Dead Birds, Data & Decision-Making:
Ways the COASST Program & Agencies Interact Through Citizen Science

By

JENNIFER MARIE METES
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Approved:

_____

Heidi L. Ballard, Chair

_____

Brett Milligan

_____

Julia K. Parrish

Committee in Charge

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Abstract

A growing interest in citizen science as an approach to natural resource management and conservation presumes that citizen science allows for collaboration between decision-makers and communities, as well as promotes solution-based conservation science. While previous research links citizen science to beneficial natural resource management outcomes, none specifically traces why or how researchers and managers from public agencies choose to interact with citizen science programs or these programs' data. Through a case study approach, we asked how citizen science contributes to natural resource management and decision-making by hearing from agency partners associate with one program, the Coastal Observation and Seabird Survey Team (COASST). We conducted and analyzed semi-structured interviews with agency personnel who partnered with COASST in their work roles, examining respondents' general perceptions of citizen science, the experiences and outcomes of their interactions with COASST, and factors that influenced their collaboration with the program. We found that COASST's strategy for working closely with both the its volunteer participants and agency partners through citizen science influenced the ways natural resource management professionals came to trust the program and program data; and, that agencies interacted with COASST data in a variety of ways that led to management outcomes. These interactions included: direct use of COASST data; integration of COASST data into broad-scale management; contribution of agency data to COASST; and, use of COASST expertise for related management. Factors that facilitated collaboration between COASST and its agency partners included: strong data quality assurance/quality control; positive partnerships; building trust; and opportunities for public engagement. Our findings suggest that citizen science can play a dynamic role across and

between the boundaries of science, public engagement, and decision-making—in addition to building social-ecological systems resilience into resource management and conservation.

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Table of Contents

List of Figures & Tables

1. Introduction

Understanding and navigating complex human-ecological connections is one of the grand challenges of the 21st Century (Ostrom, 2009). Yet a shift is underway involving the participation of more people than ever before in science, conservation, and natural resource management (Bonney et al., 2014). Across the country and the globe, a variety of collaborative initiatives called citizen science—ranging from grassroots to global in scale, are emerging and growing. Citizen science (CS) projects involve multiple groups, including local communities, indigenous tribes, government agencies, academic institutions, and non-governmental organizations (NGOs) (Shirk et al., 2012). They include activities in which members of the public work with professional scientists on authentic research and/or monitoring and are organized by either professional institutions or community-based programs (Shirk et al., 2012; Bonney et al., 2009).

In natural resource management (NRM), there is a growing call for collaborative learning and knowledge sharing that goes beyond the realm of traditional science and resource management (Schwartz, 2006; Bennett et al., 2016). Therefore, it is necessary to further explore the initial successes and untapped potential of citizen science. The unique possibilities of how citizen science may contribute to conservation and NRM are intriguing and deserve more in-depth study to understand how citizen science can serve as a novel approach to solutions-based science.

Recent strategies in conservation and NRM more frequently employ holistic thinking about social *and* ecological systems. These approaches emphasize how human and natural processes relate to and affect one another as part of a larger environmental system (Walker et al., 2006). This coupled human-natural system concept is also applied to the theory of resilience—

the capacity of a system to engage and cope with changes or disturbances while retaining its basic structure and function (Walker et al., 2006). Resilience is essential to building a sustainable social-ecological system, which invariably operates across several scales of time and space. Together, social-ecological resilience is about embracing change as opposed to striving to maintain constancy within a complex system (Walker et al., 2006). A fundamental component of a resilient system is learning, which when applied to conservation means monitoring both social and ecological processes in order to adapt to perturbations to maintain resilience (Walker et al. 2006). Citizen science offers ways to address social-ecological resilience by contributing to the ecological (and possibly social) monitoring of the system, which creates capacity for learning and adapting within the system. The wide spectrum of participant and project breadth that citizen science can (but does not always) afford means that more diverse local and traditional knowledge can be incorporated into the monitoring of the system (Bonney et al., 2014). Similar to citizen science, resilience incorporates diverse forms of knowledge and participatory processes (Krasny and Tidball, 2009). Thus, there are unique opportunities for citizen science approaches to both learn about a social ecological system, and potentially contribute to its resilience.

While previous research implies that citizen science can uniquely connect participants to science, resource management, and place (Newman et al., 2017), as well as boost social-ecological resilience (Shirk et al., 2012; McGreavy et al., 2016), there is less evidence about how existing citizen science programs may directly or indirectly lead to valuable NRM or conservation outcomes. In fact, a challenge of citizen science is knowing if and how collected data are actually used within the decision-making process (Conrad and Hilchey, 2011). Probing

the realistic extent and capacity of citizen science outcomes in NRM can provide insight onto how to improve upon its overall impact with respect to decision-making and conservation.

Citizen science may not be a panacea to every scientific question or environmental problem, however it may hold potential to play successful roles in both the scientific and social realms of conservation (Aceves-Bueno et al., 2015; McKinley et al., 2017). To build a more complete understanding of how citizen science influences conservation and NRM, research is first needed to substantiate if and how this emerging field can indeed provide a trusted tool to help scientists, resource managers, policymakers, and communities tackle environmental issues.

Several researchers believe this emerging field offers great potential for addressing environmental issues, particularly through broadening the awareness of and access to citizen science for biodiversity researchers (Theobald et al., 2015; Burgess et al., 2017). However, many uncertainties remain regarding citizen science's direct impact and effect on prompting management actions and catalyzing decision-making. Danielson et al. (2007) concluded that participatory monitoring within local communities was an effective tool for site-specific conservation. Devictor et al. (2010) found that citizen science also promotes landscape-level biodiversity conservation through collecting large spatial-temporal extent data. With a focus on adaptive management, Aceves-Bueno et al. (2015) stated that resource managers could successfully use citizen science to address adaptive management's need for increasing environmental monitoring and engaging more people in conservation. Similarly, McKinley et al. (2017) identified two pathways—science and public engagement, of citizen science that improve conservation by increasing scientific knowledge and public engagement (Fig. 1).

Previous research indicates that citizen science can provide data comparable in rigor and scale to professional science (Szabo et al., 2012). Despite this promising potential, authors' use

of citizen science data is still lacking among peer-reviewed publications (Theobald et al., 2015). Burgess et al. (2017) attribute this absence of citizen science in the literature to skeptical attitudes and minimal awareness towards citizen science among biodiversity researchers. Yet most scientists from the Burgess et al. (2017) study reported that trained citizen scientists could feasibly collect their data, which indicates that more needs to be understood about what influences the perceptions and practices of professionals who might be able to apply citizen science to their work.

While other studies have researched factors of trust between the public and scientists (Thiel et al., 2014) as well as community members' willingness to trust citizen science data (Thornton and Leahy, 2012), data credibility and trust of citizen science data among NRM professionals specifically, have been less explored. Thiel et al. (2014) examined over 200 published studies in which scientists collaborated with volunteers to conduct a wide range of marine-based investigations and found that citizen scientists met standards of rigorous science; and further, that scientists who worked with participants trusted them to carry out scientific monitoring more afterwards. Thornton and Leahy (2012) conducted a study on what factors contributed to local community trust in citizen science data on water quality. They learned that factors of trust are based on the interpersonal relationships and familiarity formed during a project. However, the ways trust influences relationships and interactions between citizen science programs and NRM professionals are still unclear.

Additionally, the NRM field is still limited in its understanding regarding types of citizen science programs that produce data which are both credible and useful for resource management and conservation (Burgess et al., 2017). While Freitag et al. (2016) proposed some credibility-building strategies for citizen science programs compiled from various coastal monitoring

programs during training and planning, data collection, and data analysis phases—the citizen science field still lacks a strong understanding of what specific factors motivate NRM professionals to apply data from citizen science programs to their management actions.

Our study uses a case study approach to trace how one citizen science program informs resource management actions and decision-making and, how this varies across different natural resource managers from federal and state agencies. This is a necessary step to determine whether citizen science can be a rigorous and reliable scientific tool that many hope and claim it can be. If this new frontier of science and community-generated information is to become a worthwhile pursuit for the field and indeed contribute to social-ecological systems resilience—understanding how citizen science is perceived, valued, and applied directly to resource management by researchers and managers themselves is an essential next step.

This research focused on a single citizen science monitoring program—the Coastal Observation and Seabird Survey Team, or COASST (www.depts.washington.edu/coasst/). We looked closely at the relationships between COASST and the managers and scientists the program collaborates with. Through asking in-depth questions about the relationships and partnerships that take place between the program and various state and federal agency partners, we can better articulate the roles these types of citizen science programs and data play within management and decision-making.

Specifically, we explored how the program translates its data into actionable science by identifying ways the program's collaborations with government agencies influenced NRM practices and outcomes. This research helps distinguish some of the specific management and decision-making issues that NRM professionals choose to address and learn from using data from COASST and/or other citizen science programs. By weaving together NRM professionals'

experiences interacting with COASST and the program's data, we identified how COASST operates within the purview of resource management jurisdictions and government agencies; and, how researchers and managers within these agencies formed trust in the program.

In this case study, our main interest was in examining whether and how citizen science contributes to NRM and decision-making, as evidenced by the COASST citizen science project and its interaction with NRM professionals at the state and federal level. We focused on three aspects of NRM-citizen science interactions:

1. Interactions surrounding citizen science data that were requested and/or used by the NRM professionals.
2. Other modes of interaction between citizen science and NRM outside of data transfer.
3. Perceptions of the NRM community regarding citizen science.

We investigated these aspects by asking NRM professionals about ways they partnered with COASST to address resource management issues and how the program's data impacted their work more generally. We also inquired about individuals' general perceptions of citizen science and other factors that influenced their willingness and/or ability to incorporate citizen science into their work.

Our results suggest that COASST and other citizen science programs can influence conservation and address environmental change by establishing clear, transparent, and collaborative strategies with project participants and NRM professionals.

2. Methods

2.1. Case Study Background

COASST is a marine-based citizen science program which monitors beached birds in coastal Alaska, Washington, Oregon, and Northern California, and as an organization is housed

within University of Washington's School of Aquatic and Fishery Sciences. As an organization based in an academic institution, the monitoring program focuses on a single data type—beached birds. It is not the only bird monitoring program of its type, but it is geographically the largest (Parrish et al. in press). COASST monitors long-term coastal changes as a function of anthropogenic activity and environmental forcing. The program's goal is to translate its broad spatiotemporal scale data into actionable science for conservation (Litle et al., 2007).

Participants undergo a thorough 5-6-hour training from COASST staff in which they learn to identify beached bird traits and how to survey a standardized beach site for carcasses. Upon completing the training, participants, referred to as 'COASSTers' choose a local beach to monitor at least once monthly. During each survey, participants collect a range of data on each carcass, including three standardized measurements, foot type, and additional carcass characteristics which are then used to assist them in species identification with the help of a dichotomous key devised by COASST. These data, as well as scaled photographs are sent to the COASST office for independent verification of species identity. Identification accuracy averages approximately 85% for participants (Haywood et al., 2016). COASST also maintains a high participant retention rate averaging 70% annually, with an average participation length of four years (Litle et al., 2007). Since its inception in 1998, COASST has grown to nearly 900 participants who collectively, gather data on over 480 beaches (Parrish et al. in review).

We focused on COASST as a case study of the use and role of citizen science data in NRM specifically because of evidence the program contributes to coastal and marine resource management (Parrish et al., 2007; Moore et al., 2009; Hamel et al., 2009). To address the question of how COASST plays a role in management and decision-making, we conducted semi-

structured phone interviews from September through December 2016 with 18 natural resource professionals from state and federal agencies active in seabird and marine management.

2.2. Interviewee Selection

The COASST Executive Director contacted a total of 28 NRM professionals who had collaborated with and/or requested data from the program within the past three years. Out of this group, 18 (64% response rate) responded—all affirmed permission to be contacted for an interview. Individuals who did not respond to COASST's initial inquiry about participation in the study were not contacted for an interview, which we consider as a source of possible bias in our analysis of responses. COASST subsequently provided a list of all affirming individuals, their contact information, and a short description summarizing how each person was connected to the program. Interviews were scheduled via email and conducted via phone.

Interviewees were ensured that any information they shared would be kept anonymous and used solely for research, according to IRB standards (IRB approval no. 839284-1). Interviews were conducted independently of COASST and respondents were ensured that participation in the study would in no way affect any existing or future working relationships between themselves and COASST. Interview questions probed into the challenges, benefits, and critiques of working with COASST and other citizen science projects to gain individuals' well-rounded perspectives across a critical spectrum (see Appendix A for a transcript of all questions). Interviewees represented a range of federal and state NRM agencies—each active in seabird and marine research or management across Alaska, Washington, Oregon and California. Fourteen respondents primarily worked for one of three federal natural resource agencies conducting

marine resource management and/or research while four respondents primarily worked for one of three state natural resource agencies that primarily conduct resource management.

2.3. Interview Data Collection

Each interview lasted between 45-90 minutes; all were audio-recorded and transcribed verbatim. Interviews focused on respondents' perceptions and experiences working with COASST datasets and staff. Respondents were asked to describe specific instances when they worked with COASST, and whether and how information from COASST contributed to their management decisions or other work-related actions. They were also asked about their perceptions of citizen science overall and its effectiveness as an approach to NRM more generally.

In interviews, we asked individuals if they had ever requested and/or used a COASST dataset in their work. If they reported they had used data, we asked them to describe each specific time they had used COASST data (see Appendix A for full interview protocol). While understanding how COASST data are used among NRM professionals was crucial to this study, data use was not the only role COASST played in management and decision-making. To understand how additional experiences factored in, we asked interviewees to explain in-depth the reasons why they collaborated with COASST and to describe the ways they judge the credibility of any datasets used in their work.

2.4. Qualitative Analysis

Using QSR NVivo software, interviews were coded in several stages to identify, analyze, and report qualitative themes (Corbin and Strauss, 2014). The coding process entailed:

1. Generating initial *a priori* categories reflecting characteristics of citizen science in NRM related to science and public engagement.
2. Creating *a posteriori* categories for different resource management roles, general perceptions of citizen science, and types of interactions between agencies and COASST.
3. Searching for and assigning themes within interview transcripts.
4. Reviewing and cross-coding themes throughout the entire dataset.

Thematic coding followed a multi-step process (Corbin and Strauss, 2014). First, we drew *a priori* themes from previous literature (Aceves-Bueno et al., 2015; McKinley et al., 2017) outlining two pathways of citizen science that inform NRM: 1) acquiring science and 2) fostering public input and engagement (Fig. 1). One example of this *a priori* process included course-level coding for salient mentions of 'public engagement' noted in interview memos to gain better understanding about where and how often these themes occurred. Next, major concepts from literature on public engagement in conservation, including information on the categories 'volunteer/participant' and 'social capital[1]' (Schwartz, 2006; McKinley et al., 2017) were developed as sub-themes within the 'public engagement' theme and then coded for across all questions within all interviews, sometimes being cross-coded with additional *a priori* and/or *a posteriori* themes.

[1] For purposes of this analysis, we referred to 'social capital' as it pertains to environmental issues—specifically, networks and relationships that benefit and/or encourage conservation and NRM actions (Schwartz, 2006).

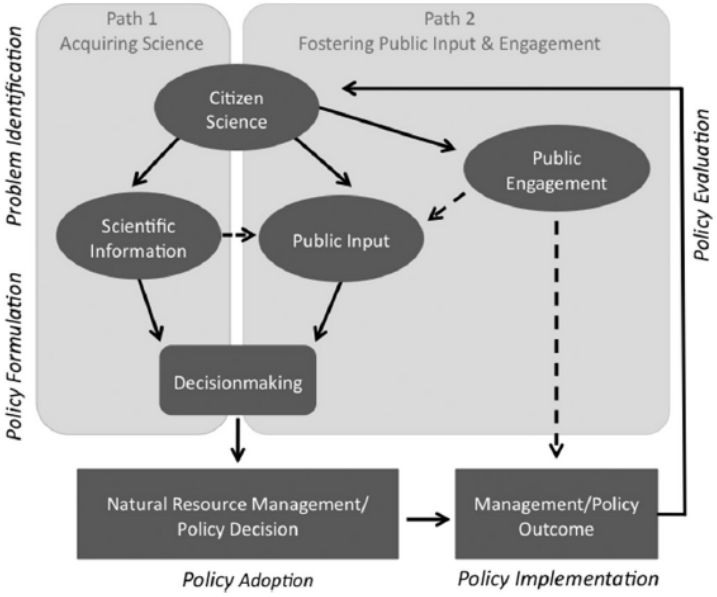

Fig. 1 McKinley et al.'s (2017) concept model of two citizen science pathways within NRM. This framework served as the foundation for this study's *a priori* themes, as they related to NRM professionals specifically.

A posteriori themes were developed directly from data. These were re-occurring themes that emerged across multiple interviews as either common responses to individual questions, or, similar topics, ideas, experiences, or perceptions that multiple respondents described throughout their interviews (Corbin and Strauss, 2014). One example of this *a posteriori* process included discovering that interviewees described many different types of interaction with the COASST program and COASST data varied across interviews and realizing these themes were a pertinent part of interviewees' experience in citizen science. Across all interviews, after multiple readings of the interviews, we categorized and then tracked the different types of interactions the interviewees described.

Iterations of code categories were revised by multiple researchers for thoroughness and accuracy while interview coding was completed by a single researcher. All interviews were analyzed with the same final version of codes (Table 1). The *a priori* and *a posteriori* themes allow for deductive as well as inductive analysis. This analysis led us to identify: 1) general

perceptions of citizen science among the natural resource professionals we interviewed, 2) patterns across different management actions and the roles a citizen science organization can play in those, and 3) factors that influenced collaboration between agency personnel and COASST. For example, we used the axial coding method (Corbin and Strauss, 1990) to further define the *Information exchange* category within the 'Interactions with COASST' theme in our analysis. We also used a selective coding method (Corbin and Strauss, 1990) to cross-code categories from the 'Natural Resource Management Roles' theme across categories from 'Interactions with COASST' to further develop and explain the later theme during analysis.

We searched for counterexamples of themes, incorporating Glasser & Strauss' (1967) constant comparative method into analysis. We checked emergent concepts against any conflicting counterexamples that may have elicited different interpretations and revised the codes accordingly, recoding where necessary.

Table 1

Describes definitions for themes within each of the six major categories used for coding analysis. Example quotes for subjective or implicit themes included.

