to blend what was of interest to people outside Cornell with what they thought they could actually do in the project being that they were more familiar with their tagging data requirements and...how they set that all up because when we were doing he design of the questions they kind of gave us a vague idea of what the limitations of the data collection but you got a better appreciation of that only after they came up with the questions…It seemed like one of the biggest challenges was just trying to help non-scientific community members come up with a topic that you know they could actually research." (CFL11)*

> *"Got you excited to get started and doing the observations and just have fun with it. If it's not fun, people aren't going to participate. They did a good job making it fun." (BBP5)*

> *"As an amateur, it can be quite intimidating to assert ideas or to ask questions to scientists and experts. I am so pleased to feel the opposite—the webinars, the comment boards during data collection, questions regarding the peer-editing process, and direct communications with the Cam Lab Team—it has felt that my questions and input was valued, taken seriously, and appreciated. I also really loved seeing the comments and suggestions of participants included in the final data overviews and results. It's incredibly motivating and inspiring to feel truly embraced as part of a community that includes both revered experts alongside citizen-scientists." (HH6)*

With Bird Cams Lab, most participants assumed that the work being done had value, but there were strategic things done by the team to communicate that fact to everyone involved—by email, posts to the website, and during webinars—and that was appreciated. As such, one takeaway from this project is that it is important not to assume that participants know they are having an impact. Participants also commented on the facilitators' ability to make participants feel like they have something to contribute, no matter their skill or knowledge level.

> *"It's okay if you don't get everything. You know, that's okay because we're not professional ornithologists and stuff like that so that was really, really nice...It makes you want to participate because no one seemed critical." (PPB5)*

> *"The team is very intentional and you can tell that the purpose is actually to make sure that we are all involved and have potential to contribute make suggestions." (BBP7*)

> *"It seemed as though what we collected was something that [Dr. Miller] could, you know, connect to what he had been studying in North America. And it seemed as though from the webinar that we had that, that, that our contribution had some value." (BBP7)*

> *"You feel like you have value…and something that you have to offer...everybody gets to participate and there's no, I guess, dominance...it's just a comfortable environment to work in where you can be free to express yourself and be involved without any kind of intimidation." (CFL12)*

Timely and Effective Communication

Participants appreciated the timely responses of project facilitators and felt that was an important element of effective facilitation of co-created research.

> *"The engagement of the team was exceptional, makes me feel as though I were part of that study. I tried other co-created projects and it was not as easy to feel as connected...Throughout every step it felt as though the Cornell team was accessible. If you made a suggestion for a question to investigate they were always responding. Regular presentations made the projects feel very engaging." (BBP2)*

Participants also appreciated the fact that facilitators set and communicated expectations clearly.

> *"I think the team was very good at checking our expectations and making sure that people understood that this was not going to be the end all be all studies of birds….And so I think that in this respect I learned about how to basically manage applications and how to communicate to people in this style study to kind of make sure that people were still willing to participate, even if they didn't get exactly what they wanted." (CFL6)*

> *"Webinars were fascinating because they did such a job explaining what the process would be, expectations were, what get out of it. Didn't have problem but had sense that if I did, help was there." (BBP5)*

> *"They clarify very well what's expected of us, what we can do, what not." (HH12)*

Likewise, participants appreciated that facilitators kept momentum for an investigation going throughout, and not only kept people apprised of the progress being made, but also let people know if there was going to be a lull, e.g., during the data analysis and reporting stages.

> *"It's really exciting to get those updates and say, 'Okay, so now's the time to post your questions or some of the things that you want to learn, here's a survey so we can start calculating everybody else's responses…here's what we're going to pursue based on what everybody voted for…and now we'll start the data collection'…I like having those updates and like [that] you're almost achieving milestones along the way as the project, is going." (HH5)*

> *"They really say, 'Well, we're doing this because of this, and this is what we're hoping to do.' And they keep coming back and explaining things and making it very easy to access…But if you don't tell your participants what your intent with the research is, 'what are you trying to gain?' then you limit the ability of the individual participating to contribute towards that set of objectives….you need to help channel that input that you're receiving and you do that by setting, here's what we want to know. Here's what we're trying to gain—a better understanding and you can help us because you're going to look at it differently than we do." (HH12)*

Facilitating Discussions

In addition to effectively communicating information to participants, facilitators also played an important role in facilitating communication between participants. Team members found that it took a fair amount of time and skill to facilitate discussions effectively. Even then, it proved challenging to foster the type of engaged conversations the team had hoped for. The lack of critical mass and the temporary nature of investigation experiences were potential hindrances to more engaged conversations among participants on the discussion boards. Only a handful of participants, out of the dozens that were interviewed, had participated actively in the discussions. When asked why they hadn't participated more fully, several noted that they didn't feel like they had anything to contribute, some felt they didn't have the requisite knowledge to contribute productively to conversations, and a few faced technical challenges.

> *"I got to know other people that show up regularly...I feel pretty comfortable. I don't always comment until I see where people are going with a thought or idea…just because I'm not an internet chatter." (BBP3)*

> *"Once I kind of got used to this idea of doing it all online like this and realizing that your conversation may actually be taking place over a longer period of time as you come back and check what's going on in the discuss it was it was a nice way to share our ideas and our thoughts. And in some ways, probably better than when you're just sitting around a table and maybe one person starts doing all the talking. You know, this was a way I think it was, gave everybody a chance to really contribute." (BBP7)*

> *"When people post questions whether they've been around a long time or whether they are new [they guide] us very well…Its a good community to get feedback without the feedback being harsh...it's pretty welcoming. Some have way more experience than I do but don't flaunt it. There seems to be high level of respect for everyone." (BBP3)*

PARTICIPANT INSIGHTS

FOSTERING MORE ENGAGEMENT IN COMMUNITY DISCUSSIONS

One participant provided additional thoughts about why he felt the discussions lacked higher levels of engagement: *"I feel like there was not enough participation to actually generate discussions…where people actually would go back and forth...There was kind of this Q&A format where someone would have a question and someone who knew quite a bit [would answer the question]. Felt like: 'oh, this is a good place to talk about what we're doing'...it never felt like a discussion board per se."* When asked if he had a sense of what might keeping people from participating in the discussions, he explained that there were simply not enough people participating, *"it's the kind of thing where you need, maybe, at least, 100 people to sustain a conversation."* He also noted the finite nature of the investigations as another possible reason there wasn't much discussion taking place. *"People were there because they enjoyed the process of tagging...right? It's kind of fun it's kind of enjoyable you get to watch birds and all that....I don't know that they were necessarily interested in creating a community that can gather and talk...And maybe the other thing is that it is very clearly a finite engagement...there is a beginning and then there's an end. There's not really any promise of this being an ongoing thing or an ongoing platform for engagement. It's not like some of the other YouTube Bird Cams I follow...these are people that come again every single day, and they know each other and they enjoy this this interaction. For this project it very much felt like we're coming together for this specific purpose, and then we're done. There's not going to be any kind of follow up or there's not really any reason for us to get to know each other." (CFL6)*

Even though they weren't directly interacting with each other, participants did come away with a sense that they were a part of a community. For example, one participant explained that they hadn't participated in conversations because *"I'm doing this late at like three or four in the morning and I don't know who's up in order to be able to converse with me at that time so no I never did get a chance to interact with anybody other than the, you know, the birds on the bird cam."* We asked if they would have had had a sense that they were part of a community, even though they weren't engaged in conversations directly with other participants on a regular basis and they responded, *"Oh definitely, the emails…felt like it was going to a family or a group of friends more than, you know, just a sterile scientific research thing. I felt like we were valued more like a...group of friends, more than you know just people around the world doing computer stuff." (HH11)*

Setting Appropriate Constraints for Investigations

Another key role of the facilitators in these investigations—according to participants—was their ability to set appropriate constraints for investigations. Providing the right **constraints** helped to ensure that the questions being answered would ultimately help to advance scientific knowledge.

> *"If the goal is scientific knowledge generation, people understand need for constraints." (CFL6)*

> *"You realize that there were going to be limitations based on the platform you are using. Once you knew that, it was clear that you'd think about types of questions…Having gone through that process of developing questions…the idea of something testable...[or] feasible…was straightforward." (BBP7)*

Lastly, where facilitation was concerned, participants recommended giving people time to acclimate to the tasks and giving feedback about how they are doing. Most participants understood the measures in place to enable robust analyses even when data might be entered incorrectly, but participants still really cared about doing a good job.

