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How Can Citizen Science be used Effectively Within Environmental Education in order to Foster Environmental Change?

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by

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Chapter 1

Introduction

I have often been asked, “is there a job out there you haven’t done?”. I have worked as a zookeeper and zoo educator, an elementary school aide, guided tourists through the Everglades, counted scat, and backpacked to remote areas to set up wildlife cameras just to name a few. While it is true, I have worked in many different capacities at many different places, these various jobs have all been fueled by my love of nature. Throughout college and my professional life, I have often felt torn between two passions, wildlife conservation fieldwork and environmental education. But maybe being a field researcher and an educator are just two sides of the same coin. I have been fortunate to work both in the field and directly with biologists on various wildlife studies. I have also been the educator teaching the public about these amazing lifeforms. I have enjoyed both, but the combination of the two together through Citizen Science is something I find particularly impactful. Ultimately, I believe the two can and should meet and benefit one another. Citizen Science allows individuals to connect with and learn about resources in their own backyard. Whether it is a plant, animal, or something like protecting their local watershed, it is personal and it matters to them as an individual (Citizen Science: Activating STEM learning out of school). Developing a personal connection is the goal of nearly all my environmental education programs. This connection is what causes individual attitudes and behavior changes.

This capstone project focuses on the following question: *how can citizen science be used effectively within environmental education in order to foster environmental change?* Throughout this project, I explore how to build programs that use Citizen Science to raise environmental awareness and change environmental attitudes and behaviors to encourage more eco-friendly behaviors within communities.

My personal and professional journey has given this question meaning and context. Throughout this chapter, I explore the thoughts and experiences which have led me to this capstone question and the merging of two passions: science and education.

My Journey: Nature, Wildlife, and Education

Nature and wildlife have always intrigued me, particularly wildlife and animals. Growing up I cannot remember a time when my family did not have dogs, cats, horses, and cattle. Evenings and weekends often consisted of chores; feeding and caring for the animals. Summers meant hard work hauling hay and 4-H livestock projects. Downtime consisted of horseback riding, and family vacations camping up the nearby canyon or to National Parks such as the Grand Tetons, Yellowstone, and Zion where any wildlife sightings were always a trip highlight.

In college, I became particularly comfortable working and playing outdoors. I majored in animal science and worked as a part-time zookeeper at a small local zoo. At the zoo, I was able to observe and work closely with the zoo educator. It did not take me long to decide that I wanted a similar profession. After graduating, I worked for nearly two years as the full-time Education Coordinator at the zoo. As I shared amazing stories and facts about zoo animals with visitors I found myself wanting to do more. I wanted my boots on the ground doing the physical

legwork necessary to protect some of the endangered and threatened animals I so often talked to zoo visitors about.

This desire led me to work on a sea turtle and jaguar research project on a biological research base in Costa Rica for three months testing out the waters of fieldwork. The work was fascinating and seemed to be making a difference. Over the 50 years prior, the Green Sea Turtle population within the National Park we worked within had increased by nearly 500%. The effect on the local people, or Ticas as they are often called, was harder to measure. Over the course of three months, park rangers recovered two full nests of poached eggs. We also narrowly avoided running into poachers during more than one nighttime survey. However, for the most part, the Tica population seemed willing to protect the turtles realizing they provided a valuable source of income through the area's eco-tourism industry. While the bulk of our work focused on data collection, we tried to provide educational experiences to the locals when possible. Middle school students visited the base to observe our work. The language barrier made it difficult to connect to these students, but their excitement when they saw hatchling seas turtles was obvious.

Following my time in Costa Rica, I began work as an Interpretive Ranger for the National Park Service on the Gulf Coast of the Everglades. I became known as the turtle girl, probably due to my ranger talk on sea turtles and my need to collect any plastic bags or balloons found on kayak excursions. Sharing my personal experiences with sea turtle research created a connection to the Everglades' own endangered sea turtles to which the park guests seemed to relate. The comments and questions received following my sea turtle ranger talk began to spark my interest in the possibilities of getting everyday *citizens* involved in fieldwork and science.

This spark grew even more as I joined the fisher reintroduction crew in Olympic National Park. Fishers (a member of the weasel family) had been extirpated from Washington State in the 1930s. Fishers from British Columbia had previously been reintroduced to the park. The fisher crew was tasked with monitoring the population through remote cameras. I loved working in the field, being constantly surrounded by nature, and the research was fascinating. However, I missed the human connections made during interpretive programs. Occasionally we would talk with hikers encountered along the trail about the project. There was not, however, any educational programs about the fisher project offered within the park. Very few of the visitors we conversed with knew anything about fishers displaying an unmet need. Visitors needed to learn about these amazing animals, what we were doing, and its impact on the Olympic ecosystem.

My Experience as a Citizen Scientist

My first real involvement in Citizen Science projects came when I made the move to rural Kansas to lead the Education Department of a small zoo. My work there intersected with three different Citizen Science projects. The zoo tagged monarchs every year and diligently worked to create pollinator habitat. Residents got so excited during the monarch migration that we ran out of tags long before the season was over. The zoo offered support for the reintroduction of black-footed ferrets in the state by sending staff to participate in yearly surveys with the United States Department of Fish and Wildlife. I spent three days, or rather three sleepless nights as surveys are conducted at night when the ferrets are active, driving around the Kansas prairie searching for the green glint of ferret eyes. I enjoyed the experience, sleep deprivation and all, and did find it easier to connect with zoo visitors regarding black-footed ferrets after participating in the surveys.

The third most grueling project concerned the plight of the Kansas state reptile, the ornate box turtle. The status of the box turtle became a major concern for the seven state zoos accredited by the Association of Zoos and Aquariums (AZA). Anecdotal evidence suggested a decline in turtle populations throughout Kansas, however, no current research existed to support this hypothesis. Kansas law allowed anyone with a hunting permit to have up to five turtles in their possession. State game wardens knew this law was being abused by wildlife traffickers who ship the turtles to pet markets in Asia. Additionally, years of local residents collecting animals for turtle races or pets may have also taken its toll on the population. Without this data to verify the decreasing population, state agencies were unable to change laws regarding turtle collection. Together, all seven zoos began undertaking a Citizen Science project to gather the needed data using volunteers trained and led by zoo staff. I was responsible for the volunteers and survey sites in our area.

The ornate box turtle project turned out to be a great tool within the zoo's education programs. Sharing research happening in our zoo patrons' own backyards with a species they knew and loved delighted zoo visitors. There were challenges such as keeping study sites confidential in order to avoid leading poachers to them. Zoo patrons, however, proved to be a useful source of information by alerting us to box turtle sightings. Educationally, our largest challenge was stopping the practice of turtle racing. Annual turtle races are still held throughout rural communities and most participants did not realize this was harming the population of the state reptile.

The Blending of Two Passions

I currently work as a Naturalist Educator at a small Nature Center in northern Utah.

The position offers a lot of freedom in choosing the programs I lead and develop. No Citizen Science projects were in practice when I started work for the Nature Center. However, center staff do lead yearly, educational firefly viewing walks each summer. The vast majority of Utah residents who hear about fireflies through the Nature Center are surprised to discover fireflies reside in Utah. This made creating a Citizen Science firefly curriculum a perfect fit for the Nature Center allowing me to blend together my love of science and education.

This capstone encompasses a comprehensive environmental education curriculum targeted at schools, families, and community organizations to create more Citizen Scientists within local Utah and Idaho communities. These Citizen Scientists can be powerful motivators for environmental change through their behaviors and roles as leaders within their personal and professional sphere of influence. Ultimately, not only should awareness of the little known western firefly increase, but also the desire to embrace attitudes and behaviors which protect these insects and their wetland habitat.

Rationale

Through the many different projects I have been involved in, there was never any initiative taken to find out how these various studies impacted the volunteers/citizen scientists participating in them and the communities they lived in. Did these citizen scientists experience a shift in attitudes or behavior and did they influence others within the community? Would they be more likely to choose eco-friendly products when shopping? Did they try harder to minimize their carbon footprint or share their knowledge with others?

The focus of the projects I have been fortunate enough to participate in was always data collection and using that data for wildlife management decisions. I did make a conscious effort to

teach our Kansas box turtle volunteers how to answer questions and interact with the public concerning the project. However, aside from what I personally saw or heard, I do not know how the project influenced local residents. Questions remained like: Did fewer people keep turtles as pets or collect them for races due to our efforts? Did more people make an effort to avoid hitting them on the road? I cannot definitively answer these questions. Most who heard about the box turtle project seemed supportive. There were also two or three individuals who said they would no longer race turtles but was this enough to have any beneficial impact on the community as a whole? I believe the implementation of an environmental education program used in tandem with the Citizen Science project would have impacted a much broader audience.

Clearly, scientists value the data gathered by citizen scientists. Scientists cannot be everywhere at once. More and more they are relying on citizen scientists to help gather data. With modern technology, almost everyone has a phone handy to snap a photo of something peculiar or interesting they happen upon in nature. Apps such as iNaturalist are making this especially easy by creating a large database capable of keeping an inventory of living organisms worldwide. This gives scientists the advantage of having many more eyes in the field and collecting far more data. In addition to the advantages this gives researchers, it demonstrates the usefulness an effective education curriculum can have by empowering citizens to choose to support and make more environmentally friendly choices. Questions that will be considered during the creation of this curriculum are: How can the viewpoints and behaviors of individuals who participate in Citizen Science projects be impacted? What effect do these individual citizen scientists have on the community as a whole? How do we keep these individuals and communities engaged in nature and encourage environmentally conscious decisions?

My capstone will show that Citizen Science projects can be a meaningful educational tool to engage individuals, families, and communities in protecting the natural wonders that surround them. I will be working towards implementing a Citizen Science program to join together the Nature Center's educational firefly walks with a Citizen Science component throughout Northern Utah and Southern Idaho. Through this project, I predict those involved will experience an increased connection to the fireflies and their ecosystem in addition to a desire to keep this unique species safe for generations to come.

In chapter two I review the literature on the subject to make a case for the use of Citizen Science as a tool within environmental education programming. I explore what has been researched on the subject as well as if and how participants in Citizen Science projects are impacting those they associate with and the communities they live in. Chapter three details the capstone project, a curriculum about western fireflies built to answer the question: *how can citizen science be used effectively within environmental education in order to foster environmental change?* Chapter four reflects upon the success of this curriculum.

CHAPTER TWO

Literature Review

This chapter reviews a selection of the literature related to the educational potential of Citizen science including

- Using Citizen Science in inquiry-based learning,
- Incorporating Citizen Science into Science, Technology, Engineering, and Math (STEM)
- Diversifying project participation,
- Effect on civic engagement, and
- Changes in conservation attitudes and behaviors following participation in a Citizen Science project.

Examining the literature surrounding these subtopics sheds light on the capstone question: *how can citizen science be used effectively within environmental education in order to foster environmental change?* Effective use of Citizen Science within environmental education raises awareness of the topic being presented and elicits the desire to support conservation efforts through personal behavior and choices.

To truly answer these questions there is a need to examine ways to include Citizen Science in curricula for youth both inside and outside the classroom and focus on ways of

including Citizen Science within STEM and inquiry-based learning. To truly impact communities, Citizen Science needs to reach a diverse audience and focus on ways of diversifying and expanding a community's Citizen Science base. By understanding these facets and reviewing related literature, educators can better understand what it takes to truly change conservation attitudes and behaviors of Citizen Science participants leading to higher environmental awareness and more eco-friendly decisions within communities.

This chapter explores the current and historical significance of Citizen Science and the challenges and benefits of incorporating it into meaningful education programs. Examples of environmental education programs including Citizen Science projects are also presented. The chapter concludes with debate over how effective these programs are toward the goal of affecting a change in conservation attitudes and behaviors within communities.

The Significance of Citizen Science

Citizen Science, or Community-Based Science, as it is newly becoming known, is not a new concept. Citizen Science is the use of the general public to collect or analyze data, usually in cooperation with a professional researcher or scientist. Early examples of Citizen Science include Thomas Jefferson collecting weather observations to create a weather network within each county of Virginia which would record observations twice daily. Bird observations on the White House grounds were personally kept by President Theodore Roosevelt (Mclaughlin & Benforada, 2019). One of the earliest well-organized Citizen Science projects was the Christmas Bird Count. The Christmas Bird Count began on Christmas Day in 1900 as an alternative to hunting birds. Organizer Frank Chapman recognized that overhunting was quickly wiping out entire populations of birds. That first bird count included 27 participants spread across North

America in 25 locations and recorded 90 bird species. The Christmas Bird Count has continued every year since then providing scientists with valuable information on bird populations and migration patterns with over 30,000 people participating and over 2,400 bird species counted worldwide (Barcus, 2014).

Citizen Science has a long and successful history demonstrating the significance everyday individuals can have toward scientific progress. Including Citizen Science within environmental education programs is one way to continue that history.

Educational Potential and Challenges of Citizen Science

More scientists than ever before are relying on everyday citizens to help collect data they might otherwise not be able to obtain. With technology continually improving it is becoming easier than ever to gather data from everyday citizens. Scientists cannot be everywhere at once, nor do most projects have the funding and time to send trained staff to gather all the data needed. Crowdsourcing data collection through the use of Citizen Scientists is a very cost-effective alternative. Additionally, it gains scientists a much larger data set to work with and allows the collection of data from private land they might otherwise be unable to access (Mclaughlin & Benforado, 2019)

Citizen Scientist success stories abound, particularly about endangered and secretive animals which would be very hard to find without pooling the efforts of outdoor enthusiasts, amateur conservationists, and professional scientists together. One such success was the discovery of multiple tiger sand sharks using shipwrecks as artificial reef sites (Spera, Filyushkina, Masse & Dolezal, 2019). By asking recreational SCUBA divers to submit photos to spotashark.com, scientists were able to confirm multiple female sand sharks repeatedly returning

to the same shipwreck. This was good news for conservationists working to conserve sand sharks whose population had decreased 75% since the 1980s (Spera, et al., 2019). The information gleaned from SCUBA photos allows wildlife managers to work toward the protection of these artificial reef sites. Stories like the sand sharks prove just how effective Citizen Scientists are in providing needed information to lead to the protection of imperiled species and critical habitat. Turning the average citizen's participation in these projects from one of mere data collection to an experience wherein citizens develop an understanding of how science is carried out, however, is another matter. For the scientist, this can require a sizable amount of time regardless of whether or not they enjoy educational outreach.

Even the federal government has recognized the important role Citizen Science has on federal research areas through the recent Crowdsourcing and Citizen Science Act of 2017 (Mclaughlin & Benforada, 2019). The act describes the benefits of public participation in science including accelerating scientific research, increasing cost-effectiveness to maximize return on taxpayer dollars, addressing societal needs, providing hands-on learning in STEM education, and connecting members of the public directly to federal science agency missions and to each other. Dr. Kelvin K. Droegemeier, Director of The White House Office of Science and Technology Policy recognized "America has always been a Nation of thinkers, doers, and problem-solvers. By encouraging everyday Americans to engage in scientific research, our Citizen Science authorities benefit communities and the country as a whole, as well as advance our science and technology enterprise" (Mclaughlin & Benforado 2019, p. 1).

Technology has certainly made it easier, not only for Americans but for people worldwide to engage in Citizen Science. Apps and tools such as iNaturalist, FrogWatch USA,

Zooniverse, and many more are making it easier than ever to allow the general public to engage in Citizen Science projects. While there are numerous ways to participate in a Citizen Science project, what is the benefit to the general populace? Are those involved in these projects better educated on environmental issues? Are they more likely to choose environmentally friendly behaviors? How can we better leverage these tools to impact and foster environmental awareness in our communities?

Educators and scientists alike know Citizen Science can be a valuable education tool (Pandya & Dibner 2018). It has the capacity to change the way people think about science and view the natural world around them. It can help inspire an appreciation for nature and foster support for conservation initiatives meant to protect natural resources. In particular, engaging young people in Citizen Science can teach them critical thinking skills and pique their interest in the sciences. These are the world's future scientists and researchers. Today's youth may have the opportunity to impact enormous issues such as climate change, marine debris, and more. Therefore, it would make sense to pair science and education together in a mutually beneficial symbiosis through engaging youth in hands-on Citizen Science projects (Citizen Science: Activating STEM learning out of school, 2020)

More and more, classroom teachers are becoming acquainted with the benefits of Citizen Science and looking for opportunities to incorporate it into their classroom curriculum (Shah & Martinez, 2016). Environmental educators at nature centers, museums, and zoos caught on to the value of Citizen Science years ago and often are on the front lines bringing classrooms of students outside to engage in hands-on Citizen Science. Environmental education is designed to not only teach about the natural environment but also to provide participants with the knowledge,

skills, attitudes, and commitment to protect and improve the environment (Monroe, 2015). Citizen Science is one tool in the environmental educator's toolbelt to do this. However, there are still challenges to overcome in breaking the barriers between scientists and educators.

Traditionally, the goals of scientific data collection and environmental education have often been in conflict with one another. Researchers may believe they have to sacrifice the accuracy of their data to provide an educational experience to the citizen scientists involved in their project. Scientists may also feel their tasks are too rigid to allow participants an engaging exploratory learning experience (Edelson 2012). As a result, Citizen Scientists are often delegated to the role of data collection and are not engaged in the whole scientific process. This distances project volunteers from scientists and rarely allows them to see science in action. While stories such as that of the sand sharks and spotashark.com tell the importance of data gathering it does not allow for participants to understand and connect with the science behind the data, a critical part of STEM and inquiry-based learning systems. Breaking down these barriers is the first step toward changing scientific attitudes and behaviors within communities.

Citizen Science has enormous potential for inclusion in any science education program. When incorporated effectively into environmental education programs participants can experience science and the natural world on a personal level. This has the potential to give these individuals the skills and desire needed to make positive environmental changes.

Incorporating Citizen Science into Inquiry-Based STEM Learning

In contrast to traditional education, inquiry-based learning is about triggering a student's curiosity and places some of the responsibility for learning on the student, similar to real-world job situations, particularly within the research sector. A teacher, rather than presenting

information about what they know, instead facilitates active learning through posing problems and questions for students to investigate and follow from start to finish (Condon & Wichowsky, 2018).

Educators are beginning to see the value of using Citizen Science as a meaningful tool within inquiry-based learning. It has the possibility of changing many people's relationship with scientific research from one of resource use to active engagement in research and conservation initiatives (Herodotou, Aristeidou, Sharples 2018). Hands-on scientific observation of the entire scientific process, not just that of data collection is necessary in order for the growth of critical thinking skills within citizen scientists. Clear communication between expert researchers and citizen scientists must occur in order for this to happen (Edelson, 2012).

The availability and ease of use of new technology such as FieldScope are allowing Citizen Scientists to not only collect data but to also analyze that data and make their own conclusions (FieldScope.org). Additionally, technology such as FieldScope and other digital platforms allows citizen scientists not only to form their own conclusions on projects they participate in but also to follow their own inquiries from start to finish through the creation of Citizen Science Projects. Essentially a concerned citizen has the capacity through modern technology to become their own scientists through a hands-on inquiry-based process that not only enhances learning but also can benefit their communities as a whole.

STEM is the idea of aligning educational curriculum in an interdisciplinary approach within four main subjects, science, technology, engineering and math, rather than teaching them as separate disciplines. This blended learning strategy shows students how the scientific method

can be applied in everyday life and focuses on real-world applications (Condon & Wichowsky, 2018).

Concerns abound today over both economic and environmental issues and if science education adequately prepares students. Economically, few students are expressing interest in entering careers in STEM leaving a skills void within the U.S economy (Shah & Martinez, 2016). Recently, the program for international student assessment (PISA), a survey that tracks the extent to which 15-year-olds have acquired knowledge and skills essential for participation in society, listed the United States in 20th place in science education, with 69% of high school graduates unprepared for college-level science (Shah & Martinez, 2016). Surprising, given the United States is ranked 6th in education spending per student. Environmentally, is STEM education really preparing students for the many environmental challenges today's youth will face? The Next Generation Science Standards (NGSS), developed in 2012 by a collaboration of states and also adopted by a growing number of states, include a significant focus on sustainability (Shah & Martinez, 2016). However, questions remain about how best to approach topics such as conservation and climate science in the science classroom and whether traditional science instruction gives students the skills and confidence they need for public engagement on these issues (Shah & Martinez, 2016).

More hands-on experience is urgently needed to enrich student's scientific understanding in addition to teacher training in scientific inquiry and methodology. One effective way to start filling this gap is to use an inquiry-based learning approach to STEM through the use of Citizen Science programs. Inquiry-based learning and STEM curriculum fit together hand in hand as questions and inquiry are what drive the scientific process. Citizen Science when presented

correctly allows students to make inquiries, gather and analyze data and participate in the whole scientific process (Condon & Wichowsky, 2018).

Citizen Science is one way for teachers and scientists working together to prepare students to tackle environmental issues such as climate change, invasive and endangered species, and others. Citizen Science immerses students in real-life science in the places where they live, learn, and play, making sense of issues close to home which still have significance to the wider world (Citizen Science: Activating STEM learning out of school). Students need to do science to learn science. Real-life problem solving is at the core of any scientific question. Using Citizen Science within the classroom engages students in real-life scientific questions. It also scaffolds STEM skills including critical thinking, observation, technology use and data literacy (Citizen Science: Activating STEM learning out of school). Although not all classrooms will be able to incorporate Citizen Science to the same degree it does prove to be a better alternative to traditional science education in many instances (Collins, 2014). It is also important for students to be immersed in the chosen Citizen Science project for the entire process, not just that of data collection in order to truly learn and understand the process of scientific inquiry (Whittington, 2016).

For students to obtain all the benefits a Citizen Science experience can provide, teachers need to be trained in how to facilitate Citizen Science within their classrooms (Collins, 2014). Teachers need to avoid painting science as an inflexible solid. Portraying science in this fashion limits students' scope of understanding and does not portray science as the constantly evolving field it is. Scientists leading Citizen Science projects also need to take the time to assist teachers and educators by offering training, guidance, and feedback to project participants. By closely

working together, teachers and scientists can ensure Citizen Science projects contribute to the community by providing participants with a meaningful and educational experience and collecting scientifically valuable data (Edelson, 2012).

Citizen Science experiences outside the classroom can also motivate youth to enter careers in science, technology, engineering and math. One example of this is the Girl Scouts of the United States which launched the Think Like a Citizen Scientist Journey Program (Sparks, 2019). This program contains a series of projects where researchers send videos explaining their work and how observations from the girl scouts could help them. Suzanne Harper, director of the program, believed "the best way to build STEM skills is to let the girls be involved in hands-on projects and teach them how their participation will help the environment, its wildlife and people". One example of this in action within the Think Like a Citizen Scientist Journey Program is California Brownie Troop 33662 who worked with keepers at the Oakland Zoo to document animals' behaviors in their enclosures. The girl scouts compared the eating and sleeping rhythms of the zoo animals to the behavior of the same animal species in the wild. A Brownie participating in the project remarked, "I learned that anyone can make observations and collect data, even if they're not a real scientist, and my Girl Scout troop can help real scientists solve problems" (Sparks, 2019, p. 1).

Incorporating Citizen Science in a meaningful way can meet STEM requirements and teach students to direct their own learning through inquiry. Building Citizen Science into environmental education programs, particularly with school groups, builds the skills needed for youth to tackle a myriad of environmental issues in the future.

Civic Engagement

With a renewed focus on STEM engagement and sustainability, very little attention is being paid to social studies and civic education. Course requirements devoted primarily to civics have declined in recent decades, and 40% of states do not include civics standards in their state accountability systems (Condon & Wichowsky, 2018). Integrating civic engagement into science curricula can improve learning outcomes in both civics and STEM. Citizen Science is perhaps the best-known model of this because it makes a visible effort to bring science and community-mindedness or civics together. Citizen scientists are engaged in endeavors meant to address shared problems within communities (Condon & Wichowsky, 2018).

There is a need for programs that involve students in this process. Engaging students in a Citizen Science based model can focus students on real-world civic issues through active learning. Citizen Science experiences address community and social needs, develop communication and teamwork skills, and ultimately create more scientifically literate citizens able to confront challenges within their own communities (Sparks, 2019).

A study conducted throughout 13 schools in Chicago demonstrated the benefits of an integrated STEM/civics curricula through the STEMhero curriculum (Condon & Wichowsky, 2018). 551 students in classrooms across 13 schools in the city participated in the study. Pre and post-exams were conducted to measure both environmental and civic efficacy on a six-point scale system. The STEMhero curriculum was inspired by the challenge of sustainably managing freshwater. STEMhero is designed for middle school science classrooms. It uses a web-based application to track and analyze utility consumption, taking advantage of resources students use every day in their homes and schools- water, gas, and electricity. STEMhero uses sustainability challenges and inquiry-based learning to engage students in science, civics, and natural resource

management. The program asks students to increase water and energy efficiency in their homes and schools. Students in the STEMhero program collaborate with each other to track water meter readings in their homes and schools. They use the resulting crowdsourced data to design and test strategies to increase water efficiency and collaborate with each other to solve an environmental collective action problem of global importance. By using data that is already available in students' homes and schools, the program is designed to empower students to leverage their own real-life data to make a difference in their communities through action as a citizen-scientist (Condon & Wichowsky, 2018).

Post exam results showed students who participated in STEMhero increased their environmental efficacy by 0.22 points more than students in control classrooms who did not (Condon & Wichowsky, 2018). The study also found that student's confidence in their ability to actively participate in civic issues within their communities increased after the STEMhero curricula.

Inclusion of Citizen Science within environmental education can create memorable experiences. These experiences can lead participants to care about nature and the civic issues surrounding habitats within their own communities. By developing environmental education programs that create these experiences through Citizen Science, educators can create tomorrow's environmental and civic leaders.

Diversifying Participation

As educators and scientists recognize the value of Citizen Science as an education tool to shape youth and prepare the world to face an ever-changing environment, the need to diversify participants within Citizen Science arises. Through connecting a diverse range of participants

within these projects, individuals and communities can better understand the world around them socially, economically, and environmentally. Individuals and communities locally and globally will be better prepared to face the issues of today (Hobbs & White, 2012).

Traditionally, most citizen scientists came from a middle-income background and a large portion are retirees (Herodotou, Aristeidou, Sharples 2018). Participants in both the Great Pollinator Project and the Earthwatch Coyote Project, which are discussed more in-depth later, were largely of a similar demographic, the majority being females over the age of 50. This is a demographic profile found in many various Citizen Science projects (Brossard, 2005). There is a need for projects that attract younger participants. One way of reaching the younger generation is through incorporating Citizen Science into the classroom and afterschool programs as discussed previously through integration with STEM and inquiry-based learning (Condon & Wichowsky, 2018). Another possibility to increase youth participation is the inclusion of technology. Projects involving social media networks and personal technology devices may offer a way to foster engagement with the younger generation. With a large portion of United States teens owning smartphones, merging cell phone use with Citizen Science projects may be an effective way to attract younger participation (Land-Zandstra, Devilee, Snik, Buurmeijer & Broek, 2015).

Finding platforms that both support the entire inquiry process, are personally meaningful, and appeal to a diverse audience can be difficult. Projects such as Galaxy Zoo (www.galaxyzoo.org) for example, may involve participants in specific pieces of the inquiry process including observation and classification of objects. However, research methods and objectives are defined by professional scientists. Therefore, projects like Galaxy Zoo will likely only engage those members of the public with well-aligned interests limiting diversification

(Land-Zandstra, et al., 2015). In contrast, a web-based initiation platform like Kickstarter (www.kickstarter.com) allows members of the public to fundraise and organize their own projects which has personal meaning to them. Such initiation platforms do not, however, provide a model of scientific inquiry or a meaningful relationship between professional scientists and the communities in which they live and work. To truly support inquiry-based STEM learning and appeal to a wide range of interests there needs to be a wide range of Citizen Science projects covering various fields of interest from botany, herpetology, ornithology, water quality, etc. (Hobbs & White, 2012).

Some web-based platforms do cover a huge variety of interests. iNaturalist for example allows for observations on any living thing or evidence of living things (www.inaturalist.org). While this might cover a wide range of interests, yet again it is often limiting participants to the role of data collectors. Smaller projects with a specific focus can provide a more meaningful experience. Smaller projects often are more able to allow participants to experience the full scientific process and connect with specific resources with meaning to them personally. There are endless questions that could be explored through means of Citizen Science. The challenge for educators lies in finding the right topic which will meet the interests of often diverse communities and choosing platforms that appeal to teens and young adults.

An additional challenge to diversifying Citizen Science participants lies within reaching citizens who are not already highly interested in nature and conservation (Toomey & Domroese, 2013). Exposing youth to hands-on Citizen Science within their classrooms could help combat this problem in the future. Creating a connection to nature and science while still in the formative years will create adults with positive conservation attitudes and behaviors already in place.

Making the goal of Citizen Science for adults one of reinforcement rather than an introduction to these attitudes and behaviors (Toomey & Domroese, 2013).

For Citizen Science and environmental education to be an effective catalyst for change these programs must reach a diverse and broad audience. Environmental educators must increase the reach of Citizen Science to reflect the diversity of the communities they serve. Creating programs to reflect community diversity is challenging, but when accomplished the effects of Citizen Science will be far more effective.

Retaining Citizen Scientists

Just as important as diversifying the demographics being reached with Citizen Science projects is retaining these volunteers (West & Pateman, 2016). Being unable to recruit and retain enough individuals can lead to the death of a project. In order for Citizen Science projects to succeed both scientifically and make an educational impact, it is crucial for project organizers to be able to find and retain their volunteer base. Citizen Science projects vary in their time commitment ranging from just a few minutes to years. Participants are unpaid acting of their own free will and desire to benefit their community or world. Volunteering in general plays a vastly important role across a broad range of sectors within society. The proportion of the population who engage in volunteer activities varies by country but in general, seems to be on the rise. Perhaps this is due to rising gaps between societal needs and funding (West 2016). This is demonstrated by the increasing number of Citizen Science projects monitoring various environmental issues that could not be possible without volunteers due to financial constraints. Three main factors have been found to influence individual decisions to participate in Citizen

Science projects: 1) they need to be aware the opportunity exists, 2) the opportunity needs to be appropriate for them, and 3) they need to be motivated (Hobbs, 2012).

Successful projects are well-organized and able to find and retain their volunteers. To do so, organizers need to take several steps to ensure their volunteers feel valued and heard (West & Pateman, 2016). First organizers must understand their participants' motivations for joining their project and create tasks that appeal to multiple motivations. Motivations could include the desire to learn new things and share this knowledge with others, wanting to help others, wildlife, love of the environment, or love of a particular site location. Expectations for Citizen Science participants should be clearly stated from the inception of the project. Once a volunteer base has been found, regular communication with participants need to be coordinated. Citizen Science project participants need to know their time is well-spent. They also need to interact with other project participants. Allowing volunteers to provide regular feedback enables them to feel heard. This feedback can be used to alter the project or the role of citizen scientists as needed. A Citizen Science project which hears and listens to its citizen scientists and then creates a project that fits their motivations and wants is much more likely to succeed and retain its unpaid citizen scientist volunteers (West & Pateman, 2016).

For environmental educators using Citizen Science within their programs, this means creating a well-organized program that volunteers will enjoy participating in, share with others, and return to. Many environmental education programs rely on volunteer educators to carry Citizen Science to schools and community outreach events. These educators will need not only a proficient grasp of Citizen Science but also to feel valued for their contributions. Otherwise, these programs will not be able to effectively use Citizen Science.

Citizen Scientists as Education Ambassadors

It is clear that to truly affect a change in scientific attitudes and behaviors within local communities, Citizen Science projects need to have some form of educational outreach programming. Citizen scientists themselves must share their knowledge and experience with friends, family members, and co-workers. Research has documented that citizen scientists are more confident to talk with others about the topic of the project they were involved in following their participation (Brossard, Lewenstein & Bonney, 2005). Little research has been done to determine exactly what the reach of a Citizen Science ambassador might be. Survey results following engagement with several different Citizen Science projects indicate that citizen scientists are highly inclined to share their experience and the knowledge they gained with others. Without project participants sharing their knowledge and experiences there will be little to no positive changes seen in communities as a whole (Brossard, Lewenstein & Bonney, 2005). Existing citizen scientists can have a great impact on the attitudes and behaviors of their families, close friends and other individuals within their personal circles. These "ambassadors" can be a powerful tool to increase and diversify participation in Citizen Science and ultimately increase interest in conservation initiatives amongst those within their community (Brossard, Lewenstein & Bonney, 2005).

Citