More than Crowdsourcing Science: The Reasons for Museum Citizen Science Programs and how and why they Change

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Abstract

This exploratory research study seeks to identify reasons why museums begin citizen science programming, why they continue to do citizen science, and how and why their programs have changed over time. Citizen science is a growing program area for museums, and yet there is little research examining the role and purpose of these programs from the perspective of museums. Within the context of a purposive sample of eight diverse science museums, three methods were employed to collect data including surveys, interviews, and document analysis. Results suggest three major conclusions. First, the museums studied here reported various institutional benefits from offering citizen science programs, for example museums now use these programs to appeal to donors, to seek grant funding, to build relationships with professional scientists, and to raise awareness of the museum and its mission. Second, the citizen science programs in this sample were highly adaptable. Museums used these programs to meet local needs such as environmental monitoring and resource protection. Third, results suggest that citizen science programs in museums are situated at the intersection of research and education, and as such may have the potential to unite disparate efforts to achieve larger institutional goals.

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Chapter One: Introduction and Problem Statement

Members of the public without professional scientific training have participated in the collection of scientific data since inquiry about the natural world began, and intensified during the Enlightenment. Early modern scientific data were largely collected by non-scientists, such as clergy, aristocrats, and others with the leisure time and means of seeking information about the natural world. In the latter part of the 20th century, citizen enthusiasts, informal educators, and professional scientists began to collaborate more formally on programs to collect scientific data to answer key research questions.

Today, participation in such efforts is generally known as "citizen science," a term coined in 1995 by Rick Bonney at the Cornell Lab of Ornithology (Gura, 2013, p.259). Citizen science is a set of activities that involve members of the public in developing research questions, collecting data, and interpreting results to advance scientific inquiry (p.259). It is also known as "public participation in scientific research" or PPSR. PPSR is a term recently created by experts in the citizen science field to more clearly indicate that members of the public are actively engaged in scientific research (Center for Advancement of Informal Science Education, 2009). "Citizen science" and "public participation in scientific research" are synonymous terms.

Little or no research has been conducted on the reasons museums decide to become engaged with citizen science programs. Why do museums choose to engage in citizen science programs? How do they integrate such programs into their institution? How do citizen science programs influence a museum's priorities and efforts? This research study is designed to begin to fill this gap, providing information on reasons why museums began their citizen science programs, why they do them currently, and the ways in which citizen science programs are

impacting, co-evolving and influencing activities within the host institution. Specifically, the study is designed to answer the following primary research question: *What factors motivate museums to host citizen science programs, and how and why do museums perceive that those factors have shifted over time?* Secondary research questions include: How are other areas of the museum adapting elements of citizen science programs for other institutional goals? How is the evolution of citizen science programming co-evolving with organizations?

Citizen science projects can focus on any scientific discipline, and can consist of any type of activity that a lay member of the public can be trained to complete. In a special report on the subject, the Center for the Advancement of Informal Science Education (CAISE) identifies three types of citizen science projects characterized by the nature of public engagement: contributory, collaborative, and co-created. (CAISE, 2009, p.11) Contributory projects are by far the most common type of citizen science project, and are designed by scientists and employ the public in well-defined data collection activities (CAISE, 2009, p.11). The San Diego Plant Atlas Project is an example of a contributory citizen science program hosted by a museum. The program began in 2003, and consists of training "parabotanists" to collect plant specimens from San Diego County in a systematic manner, tentatively identify them, and submit the plant specimens to the herbarium for study and to accession into the collections (San Diego Plant Atlas, n.d.). As a direct result of this program, over 55,000 specimens have been added to the museum herbarium, 300 species previously unknown to exist in the county have been found, and two new plant species have been discovered. The scientific impact of data associated with this collecting activity includes better understanding of plant distribution, biogeographic patterns, diversity, invasive species, and climate change effects in the county (San Diego Plant Atlas, n.d).

Another example of a contributory citizen science project is FrogWatch USA. While the San Diego Plant Atlas is hosted by a museum, FrogWatch USA is the first citizen science program operated by the Association of Zoos and Aquariums (AZA) (What is FrogWatch USA?, n.d.). It was originally created by the United States Geological Survey, and was transferred to the AZA in 2009. Any zoo or aquarium that is a member of the AZA can elect to implement a FrogWatch USA chapter at their institution. Citizen scientists that volunteer for FrogWatch USA are trained to identify frog and toad calls, conduct an "acoustical survey" during breeding season, and report observations in an online database (Grow & Gauza, 2012).

Collaborative citizen science projects are characterized by increased public involvement in project design, data analysis, and communication of findings (CASIE, 2009, p.11). Collaborative projects are still designed by scientists, and still include members of the public in data collection. Co-created citizen science projects are developed in a partnership between the public and scientists, with participants from the public contributing to most or all steps of the scientific process (CAISE, 2009, p.11).

An example of a co-created citizen science project is Project FeederWatch, operated by the Cornell Lab of Ornithology and Bird Studies of Canada since 1976 (Cornell Lab of Ornithology, 2012). Citizens that sign up and become trained to collect data for Project FeederWatch systematically observe bird activity during the winter, and record their observations. These data are then collected and analyzed by researchers at Cornell to monitor changes in population, migration behavior, and other important factors. In 1976, 4,000 people participated in the program, and this number grew to 15,000 by 2012. Project FeederWatch is one of the most mature and longest running Citizen Science programs (Cornell Lab of Ornithology, 2012).

The majority of American citizen science projects are operated by universities, research institutes, and other organizations with professional scientists on staff. However, museums are increasingly developing citizen science programs of their own to further their missions. Since the 1970s, many museums have started citizen science programs or partnered with another organization to offer citizen science programs. Science-oriented museums, including zoos, aquariums, and botanical gardens are natural institutions to host citizen science programs due to their proximity to and relationship with the public, as well as science-oriented mission and connection to the scientific community. At least forty-one science museums are currently operating citizen science programs in the United States today (Crawford & Shirk, 2011). And at least ten of these museums started citizen science programs in the three years between 2008 and 2011 (Crawford & Shirk, 2011). This is a growing program area for science museums.

Research has been conducted on citizen science programs in general, though research on programs in museums represents a small part of the literature. For the most part, the overall body of research on citizen science programs is focused on three general areas: 1) project data collection and quality; 2) participant motivation and learning; and 3) and outcomes and general scientific results. The Cornell Lab of Ornithology, the leading citizen science research group, maintains a database of research articles which include research on citizen science programs as the subject of study (Cornell Lab of Ornithology, 2013). Under the "Project Findings" header, research is organized into categories labeled "data quality," "education," "impact," and "scientific." (Cornell, 2013). In addition, a fourth collection of literature synthesizes information from these three broad areas and describes programs as well as best practices for implementing programs. This includes literature in the Cornell database categorized under "background/overview" and "models and perspectives" (Cornell, 2013).

Research on project data collection and quality focus on methods of data collection, and the reliability of the data collected by trained members of the public (Kremen, Ullman & Thorp, 2011;Au, Bagchi, Chen, Martinez, Dudley & Sorger, 2000; Lawless & Rock, 1998). Research on the motivations behind visitor participation, how the volunteer is impacted, and what participants learn during involvement in citizen science programs is an are of ongoing research within informal science education (Bonney, Cooper, Dickinson, Kelling, Phillips & Shirk, 2009; Clayton, Fraser, & Saunders, 2009; Brossard, Lewenstein, & Bonney, 2005). Research on impacts and outcomes focus on the scientific results of the research itself, and the impact and implications for the related scientific discipline (Oberhauser, 2012; Little, Wainstein & Dalton, 2009; Calhoun & Reilly, 2008).

With an understanding of what aspects of citizen science programs have been researched, this research paper identifies and addresses the gap in knowledge posed by the question *what factors motivate museums to host citizen science programs, and how and why do museums perceive that those factors have shifted over time?* As well as the secondary research questions: How are other areas of the museum adapting elements of citizen science programs for other institutional goals? And how is the evolution of citizen science programming co-evolving with organizations?

Chapter Two: Review of the Literature

Evolution of Public Participation in Science

Public participation in scientific research is situated within the greater framework of public engagement and understanding of science in society. Lengwiler (2009) provides a historical framework that is useful to help understand the rise of citizen science as an element of the recent emergence of the participatory relationship between the science expert and non-expert. Lengwiler posits that the "participatory question" of public involvement in science has gone through four distinct phases since the late 19th century, each characterized by a specific participatory relationship between the public and the scientific enterprise. The phases are hybrid, politicized, autonomous, and participatory. (p. 67) The hybrid phase of the nineteenth century is characterized by in part by permeability of the boundary between science and the public, and the efforts of the developing scientific enterprise to seek legitimacy in the eyes of the public. (p. 71). In the hybrid phase, the "actors performed hybrid roles" (p.71) in crossing boundaries and combining political and scientific agendas. The interwar period between the first and second world wars marked the politicized phase, characterized by increased differentiation in the roles of politics, science, and the public, in conjunction with disparate claims to the role of science in society by different political factions (p. 73). The global political climate of the postwar era ushered in the autonomous period of public-science relations, with science policy in the post-war years:

Based on a "social contract for science," under which the relations between science and politics were guided by the principle of "blind delegation." That principle granted science wide autonomies of self-regulation in terms of the division and use of funding as well as the instruments of quality assessment". (p. 75)

Under this system, governments and industry were given broad autonomy, and the public and society were expected to see benefits such as improved medicine, technology, and a higher standard of living. This period involved minimal participation of the public in the scientific enterprise. (p. 75)

The current phase of public-science relations began emerging in the late 1960's in response to abuses in the autonomous scientific system, and increasing calls for "social relevance" in science policy. (p. 76) Lengwiler notes that the "emergence of participatory approaches" is characteristic of this phase (p.76), and public participation in scientific research, i.e. "citizen science", is an aspect of this movement. The growth of modern citizen science programs parallels the emergence of the participatory period as described by Lengwiler, from the start of Project FeederWatch and other early programs in the 1970's, to the hundreds of programs in operation in the United States right now. The growth of citizen science can be viewed through the lens of this emerging participatory model of science, and may help explain the recent growth in citizen science programs, outside of museums and within.

Museum Programs in the Literature

To get a sense of what types of citizen science programs museums are engaged in, the Association of Science and Technology Centers (ASTC) sponsored a citizen science and community conversations survey, which was administered by the Cornell Group in 2011 (Crawford & Shirk, 2011). This survey was sent to the ASTC museum membership, and collected information on which museums are conducting citizen science programs, as well as descriptive characteristics of the programs such as scientific discipline, specific activities, and areas with which the ASTC could most help the member base. Forty three institutions responded

to the survey with information on citizen science programs they operate, establishing a minimum baseline for the number of museums engaged in this activity.

Most of the published literature on citizen science programs falls into three categories; 1) research on the quality of data collected by citizen science volunteers; 2) research on citizen scientist motivations and learning; 3) descriptive research on programs and practices. Only a very small amount of this published literature on citizen science programs is focused on a museum-related citizen science program. For example, the Cornell Lab of Ornithology maintains the most comprehensive database of literature published on citizen science (Cornell Lab of Ornithology, Reference Databases, 2013). The database lists 45 papers that report on some aspect of citizen science data quality, and none were focused on a museum-related program. In addition, the database lists 42 papers written on educational aspects of citizen science programs, and of these only one was conducted on a museum-related (Seattle Aquarium, 2005). Of the 67 papers in the database examining various other non-scientific impacts of citizen science programs, 5 were on citizen science programs in a museum setting (Havens, Vitt & Masi, 2012; Clayton, Fraser & Saunders, 2009; Falk, 2007a; Falk, 2007b; Falk, 1998).

Most of the published research is on large national and international programs such as Project Budburst or the Acid Rain Monitoring Project, or programs operated by universities or government agencies such as the EPA, on their own institution specific research projects such as vernal pool monitoring or water quality testing. Much of the literature also synthesizes projects and examines trends, needs, and models which are. Some of this literature includes data from museums by virtue of the fact that some museums are contributors to the larger project networks, such as Project Budburst (Project Budburst, 2013), but the work done exclusively on museum programs is very limited.