Thematic Code	Definition
Characteristics of Citizen Science: Public Engagement	*A priori* theme derived from McKinley et al. (2017)—public input and engagement in NRM, pertaining to both COASST and CS in general. Interviewees described and/or stated:
Relating to volunteers/ participants	• CS allows for developing and/or tapping into existing science interest among public • Ways CS creates opportunities to participate in science and learn more about the process Example: *"Local people in remote places have informed agencies for years… [This brings] local knowledge and science together."*
Relating to environmental social capital—networks and relationships that benefit conservation and NRM action (Schwartz, 2006)	• Ways that CS facilitates understanding between scientists, agencies, and the public • Ways that CS creates communication exchange between multiple parties/stakeholders Example: *"Hopefully awareness will also lead to increased engagement in whatever form they [CS volunteers] choose to do that. That's the only way we're going to get, ultimately, support for making changes to better protect the environment."*
Characteristics of Citizen Science: Science	*A priori* theme derived from McKinley et al. (2017)—CS helps acquire scientific knowledge similar to conventional research, pertaining to both COASST and CS in general. Interviewees described:
Attributes of citizen science data	• Aspects of the scale and scope of CS data acquired • Unique factors of CS data • Ways CS and conventional data compare to one another Example: *"I think a lot about time series and I am increasingly a fan of long time series [data] because…in this changing world, time series form the baseline for tomorrow's unexpected perturbations"*
Monitoring costs	• Financial, time, and personnel costs (low to high) associated with CS Example: *"The reality is most people that are involved with citizen science, that's not their full-time job. And in academics you have a couple other full time jobs."*
Data quality assurance-quality control (QA/QC)	• The process of data collection and management/analysis of data, including study design, training, database management, and science expertise related to CS Example: *"Data from COASST is defensible. It's really important for citizen science to be overall useful through unbiased and accurate QA/QC protocols. It helps us keep track of things in real-time."*

Natural Resource Management Roles	*A posteriori* theme describing what interviewees indicated as their primary work responsibilities were in general within field of NRM. Serves as an explanatory category for constant comparative coding method (Corbin and Strauss, 1990). Interviewees described roles entailing:
Research	• Investigating taxa specific or ecosystem-based questions for the purposes of gaining new scientific knowledge which are applied to better understanding and managing ecological systems; publishing findings in scientific journals to disseminate information across the field
Seabirds	• Monitoring and managing seabird populations within a specific region or geographic boundary; includes managing and/or accounting for seabird species as established by agency jurisdictions and federal laws such as the Endangered Species Act (ESA), the Magnuson-Stevens Fishery Conservation and Management Act, and the Migratory Bird Treaty Act (MBTA)
General natural resources	• Monitoring and managing the natural environments and ecological communities within a specific region or geographic boundary, as established by agency jurisdictions and federal and state laws
Department/site leadership	• Overseeing and managing all or specific site/region/department activities, planning, research, and/or management responses within an agency or at a geographic site
Hazardous spills	• Managing an agency's hazardous (i.e. oil) spill prevention, preparedness, and/or response program
Fisheries	• Monitoring and managing fishery resources as mandated by federal laws such as the ESA, Magnuson-Stevens Act, and Marine Mammal Protection Act (MMPA)
General Perceptions of Citizen Science	*A posteriori* theme developed through emergent themes of interviews pertaining to overall views and attitudes toward citizen science in general. Interviewees stated:
Benefits	• Aspects of CS described to be beneficial to their work and/or positive overall; often cross-coded with additional themes, including—public engagement, cost, capacity of data, etc. Example: *"If you've got good people it's a pleasure to work with them and they can really provide an interesting perspective to the work you're doing which is pretty cool."*
Challenges	• Aspects of CS described as reasons CS can be hard to accomplish; often cross-coded with additional themes, including—QA/QC, cost, program leadership, etc. Example: *"AK has vast stretches of coastline that are remote and we can't make much inference to them from these data from around where there's towns."*
Critiques*	• Aspects of CS described negatively; used for coding counter-examples of themes and/or cross-coded with additional themes to indicate a negative affect Example: *"I've tried different forms of citizen science and it hasn't worked out very well for me…because it takes a huge amount of time and so I can make the choice between say doing a survey or managing a person who's going out to do the survey."*

Interactions with COASST	*A posteriori* theme developed through emergent themes of interviews pertaining to ways interviewees described interacting with the COASST program and its data. These themes used for axial coding method (Corbin and Strauss, 1990). Interviewees described:
Use of data	• Specific ways data are applied to research and resource management project
Information exchange**	• Ways through which information is bi-directionally shared between COASST and individuals or groups within one or multiple agencies o Code was further refined into two additional sub-categories: 1. Integrate COASST data into broader management—a COASST dataset is included as one of several information pieces into broad-scale management product, i.e. planning document, annual report, agency memo, etc. 2. Agency data is contributed to COASST—COASST requests and/or includes an agency's independently collected data into its own scientific analysis
Communication	• Ways information is communicated to the public and across professional fields within NRM
Non-data collaborations	• Instances when agency personnel worked with COASST in ways that did not include COASST data
Collaboration Outcomes of Work with COASST and/or Other CS	*A posteriori* theme developed through emergent themes of interviews pertaining to factors that interviewees described influencing, enhancing, and/or resulting from their experience working with COASST and/or other CS programs. Interviewees described:
Partnership	• Ways that CS and/or COASST create opportunities for collaboration between individuals and/or groups within and across agencies; often cross-coded with additional themes/categories, including—social capital, benefits, interactions w/ COASST, etc. Example: "*…It was a whole bunch of people really trying to get the information processed and available as quickly as we could and everybody worked together really well."*
Trust	• Ways that CS and/or COASST earn recognition, respect, or confidence through the credibility of their policies, reputation, and/or actions; often cross-coded with additional themes/categories, including—interactions w/ COASST, data QA/QC, general perceptions of CS, etc. Example: "*There is a need to understand how data were collected and the design for collecting data—who's collecting it, who's in charge, and do you trust those people or not."*
Leadership	• Aspects of a strong, motivated, visionary, well trained, and/or reputable figurehead needed for or benefiting the way a CS program runs. Also described as a strategy of successful CS; often cross-coded with additional themes/categories, including—interactions w/ COASST, general perceptions of CS, public engagement and science characteristics of CS, etc. Example: *"I'm really interested in seeing kind of a cadre of really well-trained people emerging from universities that have a pretty good understanding of citizen science."*

*Code used to identify counterexamples within interviews where respondents shared a critical perspective of CS in general or across additional themes (Glasser and Strauss, 1967).

**Through an axial coding process (Corbin and Strauss, 1990), "Information exchange" was broken into two separate categories during analysis not originally reflected in the codebook.

3. Results

3.1. General Perceptions of Citizen Science

To understand opinions and experiences of citizen science in general, we asked interviewees what benefits and challenges they associated with citizen science. While interviewees all acknowledged that citizen science provided beneficial outcomes to resource management, not all held a solely positive view of citizen science. Across all interviews, a total of eight individuals (44%) shared some negative or neutral (meaning they did not express any affect) views of citizen science programs. Four respondents (22%) also expressed some distrust in citizen science. Negative views of citizen science stemmed from personal experiences working with citizen science programs (other than COASST) and/or general assumptions about citizen science.

The ten interviewees (66%) who described benefits of citizen science also shared some of its challenges as well—but they stated that overall the benefits outweighed the challenges. In general, benefits included: gathering broad spatiotemporal data; creating better engagement between public agencies/scientists and the public; gathering evidence to inform decision-making; and, lowering environmental monitoring costs. Interviewees described ways these benefits are often carefully weighed along with other parameters of a project or study to determine if citizen science is the right approach to a certain management issue or question. As one respondent stated:

> *"[Citizen science] can sometimes be the right tool to answer a particular question of interest—but each time, I evaluate that independently and only use [citizen science] when appropriate."*

This individual went on to explain that any scientific dataset can be constrained by various limitations and these factor into selecting the appropriate method for solving an inquiry.

However, another interviewee explained that when a citizen science program is run effectively, the benefits can extend beyond the data alone.

> *"If the program is done well, the dataset can be almost unprecedented in terms of geographic and temporal scope…I think a second benefit is just engaging non-scientists in science. I think there are huge benefits to that."*

This quote reflects a common perspective expressed by all interviewees—that broad scale data collected by citizen scientists can serve multiple useful purposes in NRM, including but not limited to public engagement. Three interviewees (17%) explained that citizen science could be a cost-effective approach to ecological monitoring. However, seven individuals (39%) reported the cost-benefits of citizen science pertained only to COASST and other programs with their own self-sustaining funding, whereas a government run program would likely be cost prohibitive. When asked the question, "Would the agency you work for be able to run a citizen science project similar to COASST?" interviewees overwhelmingly said that cost was a limiting factor.

> *"As a governmental agency, it would be extremely challenging to coordinate a citizen science program and cost-prohibitive to collect the same type of data with paid staff."*

In interviews, cost is described in terms of money, time, and staff effort and was the one theme that interviewees described as both a benefit and challenge of citizen science.

When asked, "What are the challenges of working with citizen science in general?" most individuals described persistent challenges within the field of citizen science, including: maintaining good citizen science data QA/QC; the high costs of finances, time, and staff effort associated with successful citizen science; and, difficulties maintaining strong leadership and long-term participant engagement. A challenge for agencies stated by four interviewees (22%) was coordinating and keeping participant interest piqued over the long-term. One respondent described the challenge this way:

> *"It's a lot of work to coordinate the volunteers. It shouldn't be taken on lightly…You need to make sure they're well trained, so there's a lot of investment in that. You also need to keep them engaged and keep them informed about the data they're collecting and how it might be useful, so that they realize they're contributing to something significant."*

Several others shared similar sentiments. Four interviewees (22%) also expressed that maintaining lasting leadership within a project was another related challenge. One interviewee summed up the challenge of sustaining a successful project this way:

> *"I think that any successful program really boils down to the initiative, drive, and ability of the creators to strategically put the program together in a way that makes it self-sustaining…I think that [my agency] could do [these] types of things if we had the right person."*

Multiple individuals stressed that while it's often understated in the field of citizen science, it takes a lot of time and motivation to create a high caliber project. Some interviewees critiqued citizen science for this while others stated it was a challenge that could be overcome, COASST being an example.

> *"I think the COASST program and dataset are quite extraordinary with respect to what it has accomplished and my hat is really off to [them] for initiating it and then for letting it fly and it's quite impressive. It's sort of a model for this type of citizen science."*

While interviewees' general perceptions of citizen science were informed by many of their experiences with other citizen science programs, several of them referenced COASST even when talking about citizen science in general, which indicated the program has likely influenced some of these individuals' overall views of citizen science.

3.2. Categories of Interaction Between Agencies & COASST

We asked interviewees about their specific interactions with COASST, asking both about their use of COASST data and about other kinds of interactions with the project, in order to focus on the particular ways that agency personnel interact with this specific citizen science project.

We identified five categories of interaction that took place between agencies and COASST, including: 1) direct use of COASST data to inform the NRM action and/or decision-making process (within three different management categories), 2) blending COASST data into broad-scale management—such as ecosystem-based management, 3) agency data contributes to a COASST led effort, 4) COASST data are used for professional and public communication, and 5) COASST expertise (as opposed to data) is used for NRM in other ways. These categories reflect the interactions described by multiple respondents across all interviews (Table 2).

Table 2
Types of interactions with COASST and program's data described by interviewees

Interaction	No. of Respondents
Direct use of COASST data	n=9, 67%
1. Seabird management	• Seabird monitoring/UME response: n=11, 61% • UME response: n=10, 56%
2. Oil spill planning & response	n=7, 37%
3. Fisheries interactions	n=1, 6%
Integrate COASST data into broad-scale management	n=3, 17%
Agency data contributes to COASST	n=5, 28%
Communicate data	• UMEs: n=11, 61% • Information to public/agencies: n=7, 39%
Expertise for related management purposes	n=3, 17%

3.2.1. Direct use of COASST data

We identified three main ways interviewees used COASST data directly to inform resource management. Of the 18 interviewees, 12 (67%) named at least one direct use of COASST data they engaged in, and nine (50%) cited more than one direct use of data. The most common type of use reported was seabird monitoring—which included general seabird management (such as tracking population changes over time), as well as accounts of recent

unusual mortality events (UMEs) affecting seabirds on the Pacific Coast—for which interviewees described how COASST data were used to better understand these environmental phenomena. Ten individuals (56%) used data to monitor UMEs. General seabird management was also mentioned by ten (56%) of respondents, with a high degree of overlap (9 of 10) with respondents who also discussed UMEs.

Less frequent data use included oil spill planning and response as well as managing fisheries bycatch. Seven individuals (39%) of respondents used data for oil spill management. Only one individual used the data for management decisions related to fisheries bycatch.

1. Seabird management

Over half of interviewees used COASST data for direct monitoring of seabird populations and/or responding to UMEs (n=11, 61%) across a region or within the boundaries of a specific geographic site. COASST data track carcass encounter rates, which interviewees reported using to establish mortality baselines, as well as understand more about unusual seabird mortality events.

As a long-running program tracking carcass beaching baseline data, COASST can therefore document extreme departures or slight shifts from these means. Managers described how this broad spatiotemporal scale of data provides information about seabird populations, which can supplement or add to existing monitoring data. For example, an interviewee described how COASST data helped agencies better understand the context of a common murre *(Uria aalge)* die-off through using long-term monitoring data:

> *"[Mortality] numbers were higher than normal for much longer periods of time…there was still a really small number of birds, but those 3-4 were much higher than background levels."*

This interviewee went on to explain how COASST data complements and contextualizes agency-based information collected from a specific location:

> *"We have a similar program but we just go to [remote] places where there aren't people, so COASST is a nice complement…it's focused on where there are people so they work together pretty well."*

This individual explained that the combined dataset can then be shared with resource managers.

To date, COASST has contributed a broad spatiotemporal extent of seabird mortality data in some places for over ten years. Interviewees describe how these data have established beaching baselines for multiple seabird species. So now, these data show when and where there are departures—dramatic or slight, from the baseline.

The sharp increase over the past three years of UMEs along the Pacific Coast was a major theme across most of the interviews. All the individuals who described using COASST data to address seabird die-off events (n=10, 56%) explained how through COASST's long-term monitoring, mortality baselines clearly showed the scale of each die-off. They explained these data were useful to managers charged with responding to local events; and, to the researchers investigating the causes of these die-offs more broadly.

Interviewees who described responding to seabird die-offs talked about using COASST data to differentiate and compare baseline and above-baseline mortality rates. An interviewee illustrated how the data conveyed the remarkable scale of one mortality event to fellow managers and the public:

> *"This beach probably would have only had one, maybe two birds on it, and now it's got nearly 8,000...we use the data essentially to indicate, you know, "Here's normal, here's not normal," and then really impress upon folks that [we] ...really hadn't witnessed a wreck of this magnitude previously."*

Similarly, another interviewee shared how data helped a management team deliberate decisions during a Cassin's auklet (*Ptychoramphus aleuticus*) wreck before the cause of the die-off was known:

> *"We had to go through this whole, "Okay, what do we do? How do we respond to this?" Is it up to a certain level?" It's kind of like do you let nature take its course or do you intervene? …that's on the management response end of things. You can characterize the wreck. What do you do about it?"*

In these examples, COASST provided its data and took part in the UME response effort by convening together multiple agencies and individual managers as management decisions were being made (see Section 3.3). The application of data also promoted communication to the concerned public (see Section 3.2.4).

2. Oil spill planning & response

Compared to seabird management, fewer interviewees used COASST data for oil spill planning and response (n=7, 39%). While no large oil spill event has occurred in the range of COASST monitoring in the Pacific Northwest or Alaska since COASST's inception or expansion into new regions, these individuals described ways the program's long-term data can uniquely inform spill planning and in the event of a future spill, detailed how COASST data could be used to determine the effects of a spill on wildlife populations across a broad geographic region. One interviewee described sharing COASST data during oil spill planning exercises because the data was regional. This respondent explained:

> *"We have to focus on [specific sites] and so it's a little complicated because there's all kinds of things that happen outside and around [these sites] that affect them but we have a really specific mandate."*

This person shared that site-based managers typically do not have jurisdiction to collect data outside site boundaries, and described how COASST data can be used to understand regional pattern as well as determine what environmental factors may affect change.

Two interviewees (11%) described that oil spill planning also involves anticipating areas of coastline where oil is likely to accumulate and cause harm to wildlife. Managers reported they used COASST data to identify and prioritize areas where, due to drift patterns, high deposition rates of beached birds and oil could occur in the event of a spill. Another individual who was involved in an oil spill planning and response working group that included COASST detailed the importance of gathering this sort of information from COASST data prior to a spill:

> *"General depositional patterns of the shoreline of dead birds was…used as a way [to] help identify areas of the beach where there may be more tendency to accumulate things whether it's dead birds [or oil] for the damage assessment work… [and to] target the field crews and where to send them for wildlife rehab kind of work."*

This person explained that monitoring both before and after a spill event is what can clearly show how an oil spill affects seabird populations through evidence-based documentation. They explained that when there is a baseline mortality rate used to compare how and where populations change after a spill, damages can be accurately evaluated and restoration efforts can be specifically targeted.

3. Fisheries interactions

One interviewee that we spoke to used COASST data directly for managing fisheries bycatch. This individual explained that during one regional event, COASST data evidenced a high encounter rate of beached birds, particularly sensitive species such as the common loon (*Gavia immer*) in an unusual place at an unusual time of year. Birds appeared to have drowned from gill nets; therefore, the fishery was closed in that area to reduce the occurrences of seabird drowning. As this interviewee explained:

> *"There was an immediate management action that took place in response [to these seabird encounters]. I wouldn't know about these events without COASST data."*

While this instance illustrates a direct connection between use of COASST data and a management action, ways the data are used in fisheries management tend to be more indirect due to the different management jurisdictions various federal agencies are responsible for (see Section 3.2.2).

3.2.2. Integrate COASST data into broad-scale management

For managers who employ ecosystem-based management strategies, interviewees reported that COASST datasets provide ways to discover links across broad extents of the marine environment. Many seabirds are indicator species—meaning their population status may correlate with the health of other marine wildlife; and, changes to seabird populations can evidence the presence of other environmental forcing events at large and global scales within the marine environment. One interviewee explained how, through an ecosystem-based approach, tracking seabird mortality can help resource managers understand what's going on with other marine resources:

> *"Development of ecosystem-based management and the COASST program really complemented one another. Information from COASST could be used and was an example of how [ecosystem-based management] was happening."*

Other managers who described using COASST datasets for broader marine management expressed that these data add an additional layer of information to their work as well.

Other ways interviewees described integrating COASST data into large scale management and understanding of the marine environment included: 1) adapting COASST beach survey protocols and the statistical analysis methods used by COASST to marine mammal monitoring and 2) incorporating COASST data into a peer reviewed journal article (along with other datasets) explaining the broad geographic and temporal scales of recent and unprecedented

seabird mortality events. One interviewee described the role COASST data had on this large-scale project:

> *"We're putting together a story on this [seabird] die-off that runs from San Diego to the Aleutian Islands. It wouldn't be possible without COASST because it has the spatial coverage and time scale needed that tells us in time and space how birds die."*

While COASST data were requested for this research endeavor, this example reflects an indirect use of data in resource management. While they are crucial, COASST data are one of several datasets that together, contribute to a collective scientific understanding of the broader ecosystem.

3.2.3. Agency data contributes to COASST

Five individuals (28%) did not request data directly. These individuals either: 1) shared their own data with COASST and/or 2) assisted COASST to interpret its data (upon COASST's request). One interviewee explained that while the agency s/he works for takes a multi-disciplinary and ecosystem-level approach to its monitoring. When asked how this individual had worked with COASST, the interviewee explained that COASST asked for access to additional information beyond its own in order to understand what may have caused a seabird die-off:

> *"The COASST dataset has some very nice trends and patterns of Cassin's auklets—and [COASST] wanted to know what [else] was going on. Could [our data provide] insight into what was going on with the die-off that was detected in the COASST dataset?"*

This respondent also explained how the addition of agency data helped adjust for biases in the COASST modeling effort and provided additional evidence for how patterns of environmental and physical forcing may have affected the seabird population. Thus, while this

individual was part of a larger project incorporating COASST data, s/he never personally worked with the COASST data.