Live vs. Archived Investigations

Over the lifetime of the project there were both investigations that incorporated live data tagging and data tagging via archived video footage for each of the three cams. We did not, however, seek to compare these live and archived data-tagging experiences because there were many other factors that contributed to the experiences that participants ultimately had within each investigation. Nonetheless, in more general ways, the Bird Cams Lab project provided opportunities to explore the strengths and challenges of investigations that incorporated live data tagging in comparison with those incorporating archived video clips.

Advantages of Investigations Using Archived Footage

Accuracy and precision of data tagging

Several participants noted that the investigations with archived video clips seemed to allow for greater accuracy and precision.

> *"Could slow down clips…that was genius...some things happened fast. That made tagging possible for me." (BBP1)*

> *"You want to make sure you don't miss anything. I found myself going through the same clip 4-5 times to not miss anything." (BBP5)*

Sense of accomplishment

Some participants felt that pre-recorded clips featured in the investigations making use of archived footage were more conducive to short bouts of participation and therefore lent themselves to a clear sense of accomplishment. For example, some contributors commented how processing archived clips from the Panama cam was more conducive to their participation than tagging live footage with the Cornell feeder cam.

> *"I think I probably spent more time with the Panama, just because it was broken down in smaller increment. And the Cornell bird feeder, where you just sat and watched it was more like, well, 'how long am I going to watch this for?' and I might have gotten a little distracted and cut it off after just a few minutes...Thought would be able to sit there and watch feeder for a half hour at a time...it was hard to sit and stare at a feeder for that long so I reduced my expectations—I can stare at the thing for five minutes but not sure if that's helpful." (BBP10)*

> *"Battling Birds (Panama) was easier because there were ten second video clips; I didn't have enough time for Cornell Feeders Live." (CFL7)*

Data can be tagged anytime

Unlike live-tagging, investigations using archived video footage also enabled participants to make contributions any time of the data.

Challenges of *Investigations Using Archived Footage*

Length of data collection depends on contributors

With hundreds of people engaged in the data tagging process, the data collection phase of an investigation could go really fast or could take much longer. While the number of clips and clip-retirement settings were things that facilitators could control—the overall length of the data tagging stage of an investigation was ultimately dependent on how quickly participants were able to process all the data. The uncertain amount of time necessary to complete the data tagging stage added some complexity to the planning process. It also meant that some participants missed out on the opportunity to contribute in instances where data tagging was completed more quickly than had been anticipated.

> *"I would have logged on a little bit more if I'd realized we were going to run out of it…[I thought I had] a couple more weeks to login and all of a sudden its like 'Okay, we're almost done.'" (HH7, speaking about experiences in PBB investigation)*

However, a data collection stage that goes more quickly than anticipated is arguably better from a facilitator's standpoint—in contrast to instances where data processing could drag on for a much longer period of time. Whether using live or archived footage, the length of time to complete data collection is an important consideration for community engagement.

Advantages of Investigations That Involved Live Data Tagging

Inherent appeals of this investigative format

The key advantage of live data tagging was that it allowed participants to do something productive (i.e., helping scientists collect data) while doing something they already enjoyed doing (i.e., watching live streaming bird cams). Several participants also noted the appeal of looking at things in real time rather than looking at video clips that may have been more than a year old.

Better quality video

Due to the compression necessary for the archived clips that were used on Zooniverse, some participants felt that it was easier to make observations in the investigations that incorporated live data tagging.

> *"Well, one thing I will just say—this is speaking through my fractured eyesight—the live observations, they are a little easier because they're higher fidelity." (BBP7)*

Challenges of Investigations That Involved Live Data Tagging

Limitations to what can be studied

Constraints of the live data tagging format imposed limitations to what could be easily and accurately observed in real time, which in turn imposed limitations on what could ultimately be studied using that format. One participant contrasted their experience with recorded footage of the Panama cam with life footage from the hawk cam.

> *"With the Panama one, it was really nice to have the clips for people to watch because again with that one they were looking at interactions and those interactions happen really fast...so you have to have something where you can pause it and say 'okay, this bird is flying away at this second and this one is coming in'...so that was really helpful. With the Hawk Happenings...that worked for real time because again these behaviors are very obvious...it's not like a super fast interaction where you're trying to get multiple pieces of data about that one second and what's happening there." (HH2)*

PARTICIPANT INSIGHTS

"With live observations you have to pay attention...can't rewind. They are a little easier because they are higher fidelity. Zooniverse have to compress the files so clips aren't huge. They were a little darker and little less clear--bbut you could run them over and over again....Could do that at 10 PM at night…[but]) for live, you had commit to a time something was going to be happening...realized after a few days when a feeding might occur...when chicks might be active. For live feeder, it was important to make sure when there was daylight. If I had a preference, live was my preference." (BBP7)

Participants worried about missing something

With live data tagging, participants were worried that they might miss something. Most came to understand that it was not problematic since others were watching and tagging data at the same time and the scientists would ultimately employ analysis procedures that factored in how many people had submitted a specific observation.

> *"Live is thrilling and interesting but me, I miss things and I want to go back. In clips I know they are laborious, but you can stop rewind and double check something and verify…'Wow—did that really just happen?'...I would prefer looking at little snippets of time in video vs. live….Personally I miss more on the live....when we have recorded ones, some people put in comments, 'did anyone else see this—I can't figure out what is going on'...that helps get more eyes on it. You might see the clip and I see it five days later...other people can weigh in and help clarify what's going on." (BBP3)*

> *"When I started, I was a little nervous because with live, I might miss something." (CFL8) (this participant did note that she was reassured that there'd be other people making note of things as well)*

> *"How am I going to know...be able to see who's in the screen at this time, what if I don't know and you know all these things are worrying that it's live. I don't have enough time to necessarily accurately be able to contribute. But that wasn't the case at all because of the way it was set up, you know, it would open and say okay, I've opened a session, and then I close the session, and*

whatever you happen to see whatever behavior or bird or whatever was ok. So, that eased my own concerns, and made it really fun to see." (HH12)

"It doesn't make it any difference what the time is as long as I have the ability to stop and rewind it and view it. Where if I'm doing it live online, you're only then relaying back to them what you recall, you don't get a chance to review it." (HH4)

Time of day was a limiting factor for some

Live data tagging made it more challenging for some participants to participate due to the time of day they were able to tag data.

"There was a huge time difference...being on west coast...I would have enjoyed watching early birds come...wonder if in the future ...why wouldn't it be possible to...go back to the time I want to see and then collect data?" (CFL10)

"With live cam [e.g., Panama Feeder Live] the sun was setting by the time I got on." (BBP3)

"Live ones are when I'm in the middle of teaching...I'm grateful that the videos get posted and I can look at them later." (BBP3)

"The live data collection element was challenging in a couple ways: my mind would drift off and I'd forget I was collecting data and miss out on behaviors or not end the session; also, the time I was most able to classify data was late in the evening, when most of the behaviors have quieted down, so I felt I could've/should've participated more during other hours, but it didn't work out." (HH12)

Comparisons to Traditional Citizen-Science Models

In contrast to more traditional modes of doing citizen-science (i.e., focused on data collection), participants in co-created investigations have opportunities to develop greater understanding of the whole scientific process, and therefore greater buy-in to that process.

Better sense of research goals

When asked what the benefits of this style of investigation were in contrast to projects where lay audiences are only invited to help out scientists with data collection or data tagging, one participant explained: *"Oh gosh it's a huge difference. It's definitely more engaging and rewarding and enjoyable...It makes you realize the value of what you're doing, and I enjoy meeting people from all over the world, and seeing that, you know, from around the world, people are doing the same thing and we're all engaging together for a common purpose and common cause....you are working together as a team at something like this where you're learning the whole process, and then participating in it...you do feel like you are a research scientist...this one takes it to a whole different level....I'm communicating with Cornell University and I'm just enjoying being involved and connected with you all and your staff and your team and I feel like there's a relationship that's unfolding and you're getting to know people and so it's no longer a separate entity. It's now something...that you can connect with and work on a*

project together for common good. So it's...like there's really a huge difference between the type of projects on Zooniverse and this type of investigation. It's more relational....interactive. And you get to see the results of what you're doing and participating, and that adds a lot of value." (CFL12)

"I guess co-created gives me a little bit of a seat at the table. Instead of just 'here, these are the questions we're going to answer and you're going to answer them this way.' I feel that the people on my side of the table, we're partners, we are active participants...obviously we're not full partner sort of thing. I mean, we're the junior partner at the table, and that was interesting. I mean, it gave it gave me, I think, a feeling of ownership...and more interest in what happens." (CFL2)

"I often participate in Zooniverse projects without having any input to the creation of the study's focus. The subject matter and learning new things is what draws me in to an investigation." (BBP3)

"As a career environmental educator, I consistently have been impressed with constructivist models of learning. Co-created processes usually result in projects that are more relevant with more 'buy-in' by the community. This increases the opportunity to facilitate positive changes." (BBP7)