Literature on the Quality of Citizen Collected Data

Of the several papers focused in this area in the Cornell database, none are focused on a museum-related program. Instead, these studies tend to large national and international programs hosted by universities and government agencies. Lawless & Rock (1998) argue that for student data collectors specifically, several steps can be taken to maximize data quality in student oriented citizen science projects. These steps were generated from analysis of a type of citizen science framework they call "student scientist partnership," where students and scientists partner on specific data collection projects. Examples they cite include Forest Watch, GLOBE, GREEN, and SPAN. (p.6) The steps to ensuring quality data is acquired by students include using simplified practices, precise and well written protocols, quality instruments suitable to student skill level, using multiple measurements, minimizing opportunities for error, data assessment, identifying sources of error, and defining acceptable error. (p.10) The authors provide an outline of what each step entails. They also argue that data collection methods and activities should be kept as simple as possible for the research question at hand.

In addition to outlining methods to ensure student citizen scientists collect quality data, Lawless & Rock also argue that contributory citizen science projects are a good starting place for student involvement in scientific research in general:

> *Data collection is a very reasonable place for students to begin their participation in scientific research, as it requires only limited science skills on the part of the student, but rather draws on the many other skills that the student has acquired (in mathematics, for example).* (p.7)

Lastly, the researchers point out that the process of identifying and removing bad data is a learning experience for students in and of itself (Barstow & Tinker in Lawless & Rock, 1998, p.9).

Au et al (2000) conducted a study of water contamination in Canada, with the specific intent of evaluating the reliability of data collected by student citizen researchers. They note the concerns and consequences of those concerns with regard to trust from public officials:

> *Reliability of community group monitoring of water quality, when it is used to compel changes in water and sewage management by government authorities. This becomes an especially important issue when results of public monitoring are contentious and when official distrust of them becomes an issue*. (p.214)

The researchers chose three high schools in Canada from which to recruit students to participate in data collection. High school students were chosen because they are less likely to be seen as biased, they are integral to the community, and most high schools in modern countries have the equipment to conduct the water quality tests. Students at three Canadian high schools were trained on sample collecting and testing techniques, and instructed to collect and test water samples at several sites for presence of the microorganisms, pH, and some chemicals such as phosphates. The results from the three high schools were compared to each other, as well as with the head researcher's results. All three groups of students found ratios that generally agreed with the proportion of E. coli in the sample found by the researchers, and results from chemical testing were also comparable.

Gillett, Pondella, Freiwald, Schiff, Caselle, Shuman and Weisburg (2012) compared volunteer collected data with data collected by professional scientists on subtidal reefs. They acknowledge the concern among professional scientists with citizen science programs is that "the biggest impediment to incorporation of these volunteer monitoring programs with professionally

collected data is concern about data quality" (Gillett et al., 2012, p. 3240). The researchers compared volunteer data to professional data using three different protocols, and found that both groups described similar fish abundance, abundance of dominant fish species, and similar fish communities in assigned transects. The one key difference between scientist and citizen collected data was the measured size distributions of the dominant fish species. Volunteers had a selection bias in the sites that they sampled, as the subsampling protocols for the volunteers were less detailed that for professional scientists. Volunteers tended to sample more complex parts of reefs more often. The authors describe changes to protocol as easy to implement, and if implemented "offer the promise of better integration of the trained volunteer monitoring with that of professional monitoring groups.".

Kremen, Ullman & Thorp (2011) conducted a study on the quality of data collected by citizen scientists on pollinator communities. Thirteen members of the public with diverse demographic backgrounds were given ten hours of training over the course of two days in 2008, on identifying floral visitors such as bees and butterflies, specimen observation, and supervised practice identifying pollinators at flowers. Pairs of citizen scientists collected data along an assigned transect, with one professional scientist collecting data on the same transect as well. The results "suggest that citizen scientists with modest training can collect useful observational data for detecting spatial and temporal differences in pollinator community attributes" (Kremen et al., 2011, p.615) Citizen scientist observations were positively correlated with netting and trapping in the transect conducted by the professional researchers. The area of greatest discrepancy in the study occurred with misidentification of bee species that were uncommon, difficult to identify, and unevenly distributed. The authors suggest that additional training on

identifying rarer bee groups and changing classification categories would increase reliability in identifying rare species.

Water quality testing of using various methods is the basis of many citizen science programs, and several additional studies validating water quality data collected by citizen scientists have been conducted. Canfield, Brown, Bachman and Hoyer (2002) validated citizen collected data in the Florida LAKEWATCH program. Mattson, Walk, Kerr, Slepski, Zajicek and Godfrey (1994) validated a large amount of data collected by citizens in the Acid Rain Monitoring Project. Fore, Paulsen and O'Laughlin (2001) validated procedures and data used by citizen scientists to monitor stream water quality, and also conclude "data collected by volunteers can supplement information used by government agencies to manage and protect rivers and streams" (Canfield et al., 2002, p.109).

While most studies conducted on the validity of citizen collected data show that results produced by trained volunteers are comparable to professionals, some studies show discrepancies in specific situations. In a 2010 study, Nerbonne, Ward, Ollila, Williams and Vondracek found that when using some field methods, volunteers classify water quality incorrectly more often. "Our simulations illustrate that the choice of protocol and consideration of the expertise of the volunteers conducting the sampling are important when designing a volunteer monitoring program for a low-gradient stream system containing riffles" (Nerbonne et al., 2010, p.644) The researchers note this as "volunteer bias."

The literature analyzing the quality of data collected by citizen scientists shows that with appropriate protocol and proper training, volunteers can collect data of comparable quality to professional scientists. Paul Alaback notes in the August 2012 edition of Frontiers in Ecology, published in conjunction with the 2012 PPSR conference in Portland, that with citizens "training

is generally more thorough than would be required with professional scientists or technicians" (Alaback, 2012, p.284). He neatly summarizes the emerging understanding of the role of the investigator in setting up citizens to collect quality data, and states that a citizen science approach to research requires "that investigators think very carefully about methodology and statistical approaches to ensure that a high level of data quality is maintained" (Alaback, 2012, p.284). By doing this, opportunities are created to address broad-scale issues, and a broader demographic of the public is engaged in the process of science.

This research on the quality of data collected by citizen scientists has implications for museums hosting citizen science programs, particularly those without professionally trained scientists on staff.

Literature on Education and Learning

As of Spring 2013, the Cornell database on research on citizen science programs lists 42 papers written on educational aspects of citizen science programs published in peer reviewed journals; of those, only one is related to a museum citizen science program, a study conducted at the Seattle Aquarium.

Overall, this body of literature is small but growing, exploring the learning potential for citizen science programs. A 2009 paper by Bonney, Cooper, Dickinson, Kelling, Phillips, Rosenberg, and Shirk make a detailed case that citizen science is a tool for expanding science knowledge and literacy among the public. This team from the Cornell Lab of Ornithology team describes the process of developing the ten citizen science programs they operated at the time of publication, the development of which included "a group of individuals with expertise in education, population biology, conservation biology, information science, computational

statistics, and program evaluation" (Bonney et al., 2009, p. 979) They elaborate on specific ways that participants can learn from participating in projects, including outputs such as participant duration and participant visits to web sites. They also list five other science education outcomes, including improved participant understanding of science content, enhanced understanding of the scientific process, improved skills for conducting science, increased interest in science as a career, and "better participant attitudes toward science" (Bonney et al., 2009, p. 983)

Havens, Vitt and Masi (2012), one of the few pieces of literature focused on a citizen science program hosted by a museum, describe the non-educational outcomes of the Plants of Concern program, hosted by the Chicago Botanic Garden. This program utilizes 650 citizen scientist volunteers to monitor 233 endangered, threatened, and rare plant species in the Chicago area. They give an overview of the program, and describe training requirements, which includes a day-long workshop and individual practice in the field. The program has two levels of participation. Level 1 participation involves locating and taking measurements of plants at specific marked locations, at different times throughout the seasons. Level 2 participation is available to advanced citizen scientists who are willing to undergo more training and volunteer more time, and consists of taking additional specialized measurements, such as size and reproductive efforts. The paper describes lessons learned from the specific processes employed by the program, and advise continuity in staffing, building relationships with volunteers, and a "functional, web accessible, and user friendly database has also contributed to the success of the program". (Havens et al., 2012, p. 322) The Plants of Concern website is also utilized to educate volunteers about bloom times of monitored species and other matters related to local flora.

Hudson (2001) points to the increased trend toward activity based learning that was occurring at the turn of the century and connects it with citizen science. He identifies citizen

science programs such as GREEN, the Riverwatch Network, and Missouri Conservation Foundation that involve children in activities, and notes that they provide opportunities for learning. Trautmann, Shirk, Fee & Krasny as cited in Dickinson & Bonney 2012 propose that citizen science will help teachers meet the new mandate for inquiry based science education. Specifically, the authors link student citizen science to the National Research Council's recommendations that all educated citizens should be able to know, use, and interpret scientific explanations of the world, understand the development and nature of science knowledge, generating and evaluating scientific evidence and explanations, and participate in scientific practices.

Despite evidence that citizen science programs can positively impact participant scientific knowledge and attitudes, some challenges have emerged in understanding the potential for citizen science to promote these learning and attitude outcomes among the public. Brossard, Lewenstein & Bonney (2012) studied the impact of the Birdhouse Network project on participants, and found that the program did have a positive impact on participant knowledge of bird biology. However this study found no change in participant attitudes toward science, with the mean attitude of participants remaining "slightly positive" and unchanged. Similarly, attitudes toward the environment remained unchanged, which the authors believe may be the result of participants are already specifically interested in the environment. To address this possibility, the authors recommend:

> *If new scales for the assessment of citizen-science participants' attitude toward science and the environment are designed, they should not be intended for use only in the context of a specific project. Rather, the informal science-education field should foster the use of measurement tools that can be used across multiple projects to compare their effectiveness. Such tools should therefore be tested not only with specific citizen-science project participants, but also with other citizen-science projects and with the general population* (Brossard et al., 2012, p.1118).

Moss, Abrams, & Kull (1998) describe a project-based classroom that conducted four citizen science projects over the course of the school year, including water monitoring, tree monitoring, land mapping, and a population dynamics project. Most students retained a "rudimentary" conceptual understanding of the scientific enterprise over the school year, which the authors attributed to time limitations imposed on the teachers who were trying to maintain rigorous data standards, and the teacher centered model (p.160). Similar findings about disproportionate emphasis on data were published by Berkowitz (1996) and Means (1998). The consensus is that appropriate design ensures appropriate focus and outcomes.

In a 2012 paper, Zoellick, Nelson & Schauffler synthesize the literature on citizen science projects involving students to date, and provide a framework for designing an ideal student-teacher-scientist partnership in the form of a logic model. This model takes into account both educator and scientist needs, and outlines specific requirements and constraints that need to be addressed in the design of the program. The model also details specific provisions for the implementation of the program, such as teacher professional development, protocol training, and presentations, and necessary outputs and outcomes for scientists and students. In addition to the logic model, the paper also provides a perspective on the difference between citizen science in informal science education settings, and formal science education settings. In informal settings, the authors claim that programmers think in terms of "win-win" scenarios, in that good program design results in important usable data for scientists, and fulfilling experiences for participants, particularly learning experiences. The authors then point out that when thinking about design of citizen science programs involving formal science education, the win-win model is replaced with a trade-off model. In considering why this is the case, the authors posit "one likely reason is the

additional constraints on time and logistics that are part of working with schools, but perhaps the most important factor is the need to achieve specific learning outcomes in FSE settings" (Zoellick, Nelson & Schauffler, 2012, p.310).

Because some museums are operating components of their citizen science programs in the service of meeting the national mandate for inquiry based experiences in formal education, the ongoing research and dialogue with regard to program design has implications for museums. Even outside of the constraints of formal education, relationships with scientists, relationships with partner organizations, learning outcomes, and acquisition of usable data must be considered and balanced for successful program design, and will remain topics of concern for citizen science programs in museums.

An additional body of research on and from citizen science programs was presented at the 2012 Public Participation in Scientific Research conference in Portland, OR. Of 19 plenary presenters, 2 spoke about citizen science programs hosted by museums. Arfon Smith spoke about the Zooniverse citizen science program hosted by the Adler Planetarium. (2012 PPSR Conference, Citizenscience.org, 2012) Wallace Nichols of the California Academy of Sciences spoke about the Grupo Tortuguero Network, which is a non-museum program in which the academy participates. Of 155 posters presented during the conference, 16 included museums that participated in the project or research. (2012 PPSR Conference) Among the 16 posters featuring museum involvement in citizen science, several were situated as participants within larger networks that utilized museums to operate citizen science programs. For instance, the poster by the North American Butterfly Monitoring Network lists the Pacific Science Center as a participant. (2012 PPSR Conference) Museums were included in approximately 10% of the plenary presentations as well as poster presentations. For comparison, posters on citizen science

projects hosted by national parks, or designed by environmental organizations to take place in national parks, numbered 14. (2012 PPSR Conference)

The literature reviewed delves into research that has been done on describing the kind of citizen science that is occurring, the quality of data collected by citizen scientists, and some outcomes of citizen science programs. Most of this work was completed within programs operated by institutions other than museums. This research study fills a gap in that it focuses on citizen science from the perspective of museums that host them, and lays out the reasons that museums began to host these programs as why they operate them now. It also examines the ways the programs have changed over time. By understanding how and why this growing segment of citizen science operators is conducting these programs, the field will be better prepared to design research that both focuses on museums and measures outcomes of museum programs to those factors that they consider important.

Chapter Three: Methods

The methods designed for the study explore the relationship between citizen science programs, and the institutional practices of the museums that host them. These methods are designed to produce data that describe the reasons that museums began operating and are currently operating citizen science programs, describe how these programs have changed, and describe why those changes occurred. A sample of eight museums was used, and data were collected from the museums using surveys, interviews, and document analysis. This chapter describes the study's methods, including sampling, data collection, and data analysis.

Sample Selection

Eight museums were selected for participation in the study (see Table 1)[1]. All nine institutions are registered as 501(c) not-for-profit educational organizations, and mission statements and brief descriptions of each institution are found in Appendix A.

The sample was selected purposively from a set of institutions that responded to the 2010 ASTM survey, as well as three museums that operate programs familiar to the author. Specifically, the nine museums were chosen in order to achieve diversity within a set of five factors: 1) geographical location in order to include museums from across the country; 2) museum type in order to include science centers, natural history museums, and aquariums; 3) museum size in order to include both small and large institutions; 4) researcher familiarity with the institution in order to include institutions to which the researcher would have access; and 5) a recommendation from a professional in the citizen science field in order to include an institution

[1] The term "museum" is used in this case in its broadest sense and includes aquariums, science centers, and natural history museums, all of which are public spaces where informal science learning occurs.

that has only recently begun citizen science programming, yet is already adapting their program. Budget data reported in Table 1 are from the most recent IRS Form 990 report available for each institution, acquired through GuideStar.com, and annual visitors were self-reported by each institution.

Table 1
Museum Sample

Museum	Size	Region	Budget (USD)	Visitors/Year
Boston Museum of Science	Large	Northeast	50.6M	1,700,000
California Academy of Sciences	Large	Central W. Coast	58.6M	1,600,000
Denver Museum of Nature and Science	Large	Mountain West	31.1M	1,400,000
North Carolina Museum of Natural Sciences	Medium	Atlantic	8.6M	700,000
San Diego Natural History Museum	Medium	Southwest	10.4M	1,200,000
Seattle Aquarium	Medium	Pacific Northwest	8.2M	792,000
Museum of Discovery and Science	Small	South	6.6M	400,000
Port Townsend Marine Science Center	Small	Pacific Northwest	0.62M	18,830

Six of the eight museums in the sample participated in the Association of Science and Technology Centers citizen science and community conversations survey, administered by the Cornell group in 2011 (Crawford & Shirk, 2011). This survey was administered to the ASTC museum membership and collected information on the types of citizen science programs that museums in the ASTM membership are operating.

The citizen science manager of each museum was the primary contact for the study, and the person from whom institutional data were collected. For purposes of this research, "citizen science manager" was defined as the staff member most responsible for directly overseeing the operation of citizen science programs at the museum. That individual is not necessarily in management, nor are they necessarily responsible solely for citizen science.

Methods and Data Collection

Three methods were used in this study, including 1) surveys; 2) interviews; and 3) document analysis. Each of these methods is described below.

Surveys

The first data collection method was an online, 45-item survey administered to the citizen science program manager at each of the nine museums (Appendix B). The instrument was designed to collect basic information about the citizen science program at each museum, the reasons the museum first decided to host citizen a science program(s), and the reasons the museum currently operates a citizen science program(s).

There are nine predefined purposes on the survey that respondents are asked to rate in terms of weight as a reason for doing citizen science. These nine purposes were determined from informal conversations with citizen science operators in museums, at the 2012 PPSR conference in Portland, Oregon, as well as informal conversations with experts in the field. Asking the same question across all institutions about these nine reasons for doing citizen science allows for a direct cross-case comparison of responses. The survey also contains an open ended component, to allow museums to provide reasons for doing citizen science beyond the nine identified by practitioners and experts in the field.

Surveys were sent via email to citizen science program managers at each site on April 2nd 2012, and were completed between April 2nd and April 11th. All eight of the program managers completed a survey.

Interviews

The second method was an interview with citizen science program managers at each site (see Appendix C for the interview guide). Phone interviews were conducted subsequent to the survey from April 8th date to April 18th, and were designed in part to follow-up on program managers' survey responses. Specifically, the interview not only followed up on program managers' descriptions of citizen science programming within their institution, but also was focused on the differences between initial programs and current programs to explore how and why any changes in programming may have occurred, and how these changes may be related to or impacted larger organizational changes.

Interviews lasted between 22 and 55 minutes in length, and were digitally recorded for later analysis. Follow up interviews were prepared as an additional method of data collection, given that additional review of survey data, interview responses, and document review were likely to produce additional questions for some museums. Follow up interviews were conducted with the Port Townsend Marines Science Center and North Carolina Museum of Natural Sciences for follow-up information on distinctions between local and national needs.

Document Analysis

The third component of data collection consisted of gathering documents that may provide information and evidence about citizen science programs in host museums. Specific types of documents sought included strategic plans, internal and external evaluations and reports, department or project level plans for citizen science programs, and program documents related to citizen science. Program documents include guides, processes, outlines, and information that relate to how the citizen science program operates, and intended or observed outcomes related to the museum.

Documents were sought and collected in two ways. First, the citizen science manager at each museum was directly asked for documents. Second, the process included a search of the museum web page and publicly available records pertaining to citizen science programs.

Data Analysis

As an exploratory study that relies heavily on open ended survey and interview data, and review of information in documents, the data and information collected is predominantly qualitative in nature. The Nvivo qualitative analysis software was used to organize and analyze data. Nvivo allows researchers to load data in all formats into a single useful working file, including data spreadsheets, audio and video media, and text documents. All survey responses were uploaded into Nvivo in spreadsheet format, the audio recordings from all interviews were uploaded and annotated using the media review software in the program, and all documents gathered in the document collection phase were directly uploaded into the working file.

The survey responses, all documents, and interviews were uploaded into Nvivo between April 2nd and April 20th, 2013. An emergent coding system was used, and each source was reviewed and coded with themes. These themes formed the basis of the analysis in Chapter 4, and were eventually organized into the codes presented in that chapter.

The results were analyzed in three ways. Quantitative and categorical data from the surveys are included in the results tables. These reported values are reviewed as direct evidence of institutional reasons for citizen science and, as well as how they changed over time. Analysis of quantitative and categorical data analysis is centered on directly reporting and comparing responses across organizations.

Data from interviews was reviewed and coded for purposes of analysis. The interviews began with a section of questions that followed up on survey responses about the nine pre-identified reasons museums do citizen science (Appendix C). Specific questions were asked about each survey response, for instance "you rated appealing to donors a 2 out of 4 on the survey, as a reason for starting citizen science. Why did you rate it a 2, and how specifically was appealing to donors a reason?" This was done for beginning and current citizen science, as well as to probe each change observed in survey responses from beginning to current citizen science.

To analyze survey results, survey responses connected to each dimension were reviewed for statements specifically related to the reasons the museums began citizen science, continue to do citizen science, and why the changes occurred. Statements corresponding to these prompts at each dimension, that informed the reasons for or changes in citizen science, were identified in the analysis phase. Statements that were provided that explicitly and unambiguously expressed these reasons were tagged and described in the results tables below, for purposes of cross-case comparison. The statements were further sub-coded for specific reasons within the dimension related to the statement. For instance, specific reasons for doing citizen science under the "public education" dimension include teacher training, state standards, public education, and school education. These codes emerged from examining all of the responses across the dimension at all institutions, and provide a deeper level of detail and understanding into the motivations of each organization in operating their program.

Chapter Four: Results and Discussion

Citizen Science in the Organization

The following table shows responses from the survey, describing how the citizen science program fits in each organization. Table 2 shows the year each museum began to do citizen science projects, the organizational department that manages the program (where applicable), and the current number of projects within the museum's citizen science program.

Table 2.
Citizen Science in the Museum Organization

Museum	First Year	Department	# of Projects
Port Townsend Marine Science Center	1982	N/A	12
Denver Museum of Nature & Science	1988	Research & Collections	3
San Diego Natural History Museum	1997	Research Departments	2-4
North Carolina Museum of Natural Sciences	1998	N/A	9
California Academy of Sciences	2000	Lifelong Learning	3
Seattle Aquarium	2004	Conservation Education (School & Family Programs)	1
Museum of Science, Boston	2008	Public Programs	1
Museum of Science, Fort Lauderdale	2011	Programs (Education)	1

The data show that the citizen science programs are situated in a diverse range of departments. Two museums operate their citizen science programs through the research department within the organization. Two operate their programs in the education (or learning) department. Two list the programs department as managing the citizen science program, and two museums claimed the question was "not applicable". Notably, the two museums that operate the most programs are the two in the sample that claimed there is no specific department through which programs are managed. Table 2 also shows that there is a trend for museums with newer programs to operate fewer programs. Notably, the three most recent museums to start citizen all began within the last ten years, and each operate a single project within their program. The other five museums in the

sample have operated their citizen science programs for more than ten years, and each of these five have more than one project within their program.

Table 3 below shows the nature of the staffing of the citizen science program in each museum.

Table 3.
Citizen Science Staff in the Museum

Museum	# Staff 25% Time	# Staff 80% Time	CS Manager?
Port Townsend Marine Science Center	4	1	Yes
Denver Museum of Nature & Science	4	3	No
San Diego Natural History Museum	?	1-2	No
North Carolina Museum of Natural Sciences	1	1	Yes
California Academy of Sciences	2-4	2	Yes
Seattle Aquarium	4	1	Yes
Museum of Science, Boston	0	0	No
Museum of Science, Fort Lauderdale	1	0	No

Exactly half of the museums in the sample have a dedicated citizen science manager on staff, and half do not. There is no apparent pattern between the size of the museum and number of citizen science projects they operate in their program. All but one museum has at least one staff member dedicated to working on the citizen science program at least 25% of the time, and at least three museums have four employees that work one-quarter time or more on citizen science. Six museums have a staff member that spends 80% or more of their time on citizen science. Notably, the museums with the two newest citizen science programs have the lowest level of staffing dedicated to the program, and neither of these two have a dedicated citizen science manager.

Findings

The results of the study are organized and presented according to nine dimensions. Each of these dimensions is a potential factor for initial and current citizen science offerings within the case study museums and was probed in both the surveys and interviews with citizen science

program managers. These factors were determined from informal discussions with several people working on citizen science programs at their institution, both in and out of museums. These nine general categories emerged during conversations, during the process of designing the research methodology for this paper. There was some indication that each of these areas represent reasons that citizen science program operators conduct citizen science, and were included in the survey and follow-up interview.

1) volunteer recruitment;
2) public education;
3) relationships with scientists;
4) institutional marketing and awareness;
5) grants and special funding;
6) appealing to donors;
7) meeting a local need;
8) meeting a national or international need; and
9) partnering with external organizations.

In each of the nine sections, I first present how relevant the dimension was for case study museums when they started offering citizen science programming; then I present its current relevance and discuss the change between these two points in time, along with reasons why this change might have occurred and how the changes relate to larger institutional changes. Following the presentation of data across these nine dimensions, I present additional data speaking to how each case study museum expects the size of their citizen science program to change, as well as comparisons across other institutional characteristics such as size, budget, type, and the amount of time museums have been conducting citizen science programs.

Across all of the reasons listed in each dimension, only reasons that were intended for the citizen science program and a purpose for its operation are included. Some museums observed positive consequences of enacting their citizen science programs, but noted they did not consider it a reason for doing them. In these cases, the museum listed the dimensions as "1" and therefore not a reason, even if that institution did see an unplanned benefit in that area. For instance, one museum did not consider seeking grants a reason for their program and rated it a "1", even though they did end up being awarded a grant to expand their work.

1) Volunteer Recruitment

Citizen science program managers were asked to rate the degree to which volunteer recruitment was a factor in their museum's initial decision to start a citizen science program. "Volunteer recruitment" means that the program was purposefully designed and utilized as a mechanism to bring volunteers into the greater organization, beyond the citizen science program. Managers used a scale from 1-4, with 1 and 4 containing labels. A"1" in the scale was labeled as "not a factor", and a "4" on the scale is labeled as the "main factor". In the tables that follow, the header "reason" is the coding category for the specific reason within the dimension. Table 4 shows how program managers rated this dimension. For five of the eight museums, volunteer recruitment was not a factor; for two museums it was a small factor; and for one museum it was a major factor.

Table 4.
Volunteer Reasons for Beginning Citizen Science

Museum	Rate	Reason	Statement
Museum 1	1		
Museum 2	1		
Museum 3	2	Recruitment	*We wanted more hands, more people involved to do the work.*
Museum 4	1		

Museum 5	1		
Museum 6	2	Recruitment	*The programs used volunteers from the earliest days, and they often became involved in other aspects of the center.*
Museum 7	1		
Museum 8	3	Recruitment	*We needed more volunteers back when the program began.*

Table 5 shows how citizen science program managers rated this same dimension relative to why they continue to offer citizen science programs today. Again, for five of the eight museums, volunteer recruitment is a current factor; for two museums it is a small factor; and for one museum it is a major factor today.

Table 5.
Volunteer Reasons for Current Citizen Science

Museum	Rate	Reason	Statement
Museum 1	1		
Museum 2	1	Opportunities	*We develop other ways for people to be involved, such as looking at the data, dealing with specimens, etc. We want to have multiple tiers of involvement to bring more people into the work of the museum.*
Museum 3	3	Recruitment	*The paleontology program grew so big, an Earth Science is now the biggest program, the backlog for fossil preparation is huge. It is an integral part of our paleontology program now, we need recruit our citizen scientists to do that.*
Museum 4	1		
Museum 5	1		

Museum 6	2	Recruitment	*It is connected to our volunteer program. Most of our people are volunteers- docents, tank maintainers, fundraisers. Most citizen science jobs are offered to volunteers.*
Museum 7	2	Recruitment	*At the peak, it was a big draw, we were doing lots of radio ads and newspaper articles which brought them to the museum whether they became involved or not.*
Museum 8	1		*We have all the volunteers we need, and don't need to recruit any more.*

Table 6 analyzes the change in case study museums' ratings of volunteer recruitment as a factor, from when they originally started citizen science programming to now.

Table 6.
Changes in Volunteer Reasons for Citizen Science

Museum	Change	Reason for Change	Statement
Museum 1	2 to 3	Recruitment	Paleontology program grew very large, and needs many volunteers. The backlog is huge.
Museum 2	1 to 2	Recruitment	People pulled in from the program often find other areas to work in the museum.
Museum 3	3 to 1	At Capacity	The program needed more volunteers back when the program began. They don't need new volunteers now.

As seen in Table 6, two museums felt that volunteer recruitment was now more of a factor in the rationale for their citizen science programming. These museums sought to bring in more volunteers. One museum felt that volunteer recruitment was no longer a reason for conducting citizen science programs. This museum, the Seattle Aquarium, felt that they no longer needed to recruit volunteers as they are at capacity.

2) Public Education

In addition to rating the influence of volunteer recruitment, citizen science program managers were asked to rate the degree to which public education was a factor in their museum's initial decision to start a citizen science program. Again, managers used a scale from 1-4, where 1=not a factor; 2=a small factor; 3=a major factor; and 4=primary factor. Table 5 shows how program managers rated this dimension. For one of the eight museums, public education was a small factor; for four it was a major factor; and for two it was the primary factor.

Table 7.
Education Reasons for Beginning Citizen Science

Museum	Rate	Reason	Statement
Museum 1	3	Public Education	*I started the program because I am an educator, that is what is important to me. We wanted to start a project, and weren't really trying to contribute to research.*
Museum 2	1		
Museum 3	4	Public Education	*That public education campaign part of what we do is basically equally important as the scientific research*
		Professionalize Amateurs	*The education of the paleontology group was more focused specifically on professionalizing the amateur collectors with training.*
Museum 4	3	Public Education	*A lot of people want to get involved with sea turtles, but they are endangered and can't come into contact with them. It was a good way to get them involved.*

Museum 5	4	School Education	*Education is our largest department, and citizen science programs were conceived as a good way to get students involved. You give them a way of being involved in a real project, and not some cookie-cutter project. It was mostly K-12 in the beginning.*
Museum 6	3	Public Education	*Public education was a major goal of the program going all the way back to the first water quality monitoring program.*
Museum 7	2	Public Education	*We included it in the beginning, but it wasn't the main focus.*
Museum 8	3	School Education	*Education was a major reason we started the program, and why we partnered with schools.*

Citizen science managers were also asked to rate the degree to which public education is a factor in their current citizen science programming. Table 8 shows the range of responses. One of the eight museums felt it was not a current factor at all; one felt it was a small factor; two felt it was a major factor; and four felt it was a primary factor.

Table 8.
Education Reasons for Current Citizen Science

Museum	Rate	Reason	Statement
Museum 1	3	Public Education	*The primary reason for the program is still education. The program is run by educators, which is a strength.*
Museum 2	4	Public Education	*It must contribute to science literacy or eco-literacy.*
Museum 3	4	Public Education	*That public education campaign part of what we do is basically equally important as the scientific research.*
		Professionalize Amateurs	*This is still a major goal, to educate and train amateur paleontologists.*
Museum 4	1	Disaster	*The program is on hold, hurricane Sandy washed away all of our equipment. Otherwise it would be the same.*

Museum 5	4	School Education	*Our education department works with the kids on citizen science.*
		Public Education	*In our current program, we have all ages working on citizen science.*
Museum 6	3	Public Education	*We are an educational institution and this is still a major goal of our citizen science programs.*
Museum 7	2	Public Education	*It is still a minor part of the project.*
Museum 8	4	School Education	*We have added more schools. We have raised the bar on what can be done with high school students.*
		State Standards	*With the Next Gen Science standards, there is a mandate for inquiry based science education, and this fit that need.*
		Teacher Training	*We added professional development training for teachers in 2007.*

During interviews with citizen science program managers, follow-up questions were asked about why they rated this dimension the way they did. Notably, the Museum of Science Fort Lauderdale suspended the public education part of their program due to a special circumstance. Hurricane Sandy destroyed all but one of their beach monitors in October 2012, and to bring that part of the program back online will take some time. One museum lists teacher training as a specific educational purpose, as well as new state science standards as a specific reason for conducting citizen science. Six list public education as a reason, and two list educating K-12 students as a reason.

Table 9 shows the change in public education ratings as a reason for engaging in citizen science programming initially and currently. The Seattle Aquarium added education programming tied to the newly adopted Next Generation Science Standards in Washington state as a reason for doing citizen science, as well as teacher training associated with citizen science. The North Carolina Museum of Natural Sciences is expanding the school program and it remains the highest priority

there, and the California Academy of Science now ranks it as the highest priority with the alignment of the programming behind science and eco-literacy. All programming at the Academy must have a component that aligns with science literacy or eco-literacy. The Museum of Science in Fort Lauderdale reported that public education was less of a factor than it used to be. With the Hurricane Sandy disaster affecting the Fort Lauderdale program, the education program is on hold (however they expect to continue it in the future, and education will again be a reason for the program).

Table 9.
Changes in Education Reasons for Citizen Science

Museum	Rate	Reason for Change	Statement
Museum 1	1 to 4	Public Education	*It must contribute to science literacy or eco-literacy.*
Museum 2	3 to 1	Disaster	*The program is on hold, hurricane Sandy washed away all of our equipment. Otherwise it would be the same.*
Museum 3	4	Public Education	*In our current program, we have all ages working on citizen science.*
		School Program	*We have added more schools. We have raised the bar on what can be done with high school students.*
Museum 4	4	State Standards	*With the Next Gen Science standards, there is a mandate for inquiry based science education, and this fit that need.*
		Teacher Training	*We added professional development training for teachers in 2007.*

3) Relationships with Scientists

Citizen science program managers were also asked to rate the degree to which relationships with scientists factored into the initial decision to start a citizen science program. Again, managers used a scale from 1-4, where 1=not a factor; 2=a small factor; 3=a major factor; and

4=primary factor. Table 10 shows how program managers rated this dimension. For two of the eight museums, a relationship with scientists was not a factor; for two museums it was a small factor; and for two museums it was a major factor. Three of the museums wanted to gather feedback from scientists for research operations in the museum, both in citizen science and in other parts of the organization. In one museum an educator had an existing relationship with a scientist which formed the basis for starting the program.

Table 10.
Scientist Reasons for Beginning Citizen Science

Museum	Rate	Reason	Statement
Museum 1	2	Existing Relationship	*I was introduced to a scientist at Tufts University who was studying fireflies. It went from there.*
Museum 2			
Museum 3	2	Feedback	*We had a difficult time breaking into the professional world because our professional colleagues didn't understand why a museum might be interested in doing real research (specifically in the health program).Without working with some of the other investigators we would have a hard time breaking in, we need them to "vouch for us". It was a side benefit for other programs.*
Museum 4	1		*We talked to local scientists, and they just weren't interested in working with us.*
Museum 5	3	Feedback	*Scientists help design our research programs.*
Museum 6	1		
Museum 7			
Museum 8	3	Feedback	*We wanted scientist feedback and support for all of our programs.*

Table 11 displays how these same managers rate building relationships with scientists as a factor in their current citizen science programming. One of the eight museums felt it was not a current

factor at all; for two museums it is a low priority; and for five museums it is a high priority. Specific reasons include one museum with an existing relationship with a scientist, two want to build relationships for research purposes, one wanted to increase cooperation and integration of education and science departments, three wanted to increase scientist involvement in the institution in general, and two seek feedback from scientists for programs in and out of the citizen science program.

Table 11.
Scientist Reasons for Current Citizen Science

Museum	Rate	Reason	Statement
Museum 1	2	Existing Relationship	*We still work some with scientists. Some grad students became professors and came on board.*
		Students	*Some graduate students worked on the project, and eventually became professors and came on board.*
Museum 2	3	Research	*We have an active research department here at the academy; it is part of the overarching push.*
		Cooperation	*One of the goals of the program is to integrate our research and education programs more closely together.*
		Interaction	*We wanted to give our researchers and other researchers in the area a chance to interact with the public, and the public to have a chance to interact with them as well.*
Museum 3	3	Feedback	*We learned the data we were collecting weren't working. We worked with partners to re-design the program so the data we are collecting is high quality. It is still a side benefit for other programs.*
Museum 4	1		
Museum 5	3	Involvement	*We use our program and in-house researchers, as well as partner researchers to interact with the public. All staff scientists have to*

			work with the public and this is one of the ways that we do it.
Museum 6	3	Involvement	*Half of our citizen science programs are now funded and financially sustainable. When we can collaborate with scientists on grants it makes them much stronger. They co-create projects, and these relationships provide us with access to good lab facilities, to do things like process samples.*
Museum 7	2	Research	*We have scientists as volunteers, and we have things we work with botanists on.*
Museum 8	3	Feedback	*We still collect feedback and get the support of scientists. They help with best practices.*
		Involvement	*They participate in our marine forum, and speak to our public. We are now involving tribal biologists.*

Relationships with scientists is a category where only increases are observed among the cases in the sample, as shown by Table 12. Two museums that previously did not consider relationships with scientists to be factor in the programming now consider it to be a high priority; one that considered it to be a minor priority now considers it to be a high priority; and one museum maintains that relationship building with scientists is a high priority. The California Academy of Sciences increased the importance of the relationship with scientists for a number of reasons, including working more closely with internal and external researchers on projects, getting the educators and scientists to work more closely together, and providing opportunities for internal scientists and other local scientists to interact with the public. Two museums use their citizen science programs as a way to get scientists involved in other aspects of the operation, and one added the purpose of gaining feedback on research practices is a reason for the program.