Another interviewee described a similar interaction with the program when s/he contributed complementary data during a scoter *(Melanitta spp.)* die-off in 2009. This individual stated that s/he never requested a COASST dataset personally or used the program's data specifically for management decisions. In her/his view, science requires a team of experts working together and COASST offers a unique dataset that s/he could help interpret and correlate with additional datasets. To this interviewee, a relationship with COASST was focused on communication and scientific collaboration as opposed to direct data use. S/he stated that scientists can't solve environmental problems by themselves and that when there's something weird going on with seabird populations, COASST will ask for help researching the issue.

3.2.4. Communicating COASST data

Eleven individuals (61%) described ways they used COASST data in response to seabird die-offs that were focused on communicating about these dramatic events to other NRM professionals and/or the public. This was done both through publishing COASST data in a variety of ways; and, by collaborating with COASST staff to explain these events through various communication and media channels.

Interviewees used data to communicate about UMEs in formal ways, including: writing scientific publications, presenting talks and posters at conferences, drafting agency briefings, and compiling annual reports. They reported that these communications were typically produced for professional audiences (indicating another way COASST data are used for NRM), even when no specific action outcomes may follow. An interviewee who identified as a researcher shared that

a researcher's purpose is to explore environmental phenomena and formally document their occurrence. This person described applied research as being the necessary first step that eventually leads to management action. This individual described the process of writing about the common murre *(U. aalge)* die-off in 2015-16, stating:

> *"There was a group from many agencies and COASST communicating consistently. At some point, we talked about the need to prepare papers and write about this die-off so it's available to others—to make decisions and provide insight…Papers are a way to get my work out there."*

Multiple individuals we interviewed referred to this same scenario—co-involvement between agency researchers and COASST staff on applied science potentially leading to publication. All interviewees who mentioned communication specifically referred to ways COASST data and staff expertise contributed to research publications and/or conference presentations.

Seven individuals (39%) also stated they collaborated with COASST to communicate to the public by: giving public talks, writing briefings and updates for their agencies, and/or engaging with the media. These managers explained that public engagement is part of their agencies' missions; therefore, they believe communication is a way to connect to and build support among the public, as well as keep volunteers motivated and feeling like their time collecting data is well spent. One interviewee described the benefits of public communication this way:

> *"People really want to know, 'My data makes a difference'…[The] only way we're going to get support for making changes to better protect the environment is if there's enough of a groundswell of common people saying, 'I care about this and I want you, as my elected official, to pay attention to this."*

These seven managers also described how partnership with COASST creates a clear link between science, decision-making, and the efforts of local community members—making the NRM process more participatory and knowledge more widely shared.

3.2.5. COASST expertise used for related management purposes

Even when managers may not use COASST's seabird-specific data for management purposes or decision-making, as was the case for three interviewees (17%), these individuals stated they nonetheless utilize the expertise of the COASST project and staff for related management purposes.

When asked about other ways NRM professionals collaborate with COASST, several interviewees reported ways COASST materials have bolstered, enhanced, and/or extended their work. Two interviewees described how partnership with COASST supported the development of COASST materials to serve additional management purposes, specifically adaptations of the COASST field guide: *Beached Birds*[2].

An interviewee talked about working with COASST on its new Marine Debris citizen science program, stating that the COASST approach would complement agency efforts:

> *"[COASST] focuses on the characteristics of the debris and links them to specific wildlife impacts. You're looking at size and shape and color and sharp edges and entanglement risk and stuff like that…It really tracks many of the wildlife impacts."*

Individuals made it clear that through the program's development of additional coastal citizen science projects, COASST conveys that its expertise goes beyond beached birds alone.

3.3. Factors Facilitating Collaboration in COASST Program

The reasons why managers choose to use the particular data they do and why they put in the effort to form certain partnerships helps us understand the effectiveness of citizen science in NRM. This information, even when not specifically about direct data use, can provide insight into how citizen science plays a role in NRM and decision-making in other ways. We identified

[2] COASST designed and published a series of field guides for identifying beached birds to species. Editions of *Beached Birds* include guides for the Pacific Northwest, Alaska, and the North Atlantic.

the main reasons interviewees offered about COASST's strong rapport among managers to generalize what other people in these roles may require and appreciate from another citizen science program. When asked how individuals judged data credibility and described the benefits and challenges of working with COASST, interviewees offered a variety of reasons why they used COASST data and formed relationships with the program (Table 3). The most prevalent reasons they gave were: 1) strong data quality assurance/quality control (data QA/QC) measures, 2) positive partnerships with COASST, and 3) trust in the program. The categories were formed based on responses to interview questions inquiring how individuals judged data credibility and described the benefits and challenges of working with COASST.

Table 3. Characteristics of COASST that facilitated collaboration between program and interviewees and examples of specific factors cited

Characteristics of collaborative relationship with COASST	Examples of evidence for collaborative characteristics cited by interviewees*
3.3.1. Strong data QA/QC—process of COASST data collection and the management/analysis of data; managers identified two main criteria for judging data credibility: data protocol and the training of data collectors	• Credible data protocol: n=14, 78% • Strong participant training: n=10, 56%
3.3.2. Positive partnerships—relationship building between managers and COASST facilitated through interactions beyond requesting/using data	• Joint UME response efforts: n=9, 50%
3.3.3. Trust—assurance in COASST's ability and credibility to run a rigorous CS program	• Scientifically strong and transparent protocol: n=11, 61% • Strong participant training: n=6, 33% • Respect for COASST's leadership: n=4, 22%
3.3.4. Public engagement—outreach opportunities to communicate and work with the public	• Communication with public/understanding of NRM and science: n=6, 33%

* (number of interviewees, %)

3.3.1. Strong data QA/QC

To find out how interviewees viewed the quality of the data they see at COASST and how it compares to other data they work with, we asked, "When you use any dataset in your work, how do you judge its credibility? How do you apply these criteria to COASST?" Interviewees described two main ways that COASST meets to their own criteria for judging credible data. They described how COASST upholds strong data QA/QC by 1) adhering to a clear data protocol and 2) providing strong training support for its participants. Data QA/QC describes the process of data collection followed by the management and analysis of data. This includes a project's study design, training, database management, and science expertise. For the purposes of this study we specifically refer to data QA/QC of citizen science.

Fourteen individuals (78%) mentioned COASST's data collection methods, specifically the beach survey and data validation protocols as being rigorous and credible. Ten individuals (56%) also talked about ways COASST provides thorough training opportunities for its participants.

Some managers pointed out that COASST's *Beached Birds: A COASST Field Guide* is clearly organized and works as a dichotomous key for species identification, and that it is an exemplary part of the protocol. As one interviewee explained:

> *"[COASST's] ID guides are really spectacular and impressive. In terms of making things identifiable from small parts, I think that really enables people to get good ID's."*

These managers explained how they valued the *Beached Birds* guides as a strong part of the overall protocol. Another individual explained how the ID guides were well thought-out and structured carefully. This is important for walking users through a deductive process that requires certain pieces of evidence in order for participants to make accurate identifications:

> *"Foot morphology is an incredible tool in predicting the family to which a bird belongs…Then the discriminations at a finer scale are easy to make… There's a ripe opportunity if you build your data – your tool for helping volunteers collect accurate data in a simple and foolproof manner. You get quality data in and quality inferences out."*

The fact that COASST uses this straight-forward and well-tested method for collecting data is one of the ways NRM professionals judged COASST's ability to adhere to rigorous data collection as well as methodically train its participants to do so through teaching identification skills like bird foot traits.

Another way interviewees explained COASST's strong data QA/QC was through the program's bird identification protocol and subsequent data verification process. One person who had personally gone through the COASST participant training shared that the protocol followed by volunteers and the training they receive from COASST is no less rigorous than the protocol or training professional technicians follow:

> *"From what I see from going through training is that COASST is very clear about what they want. They photo document stuff—don't push people to identify something if they can't...frankly, it doesn't get better than this even if you had all professional biologists [collecting data]."*

This respondent and others described that COASST data verification is well communicated to, and understood by, the managers who work with the program and use its data. According to interviewees, the process is scientifically accepted because verifiers are experts:

> *"[The verifier] can look at a wing and say, "Oh, that's a fork-tailed storm-petrel," or, "Oh wow, that's a Buller's shearwater."… I have complete faith that: one, those types of people exist, and two, COASST is working with them."*

As this quote conveys, interviewees are familiar with the unique expertise and skill sets COASST staff are equipped with. The program does in fact employ such experts who verify the identity of every bird reported by COASSTers.

A third way respondents describe COASST's strong data QA/QC is by referencing the leadership the program has demonstrated throughout crafting and carrying out the study design. Interviewees expressed how both the credentials and diligence of the people affiliated with COASST matter in this respect. One of the managers who did not specifically request or use the program's data (explained in section 3.2.2) made it clear that s/he still found them credible and would use the data if they were more applicable to her/his work. Likewise, this manager judged the caliber of COASST's data QA/QC from her/his experiences partnering with the program in non-data ways:

> *"In terms of accounting for veracity or credibility of COASST's work, I would say its relationship to the University of Washington…it was clear that they had a rigorous training program."*

This interviewee indicates managers may judge a program based on the relationships it establishes with its partners and the ways the program positions itself as a leader and expert in the field. Respondents described a way to discern a program's credibility is by understanding the specific QA/QC measures in place, as well as personally knowing the individuals and institutions that have established those measures.

3.3.2. Positive partnerships

Here, we examine what interviewees described as the partnerships that formed between COASST and its agency partners during unusual seabird mortality events (described in section 3.2.1). While some partnerships formed due to specific areas of expertise (detailed in section 3.2.3), relationships based on use of COASST data were also fostered between interviewees and the program, particularly during periods of seabird die-offs (UMEs). Interviewees explained how not only did COASST provide data to help them understand the scale of these events and

how to respond to them, the program also played a direct role in many UME response efforts itself. Nine individuals (50%) described this relationship and process of working closely with COASST, beyond just requesting and/or using their data.

We asked individuals what the benefits of working with COASST were. Several of the interviewees who responded to seabird mortality events described how these wrecks were stressful and demanding efforts due to the public attention and serious public health management concerns they generated. They described that the opportunity to work through these incidents with COASST's help and advice was a major benefit to the collaboration. One interviewee summed up a taxing wreck event and the advantage of COASST's support during the die-off this way:

> *"This die off could have been a very stressful event for me but it wasn't because [COASST] was so very professional and on target. I think that's part of the more important thing for me—just to have that good working relationship; and, understand that things are gonna get a little chaotic and they did but you know, COASST came through and said hey this is kind of the way it goes and it's going to be a little rocky but we'll work it out and that was just the way they came through with the perfect attitude through the whole thing."*

This individual stressed that not only did COASST contribute its data to better understand this event, the program also participated in the management response. Respondents expressed that these die-offs stretched their workload to maximum capacity and without COASST's help they didn't know how they would have handled the situations they faced. Furthermore, receiving extra help from COASST brought a sense of moral support to these challenging situations for some managers, as explained by this respondent:

> *"[The die-off] went on for months...It quickly became all we did for a while. You have to draw on these partnership relationships. Even then, it's pretty damn tough."*

This interviewee went on to describe how COASST contacted its participants in the region to ramp up beach survey frequency during some of these unusual events. S/he explained that the

extra monitoring and information was useful for management response and this was made possible through COASST's efforts to involve its participants.

Additionally, interviewees reported that COASST brought multiple agency scientists together to investigate causes behind these mortality events; and, that as the convener of such multi-agency collaborations, information was readily shared between multiple individuals. As one resource manager stated, s/he not only requested COASST's data during a mortality event, he also requested the program's participation in a statewide collaborative monitoring effort of the Cassin's auklet *(P. aleuticus)* 2015 wreck event. This example indicates that managers don't only seek out COASST for its data—in addition, they rely on building partnerships with the program to inform management and effectively address unusual environmental phenomena.

3.3.3. Trust

Thirteen interviewees (72%) expressed trust in COASST—both the program and its data. These individuals cited trust in response to interview questions asking how NRM professionals judge data credibility in all scientific circumstances and specifically how they apply those criteria to COASST.

Interviewees explained that their notion of trust, or, their assurance in COASST's ability and credibility to run a rigorous citizen science program, is fostered primarily by COASST's thorough beach survey and data validation protocols. Of these 13, 61% (n=11) referenced the program's scientifically strong and transparent protocol. This interviewee described why COASST's data could be so readily trusted by NRM professionals:

> *"By having that very rigorous key that they use where they use different diagnostics – the feet, the wing length, the bill...I think they have created a very solid survey system…I have no hesitations in using their data. It's as good as anything that we would do."*

As this individual explains, the protocol is designed just as thoroughly as any professional monitoring protocol would be. The deductive process of identifying beached bird carcasses and the data validation steps in place ensure quality control.

Additionally, six interviewees (33%) thought of COASST as a trustful or credible organization and data source. These individuals explained they formed these notions because of COASST's participant training process. Four of these individuals (22%) shared they had first-hand experience participating in a COASST training and one individual was even a previous COASSTer. A respondent summed up why COASST's trainings instilled trust for her/him:

> *"Support that volunteers are getting is really key. I do really tend to be anal and tend to look at data pretty closely and won't use it if I think it's got some flaws to it, but I wouldn't hesitate to use COASST data. I think their level of support and training is amazing."*

This quote highlights that NRM professionals often need to be selective about the data they use; findings from this study indicate that one reason COASST is trusted by agency personnel to produce reliable information about beached birds is due to the thorough level of training the people who collected the program's data were supported with.

Only one individual cited "the reputation" of COASST (i.e. its pedigree based on its highly-trained staff and affiliation with a prestigious academic institution) alone as justification for trusting the program. However, a total of four interviewees (22%) did mention that respect for leadership within COASST, or the prestige of the academic institution it is housed within, played a role in establishing trust. This illustrates that for the most part, a citizen science program cannot rely on its reputation or prestige alone in order to garner trust among managers.

3.3.4. Public engagement

Six individuals (33%) described public engagement through COASST citizen science as a general benefit to working with the program. However, interviewees indicated that outreach achieved through these partnerships did not directly influence specific NRM or decision-making outcomes. Rather, interviewees illustrated some of the implicit benefits of outreach through partnering with COASST. In their words, the program's citizen science monitoring provided opportunities to familiarize the public with the goals of NRM agencies, share values of science, and provide a channel of communication between managers and the community. In response to the question, "What are the benefits of working with COASST?" one interviewee shared:

> *"I think another benefit…is the way the data are collected, in that it is a successful example of citizen science and getting non-scientists involved with science. It peels back the layers of distance and allows people the ability to understand, respect, admire, and champion science more and champion what applied science does…So I think the COASST program is a really good example of that."*

NRM professionals in this study described public engagement as an intrinsic and valuable component of management. Yet examples were mostly anecdotal and personal rather than directly linked to decision-making. A similar perspective from a second manager explained that benefits of working with COASST included:

> *"As a resource manager, I don't want to be spending a lot of time on things that people don't care about. It's kind of demoralizing, honestly. Sometimes you're on the leading edge of that and you're getting people to pay attention, and other times, you're responding. You need both ends of the spectrum happening. To me, those are some of the less tangible but equally important aspects [of COASST]."*

This person describes how engagement affects her/him personally and also portrays that public support is ultimately needed to effectively respond to environmental issues and carry out management decisions successfully.

4. Discussion

4.1. General perceptions of citizen science

Our findings regarding the views of citizen science among NRM professionals illustrate some ways that conservation-based citizen science programs can increase their impact and relevance in the field. Evidence from interviews highlights that a variety of different types of researchers and managers agree with current research proposing potential benefits of citizen science within resource management (Aceves-Bueno et al., 2015; McKinley et al., 2017; Dickinson et al., 2012; Devictor et al., 2010). Many individuals emphasized that just like any form of professional science, citizen science can span a wide range of impact and rigor. If measures are in place to ensure quality data (which all interviewees indicated was possible), citizen science can be a useful tool in the conservation toolbox.

This study indicates that some of its potential outcomes perceived by interviewees, including gathering a broad range of robust data for lower cost (Theobald et al., 2015), may actually be much harder to achieve in practice, as McKinley et al. (2017) also suggest. Interviewees who had experience with citizen science projects explained that it can also be challenging to maintain a strong participant base for long-term projects; and, even harder to find someone with the dedication and panache for successfully managing a citizen science project—maintaining its quality and consistency over time. Thus, there is much to learn from programs that do maintain strong long-term engagement and convey savvy leadership. Sharing these programs' methods more widely within the field of natural resources is a valuable strategy to further the reach and success of citizen science.

However, the interviewees in this study indicate that many NRM professionals do recognize the value of citizen science and may be eager to partner with existing programs that

offer value to their work—though this study only included professionals who already partnered with a citizen science program and needs to be tested with a larger, less biased sample. Often the caveat NRM professionals make is that a program should be able to manage the responsibilities of participant training/engagement, data management, and cost on their own. The agency personnel we talked to described COASST as a model that stands out as a program that successfully overcomes many of the challenges of citizen science and exceeds expectations so well that even interviewees with critical views of citizen science in general still find COASST data valuable. We suggest that other programs may be able to increase their own success by drawing from COASST and other examples of citizen science that NRM professionals affirm are useful.

4.2. Interactions with COASST

By focusing on interviewees perceptions and interactions with COASST, we found ways the program's data are both directly applied to management actions and decision-making, as well as indirectly used for NRM through research collaboration and through communication of environmental events to the broader scientific community and the public. Additionally, the program's expertise creates opportunities for partnerships based on what we call COASST's "niche knowledge set" or unique expertise that can be applied to NRM in ways beyond use of the program's data alone.

COASST is flexible and responsive when it comes to meeting the needs of agency personnel and documenting unusual phenomena. It fills a need in resource management for extensive ecological monitoring (Colwell et al., 2012) and covers a wide geographic footprint. It also carries out monitoring where agencies don't always have the capacity to do so, especially in

remote parts of Alaska (Litle et al., 2007). This collaborative effort helps fill some of the data gaps, creating broader monitoring coverage across a geographically vast region that is hard to monitor due to its remoteness (Litle et al., 2007).

Over time, the program's data (along with datasets from similar beached bird programs) have become crucial for identifying shifts in the beached bird baseline during unusual seabird mortality events across the northeast Pacific coastline (e.g. Parrish et al., 2007). COASST can augment the interpretation of these events and other environmental phenomena by initiating collaborations with other researchers who can contribute additional data. As Lester et al. (2010) claim, filling key knowledge gaps with readily available science can further ecosystem-based management. Partnerships augmented by COASST bring together multiple layers of information that can provide a more complete understanding of the complex ecosystem. It would be unlikely for one agency alone to achieve such a broad perspective.

Likewise, communication between researchers and managers on the ground, within an agency and across multiple agencies and institutions, are crucial parts of the NRM process if management is to benefit from relevant research findings. Yet the disconnect between longer-term research and on-the-ground management can pose a challenge to carrying out the effective application of new NRM strategies (Dreiss et al., 2017). One of the difficulties of integrating scientific knowledge into local resource management as identified by Raymond et al. (2010) is a lack of communication and poor information flow between academic researchers and resource managers. The case of COASST illustrates that a citizen science program can be part of the solution to these communication barriers in resource management. Efficiently communicating the changes and shifts within a long-term dataset, both to others in NRM as well as to the general

public fuels the decision-making process (Cook et al., 2013), even if management actions are not taken up immediately.