Greater Accessibility

"It's all about inclusion and accessibility—makes more access for everyone—the results are more accessible to everyone. Some of the [citizen science] research I've been involved in...outcomes can be harder to access...not as easily accessible as it is with Bird Cams Lab projects. There's a real effort to be open and inclusive in all the pieces of the project including—here are the results sharing out with everybody. It belongs to all of us and that feels different for sure...So many people have been excluded from the process for so long—it is important to include people in all aspects of environmental conservation, including research, it's just a reminder to me of who has been left out of process—who needs to be included. Takes away hierarchy of who has the knowledge—who has education and ability and knowledge to conduct research vs. everyone else. Nature belongs to everyone, research should belong to everyone." (HH10)

"Not like it's …'here's a research project go and do this for us.' We're doing this together...you're equally a part of it...your contribution is as valid and important as ours...Have done citizen science projects but it's a different feeling—I'm helping to create this—can be a part as much as I want to [versus]...'here's what we are doing we need your help,' [you] don't have a say.'" (HH10)

"Anything we can do to make conservation...nature more equitable and more inclusive. Whatever you are...whatever your background is, you can be a part of this process. What you have to contribute matters. Historically that has not been the case. Nature and research about nature is for certain people and not other folks. [This is a] good step toward making things more accessible and equitable." (HH10)

Greater Participant Engagement

> *"I get something from Zooniverse about every week now that I can participate in and... those are things that are already set right and they just want a data collector...I'm more interested in the whole process." (BBP7)*

> *"It's important to recognize the value of scientific expertise, and citizens feel more invested when they are part of the entire process of science, from question generation to evaluating results." (HH2)*

CONCLUSION

The goal of Bird Cams Lab was to design a digital space and framework enabling online communities to engage in a co-created scientific inquiry process using wildlife cams to answer bird-related questions of common interest. To achieve this goal, the project engaged participants at every stage of the research process—including observation, generating and selecting research questions, collecting data, reviewing and discussing findings, contributing to data reports, and sharing results with others. In doing so, Bird Cams Lab provided opportunities for bird cam watchers to satisfy their own curiosities, become invested in stages of research that are usually reserved for experts, and bring their own perspectives and experiences to the table in scientific investigations. The Bird Cams Lab project also provided opportunities for the small team of scientists who were engaged in the facilitation of these investigations to reflect on the process of facilitating co-created investigations that make use of wildlife cameras. Through their thoughtful reflections and strategic iterations, the Bird Cams Lab team ultimately developed processes and tools that were effective in supporting co-created experiences for large numbers of participants. The team also succeeded in doing research that contributed to our collective understanding of birds and furthering our understanding of co-created investigations in general.

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APPENDICES

Appendix A: Methodological Challenges

Classifying "participants"

The disconnect between how the project team viewed participation and how participants viewed participation created methodological challenges. In earlier surveys for the project, we asked respondents whether or not they had participated in particular investigations and used their response as a trigger for additional questions on the kinds of ways they had participated. Unfortunately, some survey respondents who the team would consider participants did not self-identify this way, resulting in a loss of data. In subsequent surveys, we did not rely on participants self-identifying and instead displayed all questions to all respondents.

Tracking involvement across different participation platforms

Participation in Bird Cams Lab took place across multiple different platforms. There were therefore many different identifiers that could be used to track participants, including their email address, their Disqus ID, their Zooniverse ID, and their name. Participation data were ultimately extracted from webinar registrations, message boards conversations, data collection log-ins, newsletter sign-ups, and survey responses that sought input during the question design phase. While we were able to link many participants' IDs across platforms, the resulting participation data undoubtedly contained a small percentage of individuals with disaggregated data. If it had been possible to do more linkages based on available data it is possible that the average participation breadth for Bird Cams Lab participants might have increased slightly.

Accuracy of self-reported data

We realized that there may be inaccuracies in self-report data shared by participants. At one point in the formative stage of the project, participants were asked to indicate which stages of each investigation they had participated in; a good number of respondents listed stages that were not included as part of certain investigations. Data from Zooniverse was also compared to participants' self-reported data tagging estimates and large discrepancies were noted in many instances. These discrepancies may have been partially due to participants under- or over-estimating how many clips they had tagged, but we also realized the potential for participants to have been tagging clips without being logged into Zooniverse. It is therefore possible that some self-reported estimates were more accurate than system-recorded data seemed to suggest. Assessments of later studies suggest that participants' self-reported participation in various stages of the investigations was 83% accurate for Hawk Happenings and Cornell Feeders Live, and 90% accurate for Battling Birds: Panama.

Small Ns for some types of participation

It is also worth noting that the number of participants dropped off after data collection, resulting in fewer participants in the analysis/data exploration and sharing/reporting stages of investigations. The lower number of participants in these stages made some analyses more challenging.

Appendix B: Summative Survey Instrument

Participant Info

Your name:

First _____

Last _____

Email Your email address will help us match previous and/or future survey responses. Please provide the email address that you used to sign up for the Bird Cams Lab project, or the address you plan to use when participating in all Bird Cams Lab project activities. Note: we'll use your email address to stay in touch with you about project updates, but your responses to the survey will be confidential.

_____

Participation

Which, if any, of the following activities related to birds and/or science have you done in the past year? (Check all that apply)

- ☐ Fed wild birds
- ☐ Donated to an organization that helps birds or other wildlife
- ☐ Volunteered to help birds
- ☐ Watched birds outside or at a feeder
- ☐ Watched live cams online featuring birds
- ☐ Took a personal action to help protect birds around my home or in my community
- ☐ Read about birds
- ☐ Read science content online or in print
- ☐ Looked up information about birds in online or print sources other than from the Bird Cams website and communications
- ☐ Participated in a citizen-science project
- ☐ None of the above
- ☐ Other _____

You indicated that you watch live cams featuring birds. How often do you watch, on average?

- ○ Only once or twice ever
- ○ A few times a year
- ○ A few times each month
- ○ A few times each week
- ○ Nearly every day
- ○ Daily
- ○ Multiple times every day

Which, if any, of the following activities related to Cornell Lab of Ornithology's Bird Cams or the Bird Cams Lab have you participated in during the past? (Check all that apply)

- ☐ Watched the Red-tailed Hawks Cam
- ☐ Watched the FeederWatch Feeder Cam
- ☐ Watched the Panama Fruit Feeder Cam (on Cornell Lab website or Explore.org)
- ☐ Participated in "Hawk Talk" (Hawk vocalization investigation 2018-2020)

- ☐ Participated in “Hawk Happenings” (Hawk nest behavior investigation 2020)
- ☐ Participated in "Battling Birds" (FeederWatch cam investigation 2018-2019)
- ☐ Participated in “Panama Live” (Panama Fruit Feeder investigation 2019-2020)
- ☐ Participated in "Battling Birds: Panama Edition" (Panama Fruit Feeder investigation 2020-2021)
- ☐ Participated in "Cornell Feeders Live" (2021)
- ☐ None of the above

Bird Cams Lab is a co-created citizen science project. How often do you participate in citizen science projects (other than Bird Cams Lab)?

- o Only once or twice ever
- o A few times a year
- o A few times each month
- o A few times each week
- o Nearly every day
- o Daily
- o Multiple times every day

In past investigations, Bird Cams Lab has classified video clips on a website called Zooniverse. Zooniverse is a website that hosts hundreds of other citizen science projects. Please select all answers that relate to your participation in Zooniverse.

- ☐ I have never participated in a Zooniverse project.
- ☐ I participated in a Zooniverse project before my participation in Bird Cams Lab.
- ☐ I participated in Zooniverse for a Bird Cams Lab project.
- ☐ I have participated in other Zooniverse projects after my participation in Bird Cams Lab projects.

Bird Cams Lab Specific Activities

Over the past three years, Bird Cams Lab has offered opportunities for participants to engage at various stages of the scientific process. To help us understand your unique pattern of participation, please select the stages you have participated in for each of the Bird Cams Lab projects thus far. Please do your best to recall your experiences. We know some took place a while ago!

Battling Birds—Cornell FeederWatch cam investigation 2018-2019
Which of the following activities did you engage in for this project?

- ☐ Observe—Watch the live cams
- ☐ Question—Suggest or vote on a question for investigation
- ☐ Collect—Classify video clips by tagging events, behaviors, or species of interest
- ☐ Explore—View, discuss, or explore graphs and data
- ☐ Review Findings—Read, edit, and gave feedback on the final report
- ☐ Share—Share findings with someone else
- ☐ None of the above

Hawk Talk—Hawk vocalization investigation 2018-2020
[same list as above]

Panama Live—Panama Fruit Feeder investigation 2019-2020
[same list as above]

Hawk Happenings—Hawk nest behavior investigation 2020
[same list as above]

Battling Birds: Panama Edition—2021
[same list as above]

Cornell Feeders Live - 2021
[same list as above]

Skills and Interests

To what extent are you interested in the following Bird Cams Lab activities?
[not at all interested, not very interested, neutral, somewhat interested, very interested]

- Participating in Bird Cams Lab investigations in general
- Participating in Red-tailed Hawks Cam investigations
- Participating in Panama Fruit Feeder Cam investigations
- Participating in FeederWatch Cam investigations

To what extent are you interested in joining with other viewers and scientists in the following parts of a scientific investigation involving Bird Cams?
[not at all interested, not very interested, neutral, somewhat interested, very interested]

- Watching live bird cams
- Suggesting a question to investigate
- Voting on a question to investigate
- Collecting data by watching and tagging video clips
- Exploring or interpreting results
- Reviewing and editing the findings
- Sharing findings

Please indicate your level of agreement for each of the following statements. Please respond as you really feel, rather than how you think "most people" feel.
[strongly disagree, disagree, neutral, agree, strongly agree]

- I regularly watch for birds outdoors in my neighborhood.
- I am familiar with the lives of [birds on cam specific to this investigation].
- I am comfortable sharing my knowledge of [birds on cam specific to this investigation] with others.
- I can make valuable contributions to the scientific study of birds.
- I am interested in birds.
- I like learning new things about birds.
- I am comfortable identifying birds.
- I am comfortable identifying specific behaviors common in birds.
- I learn new things by participating in investigations about birds.

This figure displays data that participants collected while watching clips of footage at a Red-tailed Hawk nest. They recorded each time they heard nestlings vocalizing with a "peep" or a "whistle." To help us understand what different participants see in graphs, which of the following is true, based on your understanding of this graph? (Check all that apply) [picture of stacked bar chart]

- ☐ Generally, participants recorded a greater percentage of "Peep Only" vocalizations as the dates progressed.
- ☐ Generally, participants recorded a greater percentage of "Peep and Whistle" as the dates progressed.
- ☐ On all days, participants recorded a higher percentage of "Peep Only" vocalizations than "Whistle Only" vocalizations.
- ☐ None of the above
- ☐ I am not sure.
- ☐ I am not able to see the image.

Which of the following questions would be answerable using video footage from a hummingbird feeder cam, like the one shown in the picture above? [picture of a hummingbird feeder]
[answerable, not answerable, unsure]

- How many visits does the feeder receive in a day?
- Why doesn't a bird stay longer if it is the only one at the feeder?
- At what times of day is the feeder being used the most?
- Which species visit the feeder most?
- How much of a bird's daily food comes from the feeder?

Bird Knowledge Questions

[This section was customized for each investigation, containing 9 multiple choice questions specific to the birds featured on that specific cam. The questions from the Hawk Happenings investigation are shown here as an example.]

Please answer the following questions to the best of your ability without looking up answers, and don't worry about your score. We are interested in understanding the range of knowledge among those who participated.

How many times do Red-tailed Hawks typically nest in a season?

- 1
- 2
- 3
- I don't know.

What is it called when Red-tailed Hawks sit on top of eggs to keep them warm?

- Brooding
- Incubating
- Gestating
- I don't know.

In what month of the year do Red-tailed Hawks typically lay eggs in New York?

- January
- March

- May
- I don't know.

Who typically sits on the nest to keep the eggs or nestlings warm at night?

- Male
- Female
- Male and Female
- I don't know.

What word describes the event when a chick leaves the nest for the first time?

- Fledging
- Roosting
- Stooping
- I don't know.

What prey type makes up the majority of an average Red-tailed Hawk's diet in the northeastern United States?

- Reptiles
- Birds
- Small mammals
- I don't know.

When do Red-tailed Hawks get their red tails?

- At hatching
- After they lost their natal down
- After their first year
- I don't know.

Red-tail Hawks typically lay their eggs:

- All at once
- One a day on consecutive days
- Every few days
- I don't know.

What types of prey are brought to the Red-tailed Hawk nest featured on the Bird Cams at Cornell? (Check all that apply)

- Grasshoppers
- Chipmunks
- Birds
- I don't know.

What are some of the typical behaviors/events Red-tailed Hawks do at the nest at some point during the breeding season? (Check all that apply)

- ☐ Nestlings being aggressive
- ☐ Adults eating fish
- ☐ Nestlings sleeping
- ☐ I don't know.

Video Question

If you were asked to watch this video for a study of Red-tailed Hawks at their nest, how would you describe what you see? This information will help us understand how different people interpret what they are watching. If you cannot view the video, write "no video." [short video clip showing prey delivery]

Co-Creation Questions

[post-survey only]
One goal of Bird Cams Lab is exploring the possibilities of co-created research. These questions address your understanding of co-creation and ask for your feedback on this process.

How would you describe co-created research? What makes co-created research different from other scientific research?

Which of the following best describes the Bird Cams Lab investigations, based on your experiences?

- Scientists at Cornell and participants like me were equally involved in doing Bird Cams Lab research.
- Participants like me were leading Bird Cams Lab research with support from scientists at Cornell.
- Participants like me supported Bird Cams Lab research that was led by scientists at Cornell.
- Not sure

Please indicate your level of agreement for each of the following statements.
[strongly disagree, disagree, neutral, agree, strongly agree]

- This project taught me about how co-created research projects work.
- This project taught me about how scientific research in general works.
- This scientific investigation felt open and inclusive.
- I feel that I played a role in shaping the Hawk Happenings investigation.
- I feel that my participation in this investigation had value to scientists.
- Participating in this project made me feel more confident about conducting scientific research.

When contributing to a citizen science project like this, which of the following do you prefer?

- Having the scientists determine the research question
- Having a co-created process in which the community and scientists decide on the research questions together
- I enjoy both equally.
- I don't have a preference either way.

Please explain why you chose the answer above.

What challenges did you experience as part of this investigation, co-created by public participants and scientists?

What did you enjoy most about the co-created process?

Please indicate your level of agreement with the following statements.
This project improved my ability to...
[strongly disagree, disagree, neutral, agree, strongly agree]

- Understand the steps of the scientific process.
- Closely observe and record data.
- Follow the data collection protocols for a Bird Cams Lab project.
- Interpret the meaning of project data presented in graphs.
- Use the project data to answer a research question.
- Design methods to answer a question selected for an investigation.
- Share project findings with others.
- Help provide information or support for other participants.

About You (Demographics)

Which of the following best describes your **current** employment status?

- Currently unemployed
- Employed part-time
- Employed full-time
- Retired

Do you **currently** work at home or outside the home?

- I work at home.
- I work outside the home.

Do any of the following apply to you? (check all that apply)

- ☐ Student
- ☐ Disabled
- ☐ Homebound
- ☐ Stay-at-home caretaker
- ☐ English is not my first language
- ☐ None of the above

Have you ever worked as a scientist or in a scientific field?

- ☐ Yes, I am currently a scientist or work in a scientific field.
- ☐ Yes, I was formerly a scientist or worked in a scientific field.
- ☐ Yes, I am currently training or studying to be a scientist.
- ☐ No, I am not a scientist/have no plans to do be a scientist or work in a scientific field.

If you responded "yes" to any of the above, in what scientific field did you/do you work?

What is your highest level of formal education?

- Grade school
- High school
- Associate Degree
- Bachelor Degree
- Master's Degree
- PhD, JD, MD or other Doctorate Degree
- Prefer not to answer

Your age:

- >25
- 25-34
- 35-44
- 45-54
- 55-64
- 65-74
- 75+

Where do you currently live?

- Within the United States
- Outside of the United States, but within North America
- Outside of North America

What is your gender identity?

- Female
- Male
- Non-binary
- Prefer to self-describe _____
- Prefer not to disclose

What is your race/ethnicity? (check all that apply)

- American Indian or Alaska Native
- Asian
- Black or African American
- Hispanic
- Native Hawaiian or Other Pacific Islander
- White
- Other: _____
- Prefer not to answer

Appendix C: Factors influencing participation in specific stages of the investigations

During our interviews with participants, we asked for their feedback on specific stages of the project including how much they enjoyed each stage or whether they felt comfortable contributing during that stage. Investigation participation was driven to some extent by past practices, e.g., viewership/interest in specific cams or types of birds.

Observation

Observing the cams was often the common starting point for engagement. Eighty-five percent of people signing up for Bird Cams Lab for the first time said that they had watched live bird cams in the past. Some participants noted that their interest in participating in the investigations was driven by their interest in specific cams—or, more specifically, specific birds.

> *"I was really into the Panama one; I watch that camera a lot...I attempted the feeder [investigation], it wasn't as much of an interest to me." (BBP12)*

Question Design

The question generation phase was one that a large number of participants were ultimately able to participate in, though many opted just to vote on questions that were put forth both by lay participants and scientists rather than submitting questions for investigation.

Among those who did participate more actively in the question generation phase, the ability to see other people's questions was "interesting" to participants.

> *"Really fun—got my husband who's a physicist involved—he got all interested in it…looking at other people's questions was interesting. And honing in on something we were all interested and test." (CFL4)*

Participants appreciated the Wonder Board and its function as a place where people could explore and ask questions or make suggestions. For some, level of knowledge may have been a factor that limited participation in the question generation phase insofar as participants sometimes hesitated from contributing questions in instances where they felt their knowledge level was less than that of other participants. Comments about the advantages of the Wonder Board as a question-generation tool included:

> *"[Questions were] brought up on the Wonder Board and then once question was on Wonder Board then we were able to go in and prioritize the one we thought was most important. I think that was a great way to get all the participants' input because food selection might be important to me but you might have a totally different priority for what you are interested in." BBP5*

> *"Building upon each other's ideas: "with Wonder Board—you suggest your question and others build on that. Maybe I didn't word it as clearly as I could have...Nice that someone could come in and expand on it." (BBP5)*

Knowledge seemed to be a limiting factor for some:

> *"I was always hesitating...my abilities were far below other participants—especially those offering suggestions for questions."(CFL10)*

> *"Don't want to put a question in where people were like, 'What was this guy thinking?'" (BBP5)*

> *"I'm someone that can be socially anxious, so sometimes I post my question and then afterwards. I'm like, 'Oh my gosh, why did I do that…that's such a stupid question someone else asked that.' But as I went along, I realized that there's no real stupid questions, and that I felt reassured as I went along, I would say. It felt like that was a real aim as well, was to make sure that people didn't feel alienated by a lack of experience in that way." (HH6)*

Data Collection

Though question generation was a step that many participants engaged in, there seemed to be the greatest interest and engagement around collecting data. Participants thought that the data collection—or data tagging—process was fairly straightforward. Thanks to the instructions and supports that were provided, and the care that had gone into developing the data tagging system and selecting readily identifiable birds as the target of interest for each investigation, participants felt they were able to quickly get to a level of proficiency with their submissions. However, participants did note that confidence was a slight factor in how much data they were willing to tag. Even though most felt confident in the accuracy of their data tagging, they noted that they wouldn't have contributed as much if they didn't feel confident that they were able to do so correctly.

> *"Dialogue during question selection phase was interesting but I most enjoyed capturing the data…If I hadn't felt like I knew what I was doing would have been more hesitant to participate …I wouldn't want to give them bad data. But they made it really easy. Most people seemed very comfortable with what they were asked to do…anyone with basic bird experience would be comfortable doing the project." (CFL11)*

Several participants noted that they gained confidence over time; others assumed that they would:

> *"I was pretty confident. If [I wasn't] sure on bird ID, I would use the Panama guide. I asked [the lead scientist] what guide he'd recommend for Panama and that's one I'd got...I never wanted to put in [data] unless I was sure...At first I wasn't as confident, but as I gained more confidence...I was able to accomplish it quicker." (BBP5)*

> *"It made me double check some of the things that I did not because I doubted myself but because I was wanting to learn. So I was using it as an opportunity for me to grow....[there's a] part of me that wants to have someone pat me on the back and say, 'okay,' that you were you were thinking okay." (BBP9)*

"I don't want to put in false data that's gonna throw this study off if they're really trying to do a scientific study here. I don't want to give them, you know, erroneous data. That's not helpful. So yeah, that made me hesitate a little bit sometimes." (HH16)

For others, it was less about confidence and more about time availability.

"I tried to like steal just a couple of moments here and there where I can be with so it's not my confidence and the quality of data that I'm collecting that influences that it's just the amount of time that I have to dedicate to it." (HH5)

"Sometimes for 2—3 hours. Easily 100...probably more than that—lots of time for an hour...for example, on days when it was crummy, watched on big TV together with husband." (BBP9)

"Sit and do it and knew it was valuable even though short time. Just knew it was going to take a lot of observations." (CFL4)

Data Exploration

Participants enjoyed the opportunity to look at static and interactive charts and graphs that were presented during the Analyze/Data Exploration stage of each investigation. Most participants felt that the info shared during this stage was fairly straightforward and accessible to those without advanced experience in STEM. A few acknowledged the effort and skill that had gone into presenting the data in ways that were easy to interpret. However, some didn't engage fully during the analysis stage because they didn't feel they had the requisite knowledge or skills to fully comprehend the data that were presented or contribute to conversations about the data.

"I didn't look in depth because it was out of my league...couldn't really comprehend what was going on with those charts, they were too scientific." (CFL9)

However, some participants—especially those with a STEM background—were excited to engage with the data. Such was the case for a husband and wife team of participants who were both scientists—they stated: "*We like looking at graphs and data and came up with our own reactions to it."* (CFL4)

Project facilitators also made copies of the raw data sets available to participants and a few took them up on that offer.

"I discovered that I can start playing around the data and I became more and more interested in actually what came out of the study." (CFL6)

"I wanted to see how the raw data was—I don't work in that territory. It was a lot, but I did print off short bits of it because one of my math science teachers thought she could use it for statistics and probability. Got them hooked up to look at the live feeder—she created her own unit. Kind of fun…[I] think one of her students took something out of that and did something with the local science fair." (BBP3)

Efforts to make data accessible was acknowledged and appreciated:

"Must be quite a challenge for folks to take data and make it approachable to a wide audience." BBP7

"I'm assuming you know there are people at Cornell who took the data and made those initial graphs, and then who wrote the first draft of the report before they sent it out to people to edit. But, again the community was engaged the whole way through." (HH2)

Reporting and Sharing Findings

Participants shared information about what they'd learned from participating in Bird Cams Lab investigations with their spouses, parents, children/grandchildren, friends and work colleagues. Some also found ways to share information with others in their community through volunteer engagements. Some participants also found ways to incorporate elements of the Bird Cams Lab experience into their professional practices. For example, a participant who was a teacher explained that she'd *"used a lot of the experiences with doing the investigations to get kids who normally wouldn't go outside...[we] don't focus solely on birds but that's how we start."* (BBP3)

"I usually print out all the data and graphs and keep it in a notebook or file…When I pass on info to other people I like to have accurate...good information to share. I like to hang on to all the answers to the questions." (BBP3)

"[I] told some of my other birding friends. I do bird walks and tours for the nature center…telling them how great it was to have this resource. You can go birding in Panama with the click of a button…so many opportunities!" (BBP5)

In addition to sharing information, a few participants also took advantage of the opportunity to collaborate on crafting the official reports on investigation findings. Some participants didn't feel they had enough skill or the ability to contribute effectively to the reporting process.

"I don't feel like I have a lot to offer...don't know what you folks would gain from my observations." (CFL3)

"Not quite sure that I have the expertise to do that portion—I would say I'm a little hesitant." (CFL8)

For one participant who was vision-impaired, the reporting stage posed an extra challenge: "I enjoy the looking at the report phase but I realized that was a bit of a challenge for me. But that doesn't mean I am less interested in it. As long as it's a community...if I can't seem to really make the contribution that maybe I should be able to that phase, that's okay because we're working with the group and...it seems to be okay that that I maybe grow a little more slowly there. I think sometimes I just struggle with the idea of editing online in a group format….I find that more of a challenge, doesn't mean that I don't look forward to it." (BBP7)

Others—especially those with professional science and/or writing experiences—found this to be an opportunity where their skills could be put to good use. Some who had less prior experience or skill in this area also opted to participate and appreciated the opportunity to learn more while making contributions during the reporting stage. Participants felt they were able to make important contributions at this stage insofar as they could help to ensure that findings were communicated in ways

that would be clear to those without formal training in ornithology. In the end, dozens of participants were engaged in the reporting process, but data suggest this opportunity was greatly appreciated and had significant impacts.

> *"The final report, before it went out they said, 'Who would like to participate in how the final report is written?' … I thought, 'Wow, that's so cool, I wouldn't have even thought to do that to make suggestions.'"*
>
> *I CAN do this! I'm a writer, so editing is one of the things I do, and do well.*
>
> *"I have [done] some editorial work in different journals. Consequently, I liked to review and revise some of the different outcomes and helped to improve the quality of...text to provide an understandable and clear way...[for] participants not in scientific field." (CFL7)*

Some participants acknowledged the unique opportunity to participate in a part of the scientific process that is not often opened up to participants. As such, the reporting phase of the investigation process had a big impact on a smaller number of participants:

> *"I just finished reading the draft of the report, and it appears that you have had some excellent comments and suggestions from a couple of the participants. In reading their editorial notes, it looks like this is a thorough and clearly presented report. I would like to thank all of the members of the Bird Cam Lab for their willingness to let me, an amateur birder, take part in this process and investigation. It's been a privilege and an honor to be involved even in a small part. Thanks again and good luck with all future investigations." (Note shared with team member)*

To what extent were participants motivated to seek answers to questions vs. simply wanting to participate?
Based on participants' comments about motivation during the formative stage of the grant, we were also curious to learn if participants were more motivated by a desire to learn the answers to the questions that had been selected for investigation or simply interested in participating—no matter what the impetus or outcome. Participants had varied preferences and varied reasons for those preferences.

> *"Participating in the process was more important. The findings are interesting but they lead to more questions that I won't get answered—just the participating and the final results are like a nice addition. Participating was more the driving factor." (BPP12)*
>
> *"60% pure curiosity and 40% wanting to feel like I'm participating and working on something of interest to me." (HH6)*
>
> *"The process fascinated me. And because I've seen the process, more or less from its beginning to the end, you know, of course the results are going to be something that I look forward to being able to review. So I guess I'm kind of a 50/50 right now, because the beginning of the process was so important for me to be able to learn and experience." (HH11)*
>
> *"You're really concentrating...and that's a big motivator, you pay a different level of attention...the results definitely interested me, [but] the activity of watching birds is a big motivator." (HH12)*

Appendix D: Patterns of Participation

Interviews yielded four categories of participants that influenced how and why participants engaged with Bird Cams Lab Investigations:

- **Participants who were simply happy to help**
- **Participants who were motivated by the ability to contribute to science**
- **Participants who were curious about co-creation**
- **Participants who appreciated the sense of community**

Below, we've provided additional examples of quotations from participant interviews that help to illustrate the different types of motivations that underly each of the above categories.

Happy to Help

This category included individuals who were eager to do whatever they could in whatever time they have available to help scientists. It included participants who felt that they benefited from having something intellectually stimulating to do—especially during the pandemic.

> *"I just wanted to help. It just seemed like Cornell was asking me to do this, well not me personally, but they put out the call and I thought, I can do this, I can participate." (HH3)*
>
> *"I'm helping birds in general because I am supporting you guys and your effort, so I feel like I'm helping birds in general—I feel good about that, like I'm a helper." (CFL5)*
>
> *"It was easy to do—for however long you had…[just] sit and do it and knew it was valuable even though short time. Just knew it was going to take a lot of observations." (CFL4)*
>
> *"I can help with whatever research is needed. I don't have to set up the experiment." (CFL5 7)*
>
> *"Think it helped—but more the joy of doing it." (CFL12)*
>
> *"Happy to participate and provide my observations because they could not do it without many observers." (CFL4)*
>
> *"I just liked doing research. Excitement's not the right word. I think if you were to ask people how intensely they did this, it's a different question than how much it makes you excited." (HH4)*
>
> *"I just have a lot of stuff on my plate all the time so knowing that I can tune in and help when I can, and still feel like I am contributing positively to the project is nice...I like not having that weight on my shoulders of it's something that I have to do with something that I can choose to do when I have time to." (HH5)*

Quotes that exemplify statements from participants who found the experience to be intellectually stimulating and found the educational benefits of participation to be a perk of helping out include the following:

> *"If I gave a suggestion and people really liked it [or agreed]...that kind of interaction is gratifying." (CFL4)*

"I don't have any kind of a background in this so I was a little intimidated by how other people were responding and things but if I chose to keep up with it because it's a learning process…and even though I'm a grandma, I can still learn things." (HH11)

"I like to do things where I'm going to learn something. And if watching birds, which is a very pleasant thing to do and I can learn something, I'm going to do it. I like the fact also that the data is going to be utilized, you know, even though I'm really enjoying this, then I get to see the result of my time and other people's time in terms of what the findings were…it's a much more enjoyable way to do research—to do observations, as opposed to reading it in a book or reading it online." (HH9)

Contribute to Science

People in this category had a strong passion for science and were attracted by the opportunity to do scientific research and contribute to science. Some had trained to be scientists or had once been scientists—so their participation offered opportunities for fulfillment or continuation of what they considered to be a calling.

"[This was] more fun in the sense you can actually contribute instead of just reading paper." (CFL11)

"I'm sort of a science geek…and so to be able to be involved in something that is science, and be able to do that just by merely watching things, and discussing what we see…that's a pretty easy way to feel like you're being involved in science. And then have it a bird cam lab team that is able to kind of shepherd us and give us a chance to make our contributions and then just kind of gently guide…let's make sure this is something that's testable…something we can actually study in a way where we can contribute to some broader base of knowledge." (BBP7)

"Liked the fact that I could feel like I was contributing to something science and people who are really doing science and not having a masters in ornithology or environmental science." (CFL2)

"It's very valuable to be involved in something that's hopefully valuable to society." (CFL8)

"Happy that my input would serve some scientific goals even if I wasn't the one to put them together." (CLF9)

"Get to contribute while doing something fun." (CFL11)

"I'm just trying to be as helpful as possible and try to learn a little bit more science-wise and bird-wise...being invited to be an active participant in science was...that got me, I was like, 'Okay, I can do this. It's about birds, and I get to learn how the scientific process is born, and all the research and data points are created in order to be able to answer the question that they want...answered.'" HH11

"I guess what I put in is such a small part of the whole project. But then when you see, you know, each person's little bit of input makes a big impact at the end, so it's kind of like…I'm building a

snowman…it takes every little bit of snow that you put on…I don't see that I was valuable individually, but as a group it ended up being a good project to be part of." (HH11)

"That's my sense of what's the most valuable thing—allowing the people who are the most knowledgeable ones….Dr. Miller, in Panama...he needs people to look at stuff and then he can make different descriptions. I'm happy to contribute to the body of scientific knowledge." (BBP1)

Helping birds/build knowledge about birds:

"I enjoy being able to play a part in research that will have impacts on our knowledge of birds. I know this work is important to their survival and that citizen science can have a big reach under the direction of experts." (BBP2)

"Just wanted to participate in some type of research...I love nature in general and want to do everything I can to make sure our planet is protected." (BBP14)

"I just love nature, I love observing animal behavior. So being able to combine that, and my knowledge base and have it go towards something rather than just me hanging out on my porch watching the birds and the trees, you know like this is nice because it's combining my interests, and my strengths, and turning it into something that contributes to our global understanding of bird behavior." (HH5)

"I get a lot of personal satisfaction, and I feel that what I do is helping somebody, somewhere solve some environmental problems." (HH7)

Enabling participants to fulfill a life-long vocational interest in science:

"I love animals—if I didn't have allergies I would have gone to vet school. I like watching animal behavior…[this was a chance to] do some science and still participate in nature activities." (CFL11)

"If I could have pursued…I would have chosen a career as a naturalist. I love observing animals." (CFL8)

"I really wanted to be a marine biologist, and I never pursued that. And so, I feel like it's bringing back my scientific interests and research and questioning that I kind of let go of...and kind of getting back to, I guess it's a part of me that's something that I've always wanted to further develop that I never did. And so this has given me the opportunity to do that. (CFL12)

"I had really wanted to go into science so it fulfills this need I've always had to participate in wildlife science research...I get satisfaction about being able to contribute to something bigger than myself." (BBP2)

"It's a way of doing sort of what I might have wanted to do all my life, but I never had the ability to travel or become Jane Goodall...but I can still do it, I can still contribute. And just because I'm retired, doesn't mean I'm done contributing. And that's part of why I love it...I'm able to do some of this stuff and contribute and maybe somebody will find some use for it to help make our society better." (BBP9)

"Although I will elaborate and say although that I have pursued a degree in biology, life took me in another path and I have ended up self-educating and availing myself to online resources when possible. I have specific goals and conservation projects in mind that could greatly benefit from professional scientific guidance, but I have been intimidated to ask for help from the scientific community. My recent experience and interactions with the Cam Lab have totally removed that fear and I am more hopeful and confident that I can achieve my goal and make a difference." (HH6)

Enabling scientists/former scientists to continue or expand their scientific experiences:

"Nice way to feel like I'm involved in something...contributing to something and learning too. For me, personally, it was nice to be a part of that...I miss doing research since I'm now teaching." BBP12

"I miss collecting data, so that was also part of my motivation I guess I should say, because right now I'm working in environmental education so I'm not actually doing my own research. So that was really fun to get some data collection again…that was the motivation and also just sort of participating and helping is the motivation and helping contribute to learning answering these questions. (HH2, Former Scientist)

Some participants also noted that they had specialized skills that they were interested in utilizing to aid the investigations:

"People have skills and want to apply them." (CFL6)

"Coming from a zoology background, I mean, I know this stuff anyway. And that's, that's one of the reasons why I'm so interested and why I want to participate is because I guess you could say it is because this is my comfort zone like this is my happy place, so I engage with it and I participate with it because that's what I love. So for these I haven't been going at it with the mindset of wanting to learn more, I'm just along for the ride." (HH5)

Co-Creation Curiosity

This category includes participants who were intrigued about the co-created nature of Bird Cams Lab investigations. The opportunity to do scientific research alongside scientists was a motivating factor for participants in this category. There were also several individuals who indicated that their curiosity stemmed from specific professional or volunteer interests (including people in various STEM and STEM-ED careers, e.g., zoo or park-based educators, and various types of scientists).

"I'm a researcher myself…[I'm] interested in going through process... [I] get insights into [how] what I usually do is done by another field." (CFL6)

"[I] wanted to see how the data was organized—curious how it was organized…how tagging it…how set up to capture what we were doing." (CFL11)

"It was interesting...because I have a background in research. It was interesting to see the gaps between what is possible and what people want to do. That's an interesting thing to see because it shows that people are really excited about the difference, things that should be possible but

are not quite yet there. And so that was kind of a fascinating aspects of the setup of this specific study." (CFL6)

"I was interested in the process...impressed that they want to bring community in at the beginning. This was the sort of thing I was involved in as National Park Service educator." (BBP7) (Note: particularly interested in how this process could be managed online)

"Nice to see that you can have a more collaborative research project. [Finding] ways to involve a lot more people instead of...scientists out in the field collecting research alone. That was good...a difference from what I know." (BBP12)

"I learned how, how they're trying to do this. How they're trying to implement this very exciting new way of engaging people in science." (HH2)

Sense of Community

This category includes participants who enjoyed the sense of community that they got from participating in Bird Cams Lab.

"It allowed me, in LA, to work with people from all over the world." (CFL6)

"Interesting to see how many other people participating form all over the U.S. …[It is] fun to be part of a bigger project." (CFL10)

"Really cool to think there was this whole community of people doing a very scientific approach…the way we teach science." (CFL4)

"I enjoy meeting people from all over the world…people are doing same thing…for common purpose …cause…getting to connect with everybody…shows world input and value." (CFL12)

"It's a world-wide project. Whenever you get input from people from all kinds of cultures and countries [it's] going to ultimately make it better. People look at things in their own countries and…try to benefit birds in their own country." BBP5

"This is the kind of activity that people can do around the world, [is] really exciting...everyone interconnected...all kinds of places in the world have gotten people observing." (BBP10)

"I have a pretty substantial vision impairment...I've always been very interested in birds before I lost so my eyesight...and so to be able to continue to be involved in any sort of a community science or citizen science project is really something that I enjoy and find very fulfilling. And then to be able to be involved with other like-minded people in that project is also something that I find very intriguing and something that I enjoy doing." (BBP7)

"I found that to be really interesting and to be able to participate in something bigger than myself... I felt I felt it was a way that I could contribute...and be part of something larger. And at the same time it was exciting to be able to actively participate in something at a distance…from where I am and on my own time. I was able to check in and be connecting with this experiment that was ongoing and in a way that I had not been able to participate in previous instances…I'm

far removed from the U.S., and so I don't always get to participate in the same types of conservation efforts and cleanups and things like that that I'd like to and this was a way that I found that I could help and be a part of a broader scale and scope of experiment and citizen science." (HH6)

"I think people might be somewhat more engaged because they would then have a real reason to be talking about what they saw, and, you know, getting feedback from other people, and being more of a community." (CFL4)

Appendix E: Participants' perception of the co-created nature of the experience

During the questioning phase:

Many participants thought that the team of scientist-facilitators had helped to guide the group toward an appropriate and useful question to investigate.

> *"There was a lot of input from the community that were from the participants on my side of things on the Wonder board, and it was the role of the moderators and the scientists involved in the investigation to sort of guide us in what was investigated...what we could investigate via the camera and the platform and what we couldn't, but it did really feel driven by the participants...the scientists were really accommodating to what our genuine questions were. And then it felt like they were taking that and tailoring it to what could be achievable with the, with the platform given....ultimately, it felt like the final decision was made by the scientists which makes sense." (HH6)*

> *"My impression is that it is initiated from the staff at Cornell, then they open it up to the community and the community contributes 'what I want to learn about this thing...I think it'd be cool if we did this thing'...then there's a period of time where that happens, and people are just sort of throwing ideas around. And then the staff from Cornell come back in and sort of narrow in focus and group those questions, and then try to get the community to think about 'is this doable? Is this interesting?'" (HH2)*

> *"I got the sense that they were trying to...encourage people to provide...all kinds of feedback and try to help direct people into trying to think about answering the questions like a scientist would—what are the best questions to ask that we could really actually measure scientifically...so I thought they did a nice job of that during the questioning. They did that for a couple of weeks and then they took a week or two to kind of evaluate all of the dialogue and the feedback and then they eventually came back and gave us four or five things to measure. And then they rank those and pick the top two and then they tried to see how they could do the data tagging to answer the questions."* This participant applauded the facilitators' effort to guide the process of refining the question development so that the group ultimately landed on something that was feasible to answer, e.g., asking *"Which bird species do we want to look at, because we can't count everything that's going to come to the feeder." (CFL16)*

> *"They were very polite and accepted all the ideas, even though some of them...you wouldn't be able to answer, but someone who isn't a scientist wouldn't know that. And so I thought they did a very good job of fielding the questions and developing them and getting a sort of democratic count of what people were interested in, and could be useful and could actually be answered." (CFL 4 p 5*

> One participant noted that it sometimes felt that the scientists already knew what they wanted to study: *"I don't have a problem with that,"* they added, also noting that he did sense a genuine desire on the part of the scientists to engage the public. *"I think it's totally fine to just say, we know what we can do...we know what we'll probably do, but still we want to hear from you...and I think that's great. I think there should be a lot more of that actually, especially for this [kind of] study where people can be engaged and where it's something that people see every*

day...anything that is actually parts of people's daily lives is an opportunity to actually make them feel like, 'oh, I could be part of something that studies this process'...even if the input is purely lip service...where it doesn't actually influence the outcome of the study, I think it's still worth it because...those people get reinforced in that fashion...it wasn't necessarily full engagement...but I still see value in it." (CFL6)

"It's important to look at it also from the perspective of having a seat at the table with the scientists, which to me is very important, and so, just by virtue of the fact that we were part of the process that fulfilled the expectations." (HH9)

"Suggestions are made by people who are going to do the participating. Scientists helped guide things and say, 'These are things that would be helpful...things that we can do...things that we couldn't do'...like not knowing if these are the same birds that will be coming back. People like me voted... Dr. Miller said that would be something of value to answer….It was a combination of guidance...direction from the scientists…if you answer that, so what?" (BBP1)

"Let's say I get 100 suggestions for questions and the scientists pick 10 of them. The co-creation falls apart. When they have already thrown out 90% of the questions so they have already done some channeling and directing with those, with the selection of those 10 questions are going in a direction they want." (HH4)

Some participants thought it was more participant-led:

"It seems like this was all participant-led…It was our questions coming to the forefront, and we even got to rank the order of species that we wanted to observe our target as part of the research project so this one I would say it's more participant-led rather than just acting as support." (HH5, referencing CFL)

"It seemed as if the scientists kind of try to stay as far back as possible. And there were so many knowledgeable participants who had all kinds of good ideas at the beginning and then you know as the project was going on it didn't seem as if the scientists were at all pushy or trying to influence anything. It seemed like the participants were driving it more than science was trying to lead us somewhere." (HH11)

During the data collection phase:

Everyone interviewed felt they played a vital role in the tagging of data.

During the analysis and reporting phases:

A few interviewees pointed out that there was less engagement from lay participants during the analysis and reporting phases of the investigations. Others noted, however, that engagement was still possible at these stages for those who felt they had something to contribute.

"I don't recall any users…people like me…giving any input into the analysis...in terms of what metrics are going to be outputted...hourly or half-hourly intervals...that's stuff that they made decisions about based on quality of data...based on their expertise." (CFL 6)

"From the beginning, the citizens were involved at high level...and they were able to form the questions and target species and, of course, were involved in checking the data once collected.

After that I don't know that all of the participants received email about the possibility to review report...maybe it was just those who participated at higher level in watching the video clips [who were] asked to give feedback about the report. If someone followed the entire projects...they can do different parts, checking data, giving feedback about the reports." (CFL 7)

"I feel like [lay participants] were fully engaged, especially from my observation of [CFL]. It is community-driven in terms of the questions they're asking, and then the scientists are there for support...it's not really using people to answer a question that someone else is interested in...this is much more of a community-driven activity...in my impression."(HH2)

"Scientists seemed to play the role of giving a platform and a general structure to what we'd been investigating and the participants were able to give their thoughts and ideas and what was generally genuinely of interest to us. And then, the, the two together the scientists were there to support and guide along the way. And then finally, to what's the word I'm looking for, to execute the actual process itself. But it felt it didn't feel like there was that what we were as participants, contributing was actually being taken into account and it was a true contribution." (HH6)

Manuscript review

"I did actually very much enjoy the peer review part. I like to write...I enjoyed it and I did see some of my edits get taken into account on the paper so I personally do feel like my contributions were... I did contribute and it was at least a little bit meaningful in a direct way." (HH6)

"To make it easier to understand and grammar and things of that nature. Because the data part that the numbers are the numbers…[they] are what they are, but sometimes it's easier with certain language for people to, you know, don't have expertise to understand what those numbers mean." (HH8)

Appendix F: COVID Impacts

There were many actively engaged participants before the pandemic; however, it is reasonable to expect that COVID-19 had an impact on participation patterns during the later years of the Bird Cams project.

Seeking out things to do

Some participants found the Bird Cams Lab project (and Bird Cams in general) a welcome opportunity to do something safe while socially distanced. In some cases this replaced activities they had been doing or planned to do face-to-face. The need for new activities that could be done at home also led some participants to find Bird Cams Lab who might otherwise have not.

> *"I'm pretty familiar with birds with the pandemic of course things getting kind of boring. I started to do some birdwatching, and my own area and stumbled across the Cornell projects online, and I thought that would be kind of a fun thing to do, to sort of contribute a little bit and to help improve my bird identification skills...it's really pleasurable to me especially in the last year, to have something to concentrate on externally." (BBP10)*

> *"I've enjoyed going to Costa Rica and Trinidad for eco travel…[this] seemed like that was one other place where I could virtually visit, and maybe learn some more." (BBP14*

> *"Partially because I'm home, I'm not in my office and I feel more isolated, in that sense, and so then it was nice to be able to feel a little bit of connection to a bigger project, and just kind of like being outside. When I worked in my office and pre-COVID times. I didn't have the Bird Cams as my background because there's a lot more background noise and I'm talking to my co-workers and all this stuff so in that sense, it was really actually very pivotal because I started doing that as a way to kind of feel connected and engaged while I'm sitting by myself in my home" (HH2)*

> *"That we were experiencing pandemic and have limited options for what was safe to do—nature connection was important thing for me. Usually do a lot of volunteering and that was on pause this past year. This was a way to still volunteer." (HH10)*

> *"If it weren't for the pandemic "I probably wouldn't have been able to do this because I would have been out traveling...looking at birds. [Thanks to COVID] I had all this spare time because can't go traveling." (BBP11)*

> *"[Watching the cams] wasn't something I did before pandemic...I got hooked…[it was] part of my way to connect with nature...self care...I challenged myself to learn during this time...to learn about birds and their behavior." (HH10)*

> *"Within six months of us moving down here everything got shut down…. travel...and to visit friends and family was out of the question. We didn't have enough time to actually mill around here and get to know people and places, very well. But I have beautiful property with lots of trees....I've got birds galore all kinds of new birds down here that I've been learning about, so it just kind of fell into place that it interests me to keep learning about, you know, birds, nature,*

that kind of stuff, scientifically, and it's it filled a gap, a big gap in my time, because there's not a whole lot more to do other than…just kind of sit out here and wait for the birds to come." (HH11)

Impact on availability of time

Many of the participants that we spoke with noted that they had had more time on their hands during the pandemic.

"During the pandemic I spent a lot more...time watching the birds…I might not have been aware of bird cams...I was spending more time counting birds. I think somewhere along the line I either heard about the Cornell group or the bird cam…[if not for the pandemic I] might not have heard about bird cams group, because I probably wouldn't have been spending as much time do ….wouldn't have become aware of this." (CFL11)

"I had more time. Because I was just hanging around the house." (CFL4)

"Due to the pandemic I didn't have a lot of work in my office, [figured] I might as well do something with my free time." (BBP13)

"I had a little bit more time to do because we had less, you know, outside social engagements, but it wasn't tremendously time consuming anyway, because I kind of would do it in small chunks if I had, you know, five minutes here and there…I needed to let my mind relax a little bit and do something different and then could go back to...the day-to-day working life." (BBP15)

"What happened last year, it blew our calendars totally out of the water so we had an opportunity to look at OK out of all the things on the calendars, what do we want to retain? It gave us an opportunity to sit back and look at how we were living our lives and what are the things that you want to change that will allow you to live life better? Spending more time together, watching the birds more, appreciating nature more, taking more time for ourselves and less time complying with the calendar. So we were freed. But we looked at it as what could we learn from this, not what was taken away from us." (HH4)

"I'm working part-time at the moment...because I have this free time, I'm trying to take every opportunity I can to participate or do a course and actively fill that time with my learning objectives." (HH6)

"I already worked from home. But...you weren't going out, so there was a lot more time to engage in the project also during the day." (HH12)

More familiarity/comfort doing things online

It was also helpful that the need to connect with others online had brought greater familiarity and comfort using digital tools.

"I think it's really exciting that we can do some much stuff online now and might make it even more likely and people are used to it and try it out and it's fun." (CFL4)

Therapeutic

"So many people found the live bird cams during the pandemic... people were just hanging on by a thread and this was just something that they could enjoy...time and time and time again." (CFL1)

Something they make time for (when they have lots of other big things going on in their lives (e.g., hospitalization of loved ones): "COVID and this freeze [in Texas] has taken a toll on a lot of people, and the isolation and feeling...being isolated at home ...disconnected from everybody, not being able to interact." She shared her experiences with her mom: "I was sharing with her about my birds and I said, 'Let's get you set up with birds outside your window. Let's get the birds coming to you' so at least she had some, some kind of life form that was interactive that she could watch and observe. I think you know if y'all can do some kind of project connected with mental health and bird observation and the value that it has, especially for people that are isolated and need some kind of life connection...I really think there's something there because I've seen it myself." (CFL12)

"I have brought my almost 94 year old mother to live with me in our home and, and she's limited physically but her brain is perfect, and she's totally into the birds with me...As we've been so extraordinarily isolated this past year ...my husband and I, with my mother here...the three of us in our home to protect my mother. ...the birding thing, I swear it's just saved us, it's just saved all of us, it was something we could do...something we could learn. ..now I say to my mother, 'What is that, what are you hearing,' you know, so it keep sour brains sharp. [It's] totally changed our world for the better." (BBP1)

"I'm glad I had something to do so I wouldn't go totally insane. We were in total lockdown in the Bay Area. Just my comfort zone...my place to go...whether doing investigations or staring at the pond at sapsucker...it was a place I knew COVID couldn't stop me from going to." (BBP3)

"Being in lockdown and not being able to interact...it was good because with this program it gave you something to look forward to instead of just sitting at home and watching the DVR." (BBP5)

"I'm at an age where I have some vulnerabilities...the last year has been kind of tough and I haven't really gone out much...I have good broadband and ... I've been doing a lot of things to keep myself, you know occupied, mentally, and engaged...since I haven't been able to engage, face to face with people, very much...This has been really helpful to me...this project and other things that we've been able to do on zoom have been really a lifesaver for me." (BBP10)

"If I'm having a rough day at work in the office I can just pull up a bird cam on my computer and just take a couple of minutes to watch what's going on, even if there aren't any birds on the feeders at the moment just seeing nature is nice because my office doesn't have any windows." (HH5)

"When I was working at home, I wasn't doing as much with the Bird Cams because I was actually able to look outside my window...I feel like for a lot of people it was sort of like the opposite

thing happening...it was easier and more relaxing I guess for me rather than to spend more time in front of the screen, than to just look at my own window. But yeah, like I said, one of my outlets on stressful days at work when I'm stuck in a windowless box is to turn on the accounts here." (HH5)

More interest in nature

"I know that a lot of people enjoy nature that that's one of the things that the pandemic has brought back to us. That's one of the good things that now I think we appreciate our surroundings more…and all the creatures that are part of those surroundings." (HH9)

"Made me very aware, particularly in past year, about the connection of birds and humans. When I tried to get to a local feeder place I couldn't get birdseed! The whole world became birders." (BBP1)