Table 12.
Changes in Scientist Reasons for Citizen Science

Museum	Rate	Reason	Statement
Museum 1	1 to 3	Research	*We have an active research department here at the academy, it is part of the overarching push.*
		Cooperation	*One of the goals of the program is to integrate our research and education programs more closely together.*
		Interaction	*We wanted to give our researchers and other researchers in the area a chance to interact with the public, and the public to have a chance to interact with them as well.*
Museum 2	2 to 3	Feedback	*We learned the data we were collecting weren't working. We worked with partners to re-design the program so the data we are collecting is high quality. It is still a side benefit for other programs.*
Museum 3	1 to 3	Involvement	*Half of our citizen science programs are now funded and financially sustainable. When we can collaborate with scientists on grants it makes them much stronger. They co-create projects, and these relationships provide us with access to good lab facilities, to do things like process samples.*
Museum 4	3	Involvement	*They participate in our marine forum, and speak to our public. We are now involving tribal biologists.*

4) Institutional Marketing and Awareness

Table 13 displays how the citizen science program mangers rated raising awareness of the institution or institutional goals as a reason for beginning citizen science programs using the same 1-4 rating system. Three of the eight museums indicated that increasing institutional awareness was not a reason for beginning their citizen science programs; one listed it as a minor reason; one listed it as a major reason; and two of the eight museums indicated that this was the

primary reason for beginning their citizen science program. One museum listed general awareness about the museum as a reason, and three of the museums specifically listed raising awareness about their conservation mission. One museum also listed expanding the audience for citizen science as a reason, in that they wanted to raise awareness of citizen science in general.

Table 13.
Awareness Reasons for Beginning Citizen Science

Museum	Rate	Reason	Statement
Museum 1	1		
Museum 2			
Museum 3	1		
Museum 4	2	Awareness	*We have a large sea turtle program that we are involved with, and the local people don't know much about that or the sea turtles here, so we wanted to address that.*
Museum 5	4	Conservation Mission	*Monitoring and protecting habitats in North Carolina, as well as raising awareness of the issues, is a major reason we started to become involved in citizen science.*
Museum 6	4	Conservation Mission	*At first citizen scientists monitored water due to the local paper mill. The program was also intended to raise awareness of the conservation mission and community issues the center was addressing.*
Museum 7	1		
Museum 8	3	Conservation Mission	*We did it to raise awareness of our mission, to conserve Puget Sound.*
		Audience	*We also wanted to expand the audience for citizen science.*

As shown in Table 14, seven of the eight museums list raising awareness about some aspect of the museum as a reason for their current citizen science programming. For one of the eight

museums, institutional awareness is not a factor; two rated it as a minor factor; two rated it as a major factor; and three rated it as the primary factor. Four of them do it to raise awareness of their conservation mission, two do it to grow the audience through awareness of the museum in the community, and three are using citizen science programs for outreach.

Table 14.
Awareness Reasons for Current Citizen Science

Museum	Rate	Reason	Statement
Museum 1	1		
Museum 2	4	Conservation Mission	*It is related to our conservation mission. We are hoping to increase focus on stewardship of the area, creating a sense of place, and letting people know about the biodiversity of the area.*
Museum 3	2	Outreach	*The PR and marketing started to follow as we realized how novel we are. It isn't something we recognized at first, but now we can get to more of the community and achieve more learning.*
Museum 4	3	Outreach	*We are reaching a bigger audience by using this program, through people becoming involved.*
Museum 5	4	Conservation Mission	*This still pertains to our conservation mission.*
Museum 6	3		*It is our mission to protect the local ocean, and these programs raise awareness of both us and our mission.*
		Conservation Mission	
Museum 7	2	Audience	*That's always part of it for the volunteers that come in the door, but it was more about a natural community and the community of the county.*
Museum 8	4	Conservation Mission	*We still do it to raise awareness of our mission.*
		Audience	*We are expanding the audience for citizen science.*

	Outreach	*This is a great outreach tool. 400-450 students are involved, and they are part of the aquarium. Each student gets an aquarium pass, and can bring one other person. This is an investment in raising awareness.*

Across all eight cases, six of the museums have changed the role that citizen science plays in raising awareness about an institution and its mission. Table 13 displays these changes. For five of the museums, raising awareness about the institution or aspects of its mission were added or increased as reasons for conducting citizen science programs. The Port Townsend Marine Science Center decreased awareness from a primary reason (4) to a major reason (3), due to changing institutional goals and the fact that the paper mill the citizen science program was originally designed to monitor has shut down. The Seattle Aquarium now reaches up to 450 students, and gives each a free pass as well as guest passes, and considers this form of outreach using the program an investment in raising awareness about the aquarium and its activities. Denver and Fort Lauderdale have come to realize that publicity from such programs can be used to raise general awareness about the museum and increase audience size, and the California Academy of Sciences has attached citizen science to its broader institutional platform of educating the public and raising awareness of California biodiversity. Awareness is the purpose that changed the most among all reasons museums listed for conducting citizen science, and five of the museums that increased awareness as a reason are using new tools such as social media to assist in those efforts.

Table 15.

Changes in Awareness Reasons for Citizen Science

Museum	Rate	Reason	Statement

Museum 1	1 to 4	Conservation Mission	*It is related to our conservation mission. We are hoping to increase focus on stewardship of the area, creating a sense of place, and letting people know about the biodiversity of the area.*
Museum 2	1 to 2	Audience	*The PR and marketing started to follow as we realized how novel we are. It isn't something we recognized at first, but now we can get to more of the community and achieve more learning*
Museum 3	2 to 3	Outreach	*We are reaching a bigger audience by using this program.*
Museum 4	4 to 3	Conservation Mission	*It is our mission to protect the local ocean, and these programs still raise awareness of both us and our mission.*
Museum 5	1 to 2	Audience	*That's always part of it for the volunteers that come in the door, but it was more about a natural community and the community of the county.*
Museum 6	3 to 4	Mission	*We still do it to raise awareness of our mission.*
		Audience	*We are expanding the audience for citizen science.*
		Outreach	*This is a great outreach tool. 400-450 students are involved, and they are part of the aquarium. Each student gets an aquarium pass, and can bring one other person. This is an investment in raising awareness.*

5) Grants and Special Funding

Table 16 displays how grants and special funding factored into the case study museums' decisions to start citizen science programs. Again, managers used a scale from 1-4, where 1=not a factor; 2=a small factor; 3=a major factor; and 4=primary factor. Three cases among the sample listed grants as a reason to begin doing citizen science. Two received grants to begin their

programs, and these two rated the reason highly at (3) and (4). A third museum stated that by starting the citizen science program they could seek grants related to it in the future, after demonstrating some of the outcomes they initially sought to achieve.

Table 16.
Grant Reasons for Beginning Citizen Science

Museum	Rate	Reason	Statement
Museum 1	1		
Museum 2	1		
Museum 3	1		*We were going to start the programs with or without grant funding.*
Museum 4	4	Startup	*We got an NSF grant to start this project.*
Museum 5	2	Seek Grants	*This was always thought of as a way to try and look for grants.*
Museum 6	1		
Museum 7	1		
Museum 8	3	Startup	*We got a grant to start this program.*

Table 17 displays the program managers' ratings for how grants and special funding impact their current citizen science programs. The number of museums actively operating with grant money, or actively using their citizen science program to seek grant funding doubled to six. Now six museums across the sample list grant considerations as a reason for doing their citizen science program. Three of them rate it as a more significant reason (rating 3) and three as a minor reason (rank 2). Of this group, two currently receive grant funding, one was approached by an unsolicited funder who then subsequently funded program planning for the California Academy of Sciences, and four actively use their programs to seek grant funding.

Table 17.
Grant Reasons for Current Citizen Science

Museum	Rate	Reason	Statement
Museum 1	1		

Museum 2	2	Funded Opportunity	*A funder approached us and said we could be a leader in the area, but we can't just give you money. They funded a year of planning. We have been able to mobilize people to help us get this done.*
Museum 3	3	Funded Seek Grants	*We were able to get grant funding under our plan and expand the research to much bigger than we thought it was going to be, because we had the space and the know-how. I am on to finding the next grant that is going to support this public health space. It is the same for the sustainability of the other programs; we use the program to seek grants.*
Museum 4	3	Funded	*The project is still funded by the NSF.*
Museum 5	2	Seek Grants	*This is definitely something we look at, given the importance of what we are doing.*
Museum 6	2	Seek Grants	*I would like to say this isn't a reason, but it provides a way to get money and is a means to a good end.*
Museum 7	1		
Museum 8	3	Seek Grants	*We are using the program as a way to seek more grant funding. Our original grant ran out.*

As demonstrated in Table 18, four museums changed their positioning of grants as a reason for conducting citizen science programs. Of these, three museums now use it as a mechanism to seek grants. The California Academy of Sciences was approached by a funder that proposed a leadership role to their citizen science program, and combined with changes in the role of the program, leadership in citizen science is a reason that the Academy conducts citizen science programs. Notably, the Seattle Aquarium no longer received grant funding since their ten-year grant has expired. Though the funding has expired and their grant rating did not change, the aquarium considers the program very successful and switched to funding the program internally, even while growing it.

Table 18.
Changes in Grant Reasons for Current Citizen Science

Museum	Rate	Reason	Statement
Museum 1	1 to 2	Opportunity	*A funder approached us and said we could be a leader in the area, but we can't just give you money. They funded a year of planning. We have been able to mobilize people to help us get this done.*
Museum 2	1 to 3	Seek Grants	*We were able to get grant funding under our plan and expand the research to much bigger than we thought it was going to be, because we had the space and the know-how. I am on to finding the next grant that is going to support this public health space. It is the same for the sustainability of the other programs, we use the program to seek grants.*
Museum 3	1 to 2	Seek Grants	*I would like to say this isn't a reason, but it provides a way to get money and is a means to a good end.*
Museum 4	3	Seek Grants	*We are using the program as a way to seek more grant funding.*

6) Appealing to Donors

Citizen science program managers were also asked to rate donor appeal as a reason for beginning their programs. These ratings are displayed in Table 19. Of the eight museums, only two describe appealing to donors as a reason for beginning citizen science programs. One museum listed it as a minor reason, and a second museum considered it a major reason at the outset of their program.

Table 19.
Donor Reasons for Beginning Citizen Science

Museum	Rate	Reason	Statement
Museum 1	1		
Museum 2	1		
Museum 3	1		
Museum 4	1		

Museum 5	2	Appeal	*This was recognized as a way to appeal to donors who like to fund this kind of thing.*
Museum 6	1		
Museum 7	1		
Museum 8	3	Appeal	*We had discussions early on, on how this was appealing to small donors and funders interested in education.*

As shown by Table 20, which displays the impact of donor appeal on current citizen science programs, five of eight museums list donor considerations as a reason for conducting their current citizen science programming. All five of these note the general appeal of the program to donors as a reason for doing the programs. Two specifically mention instances where funding has demonstrably resulted from their citizen science program in that a donor or donors appreciated the program and gave money to the institution as a result.

Table 20.
Donor Reasons for Current Citizen Science

Museum	Rate	Reason	Statement
Museum 1	1		
Museum 2	1		
Museum 3	2	Appeal Funding	*With our external evaluation, we proved that what we set out to do, we actually did (with the health grant as well as the paleontology training). We can use this to appeal to donors. The paleontology group actually got a named lab for their work, from a donor (donors love fossils).*
Museum 4	2	Appeal Funding	*We use the program to get funding and seek our own funding, we have gotten some money from donors from this program.*
Museum 5	2	Appeal	*This is something concrete we can show the donors, some real work going on.*

Museum 6	2	Appeal	*This is appealing to donors, who sometimes contribute to the program, or education programs related to citizen science. We use it to show donors how we are meeting our goals, and some donors really appreciate the research. We use that to our advantage.*
Museum 7	1		
Museum 8	3	Appeal	*We still appeal to donors with this, such as the Seattle Rotary. People like to fund school programs.*

Table 21 demonstrates how three citizen science program managers have changed their view of donor appeal. All of the changes among the sample regarding appealing to donors consist of three museums that did not consider donor appeal a reason for starting citizen science programs, but consider it a minor reason now. Notably, two of these three are the museums that demonstrably received significant funding from donors, stemming from their citizen science programs.

Table 21.
Changes in Donor Reasons for Current Citizen Science

Museum	Rate	Reason	Statement
Museum 1	1 to 2	Appeal Funding	*With our external evaluation, we proved that what we set out to do, we actually did (with the health grant as well as the paleontology training). We can use this to appeal to donors. The paleontology group actually got a named lab for their work, from a donor (donors love fossils).*
Museum 2	1 to 2	Appeal Funding	*We use the program to get funding and seek our own funding, we have gotten some money from donors from this program.*

Museum 3	1 to 2	Appeal	*This is appealing to donors, who sometimes contribute to the program, or education programs related to citizen science. We use it to show donors how we are meeting our goals, and some donors really appreciate the research. We use that to our advantage.*

7) Meeting a Local Need

"Meeting a local need" consists of a broad category of reasons that museums began to conduct citizen science, and emerged as one of the two most significant reasons museums operate these programs. Table 22 demonstrates the program managers' ratings for this dimension. Seven out of the eight museums among the cases listed meeting a local need as a reason for conducting citizen science programs, with five of them giving it the highest rating of 4. One ranked it as a significant reason at 3, and one ranked it as a minor reason at 2. The most common local need was to monitor some aspect of the local environment, with four museums providing that as a specific reason. Two additional museums listed monitoring and collecting data regarding specific organisms as the local need. Three museums listed local learning about a topic or topics as the local need. One museum started the program to protect a local scientific resource, and one listed public demand as a reason. The Denver Museum of Nature and Science began their first citizen science program in paleontology, to professionalize amateur paleontologists in the area that were damaging the local fossil record. The Museum of Science Fort Lauderdale started their program in part to meet public demand to become involved with protecting the local sea turtle population. The public wanted to engage with and interact with local sea turtles, which is illegal, but the citizen science program provided a way for the public to become involved with them.

Table 22.
Local Reasons for Beginning Citizen Science

Museum	Rate	Reason	Statement
Museum 1	2	Monitor Organism	*People were saying they hadn't seen fireflies in the area in years and wanted to know why.*
Museum 2	1		
Museum 3	4	Protect Local Resource	*The paleontology program started because there were so many people going out on their own, without training, and bringing fossils to the museum with no information. If people are interested, let's harness that and train them.*
		Local Learning	*For the health sciences project, we were really looking to facilitate local learning in our museum, since we really didn't see a good way to engage the public on genetics based on exhibits we visited in other museums.*
Museum 4	3	Public Demand	*A lot of people want to get involved with sea turtles, but they are endangered and people can't come into contact with them. It was a good way to get people involved without coming into contact with them.*
		Monitor Environment	*Temperature determines sex of turtle eggs, so we wanted to monitor sand temperatures over times to determine how global warming might be affecting the local turtle sex ratio.*
Museum 5	4	Monitor Environment Local Learning	*We wanted a way of engaging the public and providing a public education program, while also generating information for our researchers on local habitats and issues in North Carolina.*

Museum 6	4	Monitor Environment	*The first citizen science program monitored water runoff and quality related to the local paper mill. As programs were added, they focused on other aspects of the Port Townsend shore areas.*
Museum 7	4	Monitor Organism	*The primary reason was to understand the local flora.*
Museum 8	4	Local Learning	*The program focuses on educating local students and monitoring the local beaches.*
		Monitor Environment	*The goal was to monitor the health of Puget Sound beaches.*

Currently, all eight institutions in the sample list meeting a local need as a reason for conducting citizen science, as shown in Table 23. Three museums now give local need the highest rank of 4, indicating it is a primary reason, while four give it a high ranking at 3. One museum indicated it is a lower priority reason, ranking it 2. The specific local needs that the citizen science programs among the sample are meeting have increased. The same four still monitor the local environment, two still monitor specific organisms, three still focus on local learning needs, preserving a local resource- the local fossil record, is still a reason the Denver program operates its program, and Fort Lauderdale still lists meeting local demand to be involved with sea turtles as a reason. The California Academy of Sciences now states that general conservation is a reason and goal of their citizen science programs.

Table 23.
Local Reasons for Current Citizen Science

Museum	Rate	Reason	Statement
Museum 1	2	Monitor Organism	*The program scope has increased but we are still monitoring fireflies.*
Museum 2	3	Conservation	*All citizen science programs need to have a conservation outcome. The programs are all united under the big research umbrella of California biodiversity.*

Museum 3	3	Protect Local Resource	*They are still upholding a need to protect the science, the paleontology group still operates their program in professionalizing others. Local education of the public on genetics is still the driving reason.*
		Local Learning	
Museum 4	3	Monitor Environment	*The program design is still intended to monitor temperatures at beaches over time.*
		Public Demand	*People still want to be involved with sea turtles.*
Museum 5	4	Monitor Environment	*We still engage the public with these programs and provide a public education program, while also generating information for our researchers on local habitats and issues in North Carolina.*
		Local Learning	
Museum 6	3	Monitor Environment	*We still operate programs that monitor local water quality, sea life, and it is a big part of what we do.*
Museum 7	4	Monitor Organism	*That is still why we are going, there is still a lot that we can find out.*
Museum 8	4	Local Learning	*The program focuses on educating local students and monitoring the local beaches.*
		Monitor Environment	

Table 24 displays how the citizen science program mangers rated the change for the dimension of local need. One museum found that it changed from not being a factor to being a major factor. Two museums felt while local need was previously the primary reason for their programs' existence, it is now rated one rank lower as a major reason. The California Academy of Sciences formalized its criteria for citizen science programs, and all programs must have a conservation outcome. The reason is that protecting the natural world is part of the organization's mission, and the organization is realigning programs, including citizen science, behind this mission. The Denver Museum of Nature and Science still operates its programs to meet the same local needs

they addressed at the beginning, but because they have met their goal of professionalizing amateur paleontologists, the ranking has decreased somewhat. The paleontology program now also operates a two-year training program in close association with the citizen science program. And the Port Townsend Marine Science Center changed the ranking for meeting a local need from the highest, 4, to 3. The reason for this is that the paper mill has closed, eliminating that threat to the local ocean, and the slight decrease in local need as a reason corresponds to a slight increase in meeting a national need as a reason, described in the next section.

Table 24.
Changes in Local Reasons for Citizen Science

Museum	Rate	Reason	Statement
Museum 1	1 to 3	Conservation	*All citizen science programs need to have a conservation outcome. The programs are all united under the big research umbrella of California biodiversity.*
Museum 2	4 to 3	Protect Local Resource	*They are still upholding a need to protect the science, the paleontology group still operates their program in professionalizing others.*
		Public Demand	*People still want to be involved with sea turtles.*
Museum 3	4 to 3	Monitor Environment	*We still operate programs that monitor local water quality, sea life, and it is a big part of what we do.*

8) Meeting a National or International Need

Ratings for the impact of national or international need were also collected. The ratings for these factors at the beginning of citizen science programs are shown in Table 25. Two museums listed meeting a national need as a lesser reason for starting citizen science programs, while six of the museums did not consider it a factor. Both state that the national need they seek to help meet is to help meet increasing national demand for science learning.

Table 25.
National Reasons for Beginning Citizen Science

Museum	Rate	Reason	Statement
Museum 1	1		
Museum 2	1		
Museum 3	1		
Museum 4	1		
Museum 5	2	Learning	*The kind of inquiry and education that this programming set out to do is something that is of national interest, and there are calls to do more of it nationally.*
Museum 6	1		
Museum 7	1		
Museum 8	2	Learning	*We see the need for this kind of science education as a national issue.*

The program managers' ratings for this dimension as a factor in their current programming are shown in Table 26. Four museums list helping meet a national need as a reason for conducting their current program, with three of them giving it lower priority (at 2), and one listing it as a more significant reason (at 3). Three now state that science learning is the national need they intend to help meet, and two list conservation as the national need they are aiming to help meet.

Table 26.
National Reasons for Current Citizen Science

Museum	Rate	Reason	Statement
Museum 1	1		
Museum 2	1		
Museum 3	2	Learning	*We see genetics as a national issue, and in looking at other exhibits we never saw a way to really connect people to the topic (about the genetics citizen science program specifically).*
Museum 4	1		
Museum 5	2	Learning	*The kind of inquiry and education that this programming set out to do is something that is of national interest, and there are calls to do more of it nationally.*

Museum 6	2	Conservation	*With the messaging of the microplastics program, we connected it to a global issue. The more awareness we raise, the better, and we are seeing these programs as more globally connected than before.*
Museum 7	1		
Museum 8	3	Learning	*We see this kind of science education as a national issue.*
		Conservation	*We have come to see protecting the oceans as part of a broader national movement, with all of the concern about plastics, clean waterways, etc.*

Across the cases, the changes in reasons for doing citizen science include three increases in reasons for doing so to address national or international needs. These results are displayed in Table 27. Two of these are museums that have come to view their programs as a way to contribute to national and international conservation. In both cases this consists of contributing to conservation of the ocean, with both the Seattle Aquarium and Port Townsend Marine Science Center adding this as a reason for their current citizen science programs. The Denver Museum of Nature and Science now believes that contributing to national education about genetics is important. Developers of the program were not satisfied at how genetics was represented in museum exhibits, and a minor reason for operating the current program is to find ways to better engage the national audience on this topic.

Table 27.
Changes in National Reasons for Citizen Science

Museum	Rate	Reason	Statement
Museum 1	1 to 2	Learning	*We see genetics as a national issue, and in looking at other exhibits we never saw a way to really connect people to the topic (about the genetics citizen science program specifically).*

Museum 2	1 to 2	Conservation	*With the messaging of the microplastics program, we connected it to a global issue. The more awareness we raise, the better, and we are seeing these programs as more globally connected than before.*
Museum 3	2 to 3	Conservation	*We have come to see protecting the oceans as part of a broader national movement, with all of the concern about plastics, clean waterways, etc.*

9) Partnering with External Organizations

Finally, citizen science managers were asked to rate partnering with external organizations as a reason for beginning their programs as shown in Table 28. Two of the museums in the study sample explained that building relationships with partners was a purpose of starting the citizen science programs. One rated it relatively highly at 3, while it was a lower priority for the other at 2.

Table 28.
Organization Reasons for Beginning Citizen Science

Museum	Rate	Reason	Statement
Museum 1	1		
Museum 2	1		
Museum 3	1		
Museum 4	1		
Museum 5	2	Partners	*We work with some local researchers and groups, and cooperate on various projects. Maintaining these relationships is important. We could be a space for their science.*
Museum 6	1		
Museum 7	1		
Museum 8	3	Partners	*We wanted to increase partnerships with places like King county and build those relationships.*

Under their current citizen science programs, five museums do so at least in part to develop and benefit from relationships with other organizations, as shown in Table 29. Two museums are doing so to extend their reach and expand their programs, and three are building relationships with other organizations by collaborating with them on projects. Three museums consider it a minor reason ranking it a 2, and two consider it a more significant reason, ranking it at 3.

Table 29.
Organization Reasons for Current Citizen Science

Museum	Rate	Reason	Statement
Museum 1	1		
Museum 2	3	Collaboration	*We had to have these partnerships to stay true to our goals, of conservation and management. We needed local partners to help us fill roles in our projects, in the academy as a whole.*
Museum 3	1		*The groups ended up having local organizations they worked with, but that isn't a reason we do it.*
Museum 4	2	Extend Reach	*We've built relationships through the program, and looked into working with specific organizations. It is starting to create partnerships and is definitely something we're looking at to expand.*
Museum 5	3	Collaboration	*We work more now with other organizations in the state, state agencies, parks and benefit from our relationships with these groups.*
Museum 6	2	Collaboration	*We have increasingly collaborated with other groups over time. We learned that when you collaborate with others on a proposal, it is always stronger.*

Museum 7	1		*We formed relationships throughout the project, but it is not why we are continuing to do it. It has been wonderful, the relationships with others. It is still a win-win for both.*
Museum 8	3	Extend Reach	*We wanted to increase partnerships with places like King county and build those relationships.* *We are expanding our reach to some local tribes and engaging local practices.*

Table 30 displays how partnering with other organizations is a reason that gained importance across the sample. Three museums added it as a reason as their current citizen science programs evolved, and one museum considers it an increasingly important reason. A fifth museum that already considered it a significant reason at rank 3, the Seattle Aquarium, is using partnerships with Native American tribes to extend the reach of the program. These increases are universally tied to opportunities and benefits the host institutions have come to realize are possible by collaborating with other organizations.

Table 30.
Changes in Organization Reasons for Citizen Science

Museum	Rate	Reason	Statement
Museum 1	1 to 3	Collaboration	*We had to have these partnerships to stay true to our goals, of conservation and management. We needed local partners to help us fill roles in our projects, in the academy as a whole.*
Museum 2	1 to 2	Extend Reach	*We've built relationships through the program, and looked into working with specific organizations. It is starting to create partnerships and is definitely something we're looking at.*

Museum 3	2 to 3	Collaboration	*We work more now with other organizations in the state, state agencies, parks and benefit from our relationships with these groups.*
Museum 4	1 to 2	Collaboration	*We have increasingly collaborated with other groups over time. We learned that when you collaborate with others on a proposal, it is always stronger.*
Museum 5	3	Extend Reach	*We wanted to increase partnerships with places like King county and build those relationships.* *We are expanding our reach to some local tribes and engaging local practices.*

The California Academy of Sciences stated that an additional reason for doing their current citizen science program, one that has evolved with their goals and mission, is to help lead the field. The organization created a citizen science management position, and is heavily involved in the development of a California citizen science network between museums in the state. They are also participating in the movement to create a national citizen science organization, and are exploring the use of technology and the role it can play in citizen science. This result is shown in Table 31.

Table 31.
Other Changes in Reasons for Citizen Science

Museum	Reason	Statement
Museum 1	Lead Field	*We wanted to become a leader in the field of citizen science. We also wanted to explore new technologies and networks to advance the field of citizen science.*

Expected Growth in Citizen Science

Each museum in the sample was asked how they expect the size of their citizen science program to change in the coming years. All 8 museums reported that their programs will stay the same size or grow. As shown in Table 32, three museums expect their programs to stay the same size, three expect their programs to grow a little and three expect a lot of growth.

Table 32.
Expected Change in Citizen Science Program Size

Museum	Expected Growth
Museum 1	Same Size
Museum 2	Grow a Lot
Museum 3	Same Size
Museum 4	Grow a Little
Museum 5	Grow a Lot
Museum 6	Grow a Little
Museum 7	Grow a Little
Museum 8	Grow a Lot

Citizen Science Program by Size, Budget, Location, and Type

Following the cross case-analysis within the nine key dimensions analyzed, a series of four key factors were examined to determine if there is a pattern between these factors and ratings or changes in ratings. The factors that were examined are museum size, budget, geographic location, and institution type. Comparing museum responses with these factors, no patterns or trends within the responses suggest that they are clustered or correlate with museum size, budget, geographic location, or type of institution. Interestingly, the smallest museum has the largest citizen science program, and some larger museums have smaller citizen science programs. The size and scope of each citizen science program are unique to each museum, and appear to be determined by strategic factors, rather than any of the four factors described here.

Discussion

This study investigated the following primary research question: *What factors motivate museums to host citizen science programs, and how and why do museums perceive that those factors have shifted over time?* Secondary research questions included: How are other areas of the museum adapting elements of citizen science programs for other institutional goals? How is the evolution of citizen science programming co-evolving with organizations?

Study results suggest that the reasons why museums offer citizen science programs have shifted over time. Across all cases, the changes among the reasons museums conduct citizen science programs increased at a ratio of exactly 5 to 1. Seven of the eight museums in the sample observed an overall increase in the role and purpose of their citizen science programs in their organization. The museum that did not match this trend, the Museum of Science, Boston, is unique in that operates the only program reported not to have changed at all in its five year history. Additionally, seven of the eight reasons witnessed an overall increase in representing a purpose of museum citizen science programs. The outlier here was local reasons for conducting programs, which saw a small decrease in importance at two museums.

Comparing results across cases, the two dominant reasons that museums both began and continue to operate citizen science programs are education, followed closely by meeting a local need. Education is the single reason all museums list in common for doing citizen science programs, across the lifetime of the programs. All museums currently operate their citizen science programs at least in part to meet a local need, and all but one began with that goal in mind.

Museums across the sample also increased the development role of citizen science programs in that appealing to donors, grant seeking, and raising awareness of the museum and its mission all increased in importance as reasons for citizen science across the cases. Reasons

related to building relationships with scientists and other organizations also increased in importance across the sample.

All of the museums in the sample expect to stay the same size or grow in the coming years. None expect to reduce citizen science programming. Three museums expect to grow their citizen science programs a little bit, and three expect them to grow a lot.

Study Limitations

This study is limited by the nature of the sample, which cannot be generalized to the greater field of museum citizen science. This research is exploratory in nature, and the purposive sample assembled for this study is not intended to represent museums that operate citizen science programs on the whole. The sample fulfilled its role in providing data from a set of museums that operate citizen science programs, for purposes of a cross cross-case comparison. The sample also fulfilled its role in helping describe the reasons that museums operate the programs, as well as described some ways they change over time. The results of this study will help inform future research on the role of citizen science in organizations, both in museums as well as other institutions that operate citizen science programs, by providing a starting point for focused, field-wide research that represents the field as a whole.

Chapter Five: Conclusions and Implications

Conclusions

Institutional Benefit

The museums studied here are increasingly leveraging citizen science programs for greater institutional benefit, beyond their immediate education and research goals. Once these museums decided to begin citizen science programs they continued to do them, and as they did so, their reasons for offering citizen science programs expanded. They now see additional opportunities for leveraging these programs to achieve other important aspects of their mission, for example recruiting volunteers, seeking donations and grant funding, and building collections.

Of particular relevance are the findings suggesting that as museums expand the reasons they do citizen science, they may be connecting these programs to their development framework. In this economic climate museums need to devise new methods to find the resources they need in order to do the important things they want to do. This study suggests that museums may see citizen science as one mechanism for achieving their development goals. By appealing to donors, tying programs to grant seeking opportunities, and building strategic relationships with scientists and other organizations, museums are increasingly leveraging their citizen science programs as a development tool for greater institutional benefit.

Adaptable in Museums

Within the museums studied here, the citizen science program format is highly adaptable. These museums have adapted citizen science programs to the specific circumstances of their institution and their community, in particular to achieve local needs. Study results show that a

major reason museums set out to do citizen science, as well as continue to operate and grow their programs, is the emphasis on meeting a local need. The disparate types of citizen science projects that are happening among the sample speak to the breadth of needs they can be designed to address, and the ways they can be modified and leveraged for other institutional purposes also highlights the different roles the program can be designed to play. These programs are beneficial to museums in that they are used in multiple ways, to gain multiple benefits for the organization. Due to this, museums add and increase the importance of reasons for doing citizen science by a factor of five to one. This highlights the changes that are occurring over time as programs evolve and adapt to meet new opportunities and circumstances. In particular, the format can be adapted to different needs among research, education, and programming areas, and different local needs such as water quality testing, protecting local resources, and monitoring flora and fauna. These programs are flexible enough to operate successfully in many museum departments, including research, education, and programming departments, as well as elsewhere in the organization.

Crossing Boundaries

Citizen science projects as contextualized by museums are simultaneously research initiatives and education platforms, and represent a unique synthesis of functions in museums. All citizen science projects are research by definition, and the major unifying reason science museums in this study choose to operate citizen science programs is that they contribute to the institutional goals of public science education. As an emerging practice in museums, citizen science resides at the intersection of efforts to advance research and efforts to advance education. This type of synthesis is uncommon in museums, which have historically operated departments in greater isolation from one another, with researchers focused on collecting and studying in isolation from the public eye, and educators engaging the public in the absence of researchers.

Citizen science projects involve both functions, and thus may serve as a mechanism to bring multiple museum functions together to meet institutional goals.

Implications for Future Research

Opportunities for future research in this area are informed by both the results of this study, as well as its limitations. Any of the general reasons museums provided for running citizen science programs, such as providing public education, building relationships with scientists, or appealing to donors can be explored in more depth and with a sample that can be designed to describe the field as a whole. In this way, a future study might focus on one purpose of citizen science, such as building relationships with scientists, in a more comprehensive manner. This might include collecting data from a broad and representative sample, such as the ASTC member base that participates in citizen science. With this approach, the specific reasons within each dimension can be quantified and categorized in even more detail to better understand the prevalence and weight of reasons throughout the entire field of citizen science in museums, with a sample that represents the entire field. Additionally, responses provided across both the cases and the reasons for citizen science in this study can help inform future research questions. These responses can also help inform methods and instruments used for future research on any of the purposes for citizen science described in this paper.

A second area of research is to explore other program areas in museums in a similar manner to enable comparison between types of programs. One conclusion of this study is that museums add reasons for doing citizen science over time, and that programs are co-opted for other institutional benefits. All but one of the cases in the sample added institutional purposes for their programs, and the number and importance of these purposes across all cases increase by a

factor of more than five to one. While this result stands on its own, it would be interesting to see how this compares with other programs that science museums operate, such as mobile exhibits, or after school programs. It may be that many types of programs are additive in nature within an organization in that their purpose grows over time. Growth of programs may be a common trend, so the ability to compare these citizen science data to other programs in science museums would highlight the differences between citizen science programs and other types of programs, which may reveal useful information.

A third potential area for future research is to explore a non-museum sample of citizen science programs in a similar manner as the museum sample in this study. With the results of this study, one might hypothesize that the results of the museum segment of citizen science might differ from results determined from non-museum citizen science programs explored in a similar manner. However, the extent to which reasons that non-museums operate citizen science programs differ, and what those differences might be is beyond the scope of this study. This area of future research can utilize methods similar to this study, applied to a non-museum sample, to compare and contrast the purposes that emerge for citizen science programs outside of museums, as well as describe and compare the relative weight that other organizations place on their own reasons for engaging in citizen science programming. Either of these research endeavors can be designed with a sample generalizable to the field, and there are plenty of angles and ample opportunity to study citizen science in museums from an institutional perspective. By continuing to study areas of additional institutional benefit, specific methods may be identified for museum development purposes. It may be that some methods for adapting programs for other purposes are more easily reproducible in other organizations, and may be more frequently successful. The same is true of adaptations, in that additional research on citizen science in museums may

identify consistently positive outcomes of adapting their programs for other purposes in specific ways. Additional research will help identify these benefits and adaptations, and assist other museums in increasing the overall utility and value of citizen science in museums.

Additionally, future research can focus on institutional outcomes and best practices for citizen science programs and museums, distinct from scientific and learning goals. The recent growth in the program area of citizen science provides increased opportunity to measure institutional outcomes of citizen science programs in all of the areas explored in this study, and determine and describe best practices to achieve desired goals of the program.

Implications for Practice

Science museums that do not currently host citizen science programs might consider reviewing the reasons that other museums operate programs, to determine alignment of this type of activity with their organization. Given that all of the museums in the sample are satisfied with their programs, all but one has increased the role of citizen science in their organization, and most of the programs are growing, it is an area that all science museums should evaluate as a potential activity.

In addition, study results inform how museums can use citizen science programs to benefit the organization in additional ways, such as by appealing to potential donors and grant-making organizations. Most museums in the sample are increasingly using their citizen science programs for development purposes. Specifically, they are used to appeal to donors, because these programs are appealing to some people. Some museums in the sample have received grants based on previous work in citizen science. Additionally, the external environment is also changing due to an increased focus on informal science learning, with STEM education focusing

increasingly on inquiry-based learning and applied experiences. States that have adopted the Next Generation Science Standards require that students engage in the types of hands-on experiences provided by citizen science programs. At least one museum in the sample benefitted from this change, and there may be increased opportunity for funding by providing this service in the future.

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Appendices

Appendix A: Museum Sample Overview

California Academy of Sciences

Located in San Francisco, CA, the mission of the California Academy of Sciences is *to explore, explain, and protect the natural world*. It was founded in 1853, and moved to Golden Gate Park in 1916. The large museum is both a research and education institution and has several buildings and an aquarium, and bills itself as the "greenest museum in the world". The academy participates in and hosts several citizen science programs, with the citizen science manager and staff researchers involved in the process. Web site: www.calacademy.org

Denver Museum of Nature and Science

The Denver Museum of Nature and science was founded in 1908, and operates under the mission *The Denver Museum of Nature & Science inspires curiosity and excites minds of all ages through scientific discovery and the presentation and preservation of the world's unique treasures.* The museum currently operates two citizen science programs, in paleontology and the genetics of taste. Web site: http://www.dmns.org/

Museum of Discovery and Science, Fort Lauderdale

The mission of the Museum of Discovery and Science, Fort Lauderdale *is to provide experiential pathways to lifelong learning in science for children and adults through exhibits, programs and films.* They operate one citizen science program, in which participants monitor turtle nest temperatures.

Museum of Science, Boston

The mission of the Museum of Science Boston is *to play a leading role in transforming the nation's relationship with science and technology*. The organization that started the museum was founded in 1830. The Museum of Science has one citizen science program, Firefly Watch. Web site: www.mos.org

North Carolina Museum of Natural Sciences

The North Carolina Museum of Natural Sciences is located in the state capital of Raleigh, and was founded in 1887. The museums states its mission as *The mission of the North Carolina Museum of Natural Sciences is to enhance the public's understanding and appreciation of the environment in ways that emphasize the natural diversity of North Carolina and the southeastern United States and relate the region to the world as a whole.* The museum has a Citizen Science Center located on the first floor of its new wing, where visitors can explore the museums citizen science projects and learn how to become involved. Web site: http://naturalsciences.org

Port Townsend Marine Science Center

The mission of the Port Townsend Marine Science Center is *inspiring conservation of the Salish Sea.* It was founded in 1982 by a pair of teachers, and now occupies one building on a pier and on the shore. The center operates numerous projects, currently numbering 12, though that number changes over time. Web site: www.ptmsc.org

San Diego Natural History Museum

The mission of the San Diego Natural History Museum, founded in 1874, is t*o interpret the natural world through research, education and exhibits; to promote understanding of the evolution and diversity of southern California and the peninsula of Baja California; and to inspire in all a respect for nature and the environment.* The museum operates three citizen science programs, monitoring birds, reptiles, and plants in the county. Web site: www.sdnhm.org

Seattle Aquarium

The Seattle aquarium was founded in 1977 on the Puget Sound waterfront, and is the largest aquarium in Washington State. Its mission is *inspiring conservation of our marine environment*. It features six major exhibits, and hosts several education and conservation programs. Its one citizen science project is a high school oriented program that monitors species abundance on Puget Sound beaches. Web site: seattleaquarium.org

Appendix B: Citizen Science Survey

Citizen Science in Museums Survey

Program Background Information

This section helps me learn a little bit about your Citizen Science program, and some of the resources your organization dedicates to it.

1. In what year did your first institutions first citizen science program begin?

2. Please describe the first Citizen Science program at your institution. What type of research was it, what activities did the public perform, and what were the goals of the program?

3. Please provide a brief explanation of the reason this program was implemented, if known.

4. How many unique Citizen Science projects is your museum currently facilitating?

5. How many staff your institution work on Citizen Science projects at least 25% of the time?

6. How many full time employees are dedicated exclusively to Citizen Science projects (at least 80% of their time is spent on Citizen Science programming)?

7. Is there a dedicated Citizen Science manager at your institution? (This is defined as a person responsible for managing citizen science programs, who spends at least 50% of their time managing and coordinating citizen science projects and activities).

◯ Yes

◯ No

8. How many volunteers work on Citizen Science projects with your institution at this time?

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Citizen Science in Museums Survey

9. If your Citizen Science program is organized under a specific department in your organization, please name that department:

10. What is the annual budget for Citizen Science activities for your organization (excluding employee costs)?

Citizen Science in Museums Survey

Part 2. Rationale for Beginning Citizen Science

This set of questions provides information on the factors that influenced the creation of the first Citizen Science programs at your institution, as well as reasons for doing your current programs. These questions describe some of the rationale for beginning Citizen Science programming at your museum first, followed by reasons for your current program. I realize that there are many possible potential reasons and goals goals to your Citizen Science program beyond the specific list presented, and you are encouraged to provide additional information about your program in the open ended response.

11. On a scale of 1 to 4, how much was VOLUNTEER RECRUITMENT a reason why your institution:

	1 (Not a reason)	2	3	4 (Highest reason)	I don't know
Did it's First Citizen Science Program:	◯	◯	◯	◯	◯
Does it's Current Citizen Science Program:	◯	◯	◯	◯	◯

12. On a scale of 1 to 4, how much was PUBLIC EDUCATION a reason why your institution:

	1 (Not a reason)	2	3	4 (Highest reason)	I don't know
Did it's First Citizen Science Program:	◯	◯	◯	◯	◯
Does it's Current Citizen Science Program:	◯	◯	◯	◯	◯

13. On a scale of 1 to 4, how much was building RELATIONSHIPS WITH SCIENTISTS a reason why your institution:

	1 (Not a reason)	2	3	4 (Highest reason)	I don't know
Did it's First Citizen Science Program:	◯	◯	◯	◯	◯
Does it's Current Citizen Science Program:	◯	◯	◯	◯	◯

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Citizen Science in Museums Survey

14. On a scale of 1 to 4, how much was increasing AWARENESS a reason why your institution:

	1 (Not a reason)	2	3	4 (Highest reason)	I don't know
Did it's First Citizen Science Program:	◯	◯	◯	◯	◯
Does it's Current Citizen Science Program:	◯	◯	◯	◯	◯

15. On a scale of 1 to 4, how much was receiving a GRANT OR SPECIAL FUNDING a reason why your institution:

	1 (Not a reason)	2	3	4 (Highest reason)	I don't know
Did it's First Citizen Science Program:	◯	◯	◯	◯	◯
Does it's Current Citizen Science Program:	◯	◯	◯	◯	◯

16. On a scale of 1 to 4, how much was APPEALING TO DONORS a reason why your institution:

	1 (Not a reason)	2	3	4 (Highest reason)	I don't know
Did it's First Citizen Science Program:	◯	◯	◯	◯	◯
Does it's Current Citizen Science Program:	◯	◯	◯	◯	◯

17. On a scale of 1 to 4, how much was MEETING A LOCAL NEED a reason why your institution:

	1 (Not a reason)	2	3	4 (Highest reason)	I don't know
Did it's First Citizen Science Program:	◯	◯	◯	◯	◯
Does it's Current Citizen Science Program:	◯	◯	◯	◯	◯

18. If meeting a local need was a factor in starting your FIRST Citizen Science programs at your museum, please briefly describe that need, and how your museum decided it could help meet that need:

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Citizen Science in Museums Survey

19. If meeting a local need is a goal of the CURRENT Citizen Science programs at your museum, please briefly describe that need, and why your museum believes it can help meet that need:

20. On a scale of 1 to 4, how much was MEETING A NATIONAL OR INTERNATIONAL NEED a reason why your institution:

	1 (Not a reason)	2	3	4 (Highest reason)	I don't know
Did it's First Citizen Science Program:	◯	◯	◯	◯	◯
Does it's Current Citizen Science Program:	◯	◯	◯	◯	◯

21. If meeting a national or international need was a factor in creating the FIRST Citizen Science programs at your museum, please briefly describe that need, and how your museum decided it could help meet that need:

22. If meeting a national or international need is a goal of the CURRENT Citizen Science programs at your museum, please briefly describe that need, and why your museum believes it can help meet that need:

23. How much were requests from EXTERNAL ORGANIZATIONS to create or partner on Citizen Science programs a reason why your institution:

	1 (Not a reason)	2	3	4 (Highest reason)	I don't know
Did it's First Citizen Science Program:	◯	◯	◯	◯	◯
Does it's Current Citizen Science Program:	◯	◯	◯	◯	◯

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Citizen Science in Museums Survey

24. If external organizations were a factor in creating your FIRST Citizen Science programs at your museum, please briefly describe who asked or encouraged your museum to create or partner in creating Citizen Science programs:

25. If external organizations were a factor in creating your CURRENT Citizen Science programs at your museum, please briefly describe who asked or encouraged your museum to create or partner in creating Citizen Science programs:

26. Please describe any additional reasons for STARTING Citizen Science programming at your museum:

27. Please list any additional reasons for doing your CURRENT Citizen Science programming at your museum:

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Citizen Science in Museums Survey

Part 3. Additional Citizen Science Information

This set of questions is to assess the nature and availability of any supporting documentation defining the rationale, goals, and strategy behind Citizen Science programs at your museum.

28. Is Citizen Science specifically referenced in your museum's strategic plan?

- ◯ Yes
- ◯ No
- ◯ Don't Know
- ◯ We have no formal strategic plan

29. Do you have current or historical documents describing the rationale and goals of starting a Citizen Science project or projects?

- ◯ Yes
- ◯ No
- ◯ Don't know

30. Have you ever conducted an internal evaluation of your Citizen Science program or programs?

- ◯ Yes
- ◯ No
- ◯ Don't know

31. Has an external evaluator ever evaluated your Citizen Science program or programs?

- ◯ Yes
- ◯ No
- ◯ Don't know

32. Has any other type of research been conducted on your Citizen Science program, such as educational research, marketing research, data quality analysis, etc?

- ◯ Yes
- ◯ No
- ◯ Don't know

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Citizen Science in Museums Survey

33. How do you think the scope of the Citizen Science programs at your museum will change in the next three years?

- ◯ It will shrink a lot
- ◯ It will shronk a little
- ◯ It will stay the same size
- ◯ It will grow a little
- ◯ It will grow a lot

34. How much of a priority is Citizen Science programming in relation to all other PROGRAMS operated by your museum?

- ◯ The top priority
- ◯ High priority
- ◯ Average priority
- ◯ Low priority
- ◯ The least priority

35. How much of a priority is Citizen Science programming in relation to all other ACTIVITIES operated by your museum, including exhibits and events.

- ◯ The top priority
- ◯ High priority
- ◯ Average priority
- ◯ Low priority
- ◯ The least priority

36. Please feel to add any additional information you think is important to understand the rationale, role, and scope of Citizen Science in your museum:

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Appendix C. Interview Guide

The following interview guide describes the nature of the interview for the Citizen Science research study. All interview questions will explore aspects of past and present Citizen Science programs hosted at museums ad museum-like institutions such as zoos and aquariums. The specific questions asked of each participant will relate only to Citizen Science programs, and how they relate to the museum organization. The questions will vary significantly based on responses to the Citizen Science survey that the interviewee will have completed prior to the interview.

Interview Questions Part 1: Program Origin Follow-Up

The first part of the interview is designed to follow up on information gathered in Part 1 and Part 2 of the Citizen Science survey, and is semi-structured. Specific questions asked will relate to responses in the Citizen Science survey, Part 1 and Part 2, and will vary between interview participants. Approximately 15% of the interview will focus on Part 1.

Example: “In the Citizen Science survey you took, you stated that one of the original reasons you started the program was to meet a local need for water quality monitoring in the community. What was the water quality issue in the community? How did your organization decide it could help meet the need to monitor water quality? Can you describe the process your organization went through to become engaged with this issue in the community?”

Interview Questions Part 2: Current Program Follow-Up

The second part of the interview is designed to follow up on information gathered in Part 3 and Part 4 of the Citizen Science survey, and is semi-structured. Specific questions asked will relate

to responses in the Citizen Science survey, Part 3 and Part 4, and will vary between interview participants. Approximately 20% of the interview will focus on Part 2.

Example: "You mentioned in the Citizen Science survey that you are currently using your program to build and maintain relationships with scientists. Can you expand on that? What scientists or type of science researcher do you intend to work with? Why? How does building and maintaining these relationships contribute to your institutional mission?"

Interview Questions Part 3: Exploration of Evolution of Citizen Science Program

Questions in Part 3 will probe reasons the Citizen Science programs may have changed between when they were created, and what their goals are now. These differences will be explored for interrelationships with and impacts on other organizational activities and goals. Approximately 25% of the interview will focus on questions in Part 3.

Example: "Did having a Citizen Science program affect the decision to build and maintain relationships with scientists? How? Do aspects of the Citizen Science program affect your relationship and activities with scientists? How?"

Interview Questions Part 4: Structured and Unstructured Dialogue

The final section of the interview will begin with a set of open ended questions that will be asked of all participants, and move into an unstructured dialogue about aspects of the Citizen Science program that may not have been captured in the survey or previous sections of the interview.

The final part of the interview will focus on learning about ways that Citizen Science programs at the host museum are affecting the host museum, and are being adapted for use in other parts of

the organization. This section of the interview is largely unstructured. Approximately 40% of the interview will focus on Part 4.

1. Have any aspects of your Citizen Science program been adapted for use for other institutional purposes? If so, how?
2. Have any exhibits, programs, or other activities of your museum been scaled back or eliminated due to Citizen Science programs? How?
3. Have you produced exhibits, programs or activities, based at least in part, on aspects of Citizen Science programs that came first? How?
4. In what other ways have aspects of Citizen Science programs affected other parts of your organization, or other activities in your organization?
5. How do you expect your Citizen Science activities to change or evolve in the coming years?

The remainder of the interview is unstructured dialogue pertaining to items pertaining to Citizen Science and the host museum that warrant additional discussion.