In addition to their data, COASST materials have also been directly incorporated into NRM (e.g., use of the *Beached Bird* field keys within then National Marine Fisheries Service (NMFS) Observer Program). According to Colloff et al. (2017), novel approaches to conservation science and practice will be crucial to solving the challenges of the "post-normal world" they forecast. Therefore, COASST's "niche knowledge" can be seen as a potentially useful skill to share with NRM professionals in ways that go beyond just providing data. This is what Patterson et al. (2016) refer to as "transformations towards sustainability". As previous findings from this study and others show, it is a challenge to keep citizen science programs relevant and well funded (Peters et al., 2016). Yet when a program develops a particular "niche knowledge", new opportunities may arise to share valuable expertise and build additional support for a program as well as fill in knowledge gaps (McNie et al., 2016). This is useful for decision-making, where actions and policies must incorporate multiple forms of knowledge (Epstein, 1995).

4.3. Factors Facilitating Collaboration

We heard from interviewees that for successful collaboration between citizen science programs and agency partners to take place, it is useful for the citizen science program to be closely tied to the specific information needs of agencies and flexible, meeting resource managers' needs in multiple ways without causing additional time costs, financial demands, or other undue burdens to agencies. According to interviewees who shared that they worked with COASST since inception, COASST was deliberate and patient in its protocol design and sourced

opinions and garnered support from NRM professionals (including many of the individuals in this study) long before trends became apparent from the data (Litle et al., 2007).

Respondents described that interactions between their agency staff and COASST staff, particularly during stressful UMEs, led to camaraderie and support—which made dealing with these situations more manageable. In these circumstances, this partnership opportunity created a successful adaptive response to abrupt changes in the system, helping agencies form an organized and informed management approach as opposed to choosing actions that might easily fall into chaos or lack clarity (Walker et al., 2004).

Overall, individuals from this study expressed ways that COASST has cultivated partnerships with agencies that save managers time, money, and effort; and, these strategic partnerships have offered COASST the opportunity to take on a unique role within marine management and conservation, even though the program holds no official decision-making power. Likewise, individuals shared that partnering with COASST offers their agencies opportunities to engage with the public in authentic ways because the data they use and share with the public comes from community members themselves. This draws connections to Haywood et al.'s (2016) concept of a "conservation literate community"—that through engagement in science, the public gains the capacity and commitment to better understand environmental concerns and take up environmental actions themselves.

COASST's focus on independently crafting a rigorous study design, continuing to carefully manage a credible dataset, and encouraging the growth of positive partnerships centered around program data and unique program knowledge and expertise are essential factors of the program's success in the field of NRM. Through these actions and interactions, COASST fosters a trust building pathway and promotes its ability to take on leadership within the NRM

professional community. Trust in the program is needed to initiate and further the many types of interactions COASST engages in with its partners and in turn, these interactions further the pathway of trust.

The findings from this study highlight that to be successful in working with public agency scientists and managers, a citizen science program must understand, acknowledge, and strive to overcome the challenges and critiques citizen science faces within NRM. Programs stand to do so by developing factors that can facilitate successful collaboration through building trust in a citizen science program that helps create a useful application of its data in NRM and supports non-data collaborations as well. The pathway to building trust and leadership starts from creating self-sustaining program support, cultivating partnerships with agencies and institutions, and engaging with the public. These findings follow Dickinson et al.'s (2012) suggestion that strategic collaborations and partnerships are necessary to drum up the resources and engagement necessary to sustain citizen science projects for the long-term.

4.4. Citizen Science as Boundary Work

Citizen science is often thought of as a direct relationship between professional scientists and volunteers (i.e. citizen scientists). This study may indicate that COASST could be an example of a program that operates as what we define as an intermediary organization—an independent group or institution that interacts and engages with both participants, the data collectors, as well as the data end-users—such as researchers and resource managers. This is similar to the concept of boundary work, or, the endeavor to bridge the void between science and non-science (Guston, 2001). Like some citizen science programs, boundary organizations

mediate both knowledge and action (Blal et al., 2017) by working across and with multiple groups and institutions (Leimona et al., 2015).

Mediation and strong leadership are identified as important aspects of boundary work collaboration (Lee et al., 2014). Similarly, we see these as important elements of success for citizen science. Cook et al. (2013) suggest that stronger partnerships between agency decision-makers and scientists at research institutions can help bridge the knowledge-action boundary of conservation—in other words, this refers to the production *and* use of knowledge pertaining to conservation science and subsequent NRM (Blal et al., 2017). While both boundary work and citizen science are highlighted as strategies for working within complex social-ecological systems and have both been linked to playing roles in environmental decision-making (Shirk et al., 2012; Schwartz et al., 2017), boundary work could be considered as a way to position citizen science as well. We suggest that further research is needed to investigate ways these different aspects of boundary work might occur through a citizen science approach, and whether and how they influence NRM.

This study indicated that citizen science indeed contributes useful data to NRM, as previous research also suggests (Shirk et al., 2012; Bonney et al., 2009). Looking closely at one program specifically shed new light on the intermediary role a citizen science program can play in both facilitating data collection among its participants, and in disseminating data for scientific research and resource management among agency partners. For this study, we focused on how COASST interacted with NRM professionals in particular—learning that part of what motivates researchers and managers to work with the program is the way COASST closely trains and interacts with their citizen science participants to ensure high quality data collection. By functioning in an intermediary role between the communities that participate in data collection

and scientists/managers who use the data in partnership with COASST (Fig. 2), the program is constantly working across the spectrum, playing an active role in the entire process from study design through analysis and dissemination.

This intermediary role that COASST plays may be an example of "boundary work" within science, which is defined as structured partnerships between practitioners and scientists that facilitate turning knowledge into action (Guston, 2001; Lee et al., 2014). Often used to link science to policy, the traditional goal of boundary organizations as competent mediators is to cohesively streamline connections across various partners—producing useable knowledge, leadership, and working relationships among stakeholders, often to address environmental challenges (Leith et al., 2016; Lee et al., 2014). Similarly, COASST works to produce the best data possible and make those data widely available to all its partners (Fig. 2)—scientists, resource managers, the broader public, and the communities it works in collecting data (Parrish et al., in press).

By taking on the role of promoting strong collaboration among agencies that use the data, COASST makes it easier for agency partners to collaborate with the program and with each other. Likewise, COASST's strong ties to local communities and its participants keeps engagement high and data collection accurate, which helps build in trust of the program among NRM professionals.

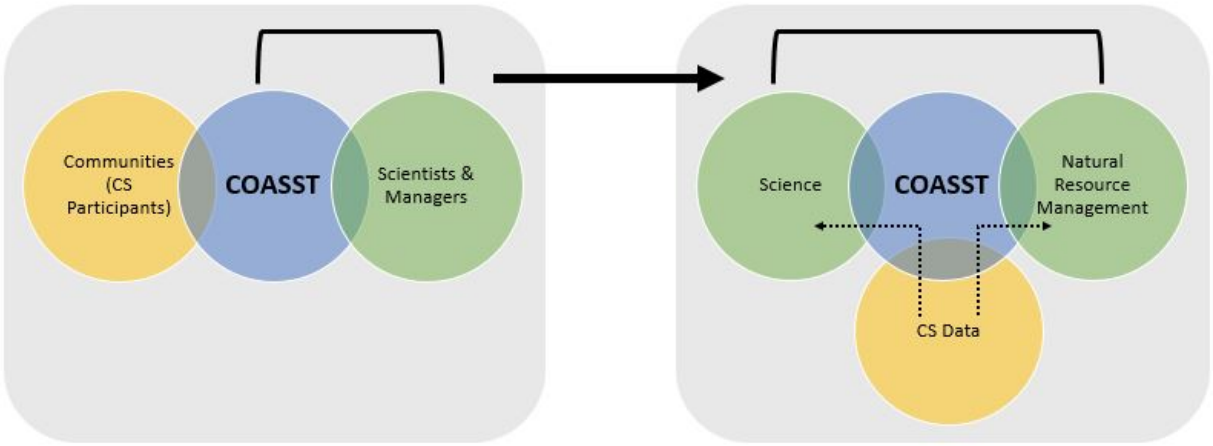

Fig. 2 The image on the left demonstrates how COASST works closely with both the local communities (where participants are recruited from) and the data users affiliated with the project. The image on the right shows how COASST shares CS data with both science and management, brokering its own roles across the entire conservation spectrum.

The case study of COASST demonstrates the program's adaptability to interact with multiple groups successfully—a key component to its citizen science strength and an opportunity to redefine this caliber of citizen science as boundary work. Tracing the multiple ways COASST uses its data and expertise to contribute to resource management are similar to the actions Schwartz et al. (2017) identify for improving conservation practice through boundary work. Schwartz et al. (2017) state that conservation boundary work requires planning for both action and learning. We believe the same is true for management-relevant citizen science. NRM decision-making is a process that relies on the collaborative efforts of many, but often needs a convening organization to mediate the complexity of this (Cook et al., 2013). COASST is positioned as such and demonstrates that its model contributes valuable information and expertise to public agencies that don't always have the same flexibility or capacity to do so on their own. The ability of a citizen science program to work dynamically across a broad spectrum of both participants and data users (Fig. 2) aligns with the principles and practices guiding successful boundary work. Citizen science may position programs and organizations to

communicate and work successfully across multiple groups including local communities, scientists, and decision-makers.

Some citizen science programs may be better suited for boundary work than others. Large, crowd-sourced databases include programs that have online interfaces, crowd-sourced platforms, and global scale data. These programs might have less influence on place-specific or community-focused resource management outcomes because they produce relatively coarse datasets and maintain less communication both with data collectors and data users. Yet other programs that operate at a regional level and involve hands-on and in-person studies with multiple conservation stakeholders could position themselves as citizen science boundary organizations because like COASST, they conduct focused citizen science that may feed more directly and specifically into resource management on a finer scale. We see an area of fruitful potential research in using the framework of boundary spanning organizations and functions to compare across different types of citizen science programs.

Likewise, a boundary work model could be used as a guiding framework as organizations and agencies continue to create new programs in the future. The Washington Department of Fish and Wildlife (www.wdfw.wa.gov/about/volunteer/citizen_science) for example has recently worked to partner with existing citizen science programs and build out their own citizen science programs in order to tap into existing community knowledge as well as address specific resource management goals. State and local agencies, as well as regional or site-specific divisions of federal agencies may also be aligned to take up some boundary work roles, concentrating their engagement and conservation efforts more regionally and locally. Yet one of the most recurring solutions for effective conservation practice is dynamic engagement among multiple groups and institutions (Schwartz et al., 2017; Schwartz, 2006; Cook et al., 2013). Partnership with

organizations like COASST and other independent projects operating at the boundaries of science and decision-making can help agencies take part in public engagement and research, or, influence and contribute to management in ways that agencies may not be able to accomplish alone.

4.5. Bringing Consistency to an Inconsistent System

Citizen science programs can build resilience into a social-ecological system by capitalizing on ecosystem changes as opportunities to organize, learn, and adapt (Berkes and Jolly, 2002). Increasingly, NRM professionals realize that resource management and conservation success requires tackling issues from a broad social-ecological systems perspective (Bennett et al., 2016)—which not only factors in how species, resources, and landscapes are understood scientifically, but also includes how information is disseminated to and taken up by resource managers as well as the public (Schwartz et al., 2017). As such, the institutions that plan for and address both ecological and social responses and adaptations for unpredictable and uncertain environmental events convey examples of building resilience into the coupled human-natural systems. Citizen science could be an effective tool for social-ecological systems-based research (Crain et al., 2014) and could offer resilient ways to anticipate future change. This research identifies ways COASST's model of citizen science helps NRM professionals rely upon consistent and trusted interactions in order to anticipate and respond to uncertainty.

Conservation decision-making processes struggle to keep up with the rate of current environmental change (Mortreux and Barnett, 2017). Therefore, conservation needs additional support mechanisms to stay in step with, and effectively respond to, the future's uncertainties (Schwartz, 2006; Bennett et al., 2016). This came to light during the recent ocean-warming

event that occurred from 2013-15 in the Northeast Pacific. This environmental phenomenon involved several unusual and mass seabird mortality events and may be evidence of climatic changes we are likely to see more of in the future (Kintisch, 2015; Di Lorenzo and Mantua, 2016). In response to these UMEs, COASST convened multiple agencies and stakeholders together, which may not have taken place without the program's direction. As interviewees in this study described, a seabird mortality event is energy-intensive and demanding on agency personnel who are often tasked with multiple responsibilities including: informing the public, protecting human health, and understanding and solving the environmental problem at hand. Yet as these unexpected and unpredictable die-offs unfolded throughout 2013-2016, COASST provided consistent support to its agency partners. Based on explanations the individuals in our study gave, we discerned that COASST played a crucial role in UME response efforts through the program's consistent communication, data analysis, and leadership.

With global change rising in scope and scale within an increasingly complex social-ecological system, resilience may be achieved through solution-based science that provides consistent data and leadership to address the inconsistencies NRM faces. Theobald et al. (2015) assert that citizen science is an opportunity to locally collect data needed to track and solve today's global environmental challenges—in effect traditional scientific approaches alone are not the only solution for increasing science knowledge. Likewise, Armitage et al. (2008) position change and uncertainty as an opportunity for learning and argue that innovative approaches to learning can result in collaborative forms of NRM. Therefore, citizen science may be well equipped to help address global change through the organizational, learning, and adaptation principles of resilience. Although we can never fully prepare for or predict the events of the future, identifying and responding to signals of change is nonetheless crucial and achievable.

5. Conclusion

We found that COASST is an example of citizen science that subscribes to and prioritizes the design principles of science while making its science visible to agency partners and community participants. The program informs NRM directly through multiple uses of its data as well as indirectly through collaboration with agencies and other institutions. COASST alleviates concerns that NRM professions express about citizen science in general through rigorous data QA/QC policies, fostering strong multi-collaborator partnerships, emphasizing public engagement and communication, and by leveraging trust through promoting evidence of its credibility and reputability to the conservation science and management field.

As the recent and extreme seabird mortality events described in this study demonstrate, COASST responds to crucial needs within resource management to understand and manage environmental disturbances like these. The program develops multi-agency collaborations involving scientists and resource managers alike to address such events; and, communicates to and involves the public in their discourse. This approach to citizen science involves a strong emphasis on study design, data management, and agency cooperation. COASST promotes convening and interacting with multiple agencies and institutions. In this study, we learned more about the ways COASST engages closely with these people (both its participants and data users) *and* systematically with its own data, which builds a foundation for trust in the program and the information it provides.

This research identified that discernable benefits and challenges exist between citizen science and NRM interactions. Understanding these aspects provides an opportunity to ensure that interactions taking place between a citizen science program and agency partners are realistic and intentional. These interactions involve collaboration around relevant data (i.e. spatio-

temporal scale) and transferable and/or adaptable knowledge between a citizen science program and NRM. Importantly among NRM professionals, a citizen science program employing strong leadership and emphasizing trust is integral in building and sustaining these interaction pathways. However, these layers of trust and leadership must first emerge from the essential factors of citizen science that allow for it to become relevant to and taken up in NRM decision-making in the first place.

The dynamic role citizen science can play in NRM is a key component of a resilient coupled social-ecological system. When citizen science garners a broader spectrum of knowledge from diverse groups of people, it may be a natural resource management and conservation strategy that allows managers to anticipate and confront complex perturbations occurring across multiple scales of time and space. The need to build robust social-ecological systems that anticipate, adapt to, and sustain themselves through unexpected and at times unprecedented events and circumstances is the new normal within our changing world. Real-time data collected over issue-relevant scales of space and time has the promise of promoting solution-based science needed to respond to changes and allowing well-placed leaders and other boundary spanners to communicate them across broader networks of policy-making and communities.

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Appendix A – Interview Protocol

Introduction: Thank you for agreeing to take time out of your day and talk to me about your involvement with the COASST program. I am a graduate student at UC Davis and for my thesis research, I'm studying how resource managers use COASST citizen science data in their work. This interview will last for approximately 1 hour. Feel free to ask me to repeat or clarify any questions I ask you. Before we start, I want you to know you can skip any questions you want, you can end the interview at any time, and I will keep your responses confidential from the COASST staff unless you give me permission to share them. May I audio record this conversation? This recording and all notes from this interview will be stored in a secure data storage system and your responses will be kept anonymous.

Interviewee:
Interviewer:
Date:
Start Time: End Time:

Background Information

1. Agency:
    a. Job Title:
    b. How long have you been in this role?

2. In your current position, what are your primary work responsibilities/roles (**Probe:** i.e. resource manager, research scientist, program manager, outreach/education, administration)

COASST Program

3. What was your first connection to COASST and how did you interact with the program? (**Probe:** i.e. analyze data, cited project in publication, assisted with project protocol/implementation, interacted with participants, ran/attended training, collaboration)

4. Have you ever requested, received, and/or used a COASST dataset? (**Probe:** data visualization/analysis from COASST, raw data for specific question/task). **(If yes, go to Question 5. If no, go to Question 7).**

5. Tell me about a specific time when you used a COASST dataset – what were you working on or trying to find out? (**Prompt:** Will ask sub-questions below as necessary if interviewee doesn't provide here)
    a. What did you need the data for?
    b. What were you trying to decide?
    c. How did it work for you to get the information from COASST? Who did you work with to get it?

d. How did the process of getting COASST data compare to getting other kinds of information about that issue?
e. How did you end up using the data?
f. Did you write anything up about that instance?
    i. What happened with it?
g. Did you share the data with anyone else in your organization? How did they use it?
h. How did you disseminate this information in your organization or to others?
    i. What did they do with it?
i. Would you have been able to obtain that information without COASST? Why/why not?
j. What was the relative role of the information you got from COASST as compared to other sources of information you used to work on this issue? What other sources of info did you use?
k. Do you use information gained through COASST in your work decisions or actions? How so?

6. Are there other instances when you used COASST data? (Repeat Question 4 above for another instance of using COASST data if possible).

7. Aside from/In addition to requesting and using specific dataset(s), have you worked with COASST on anything else? Please tell me about a specific way you interact with COASST. (**Probe:** i.e. received biological samples, formed collaboration/partnership, discussed policy/advocacy, grant project, journal publication, etc.)
a. What was the purpose of this interaction?
b. What were you trying to decide or accomplish? Were you successful?
c. Who did you work with on this (from COASST and/or other organizations)?
d. Did you or anyone else write anything up about this instance?
    i. What happened with it?
e. What was the outcome of this interaction?
f. Would you have been able to accomplish your goal without COASST? Why/why not?

8. Are there other instances when you worked with COASST in a specific way but didn't request/use a dataset? (Repeat Question 7 above for another instance if possible).

9. When you use any dataset in your work, how do you judge its credibility?
a. How do you apply these criteria to your work with and/or use of COASST data?

10. (If not already stated…) What are the benefits you experience in working with or using COASST data in your work?

11. What are the challenges you face in working with or using COASST data in your work?

12. Would you or your organization be able to run a program that accomplished similar outcomes to COASST? Why/why not? (**Probe:** Do you/your organization possess the expertise to run such a program? Do you have the funding to do so? Do you have the desire/will to do so?)

Perceptions about Citizen Science

13. Does your organization have an official policy about using volunteer-collected data? If so, what is it?

14. How do you personally define "citizen science"?

15. Have you worked with other citizen science programs other than COASST? If so, which ones?

16. In your position as the**…..[title at org. name],** what are benefits from working with citizen science? In any capacity?

17. In your position as the**…..[title at org. name],** what are challenges associated with citizen science?

18. What resources or support, if any, do you need from your organization in order to work with citizen science or citizen science organizations?

19. Is there anything else you would like to share regarding your personal thoughts/feelings/ideas regarding COASST or CS more generally?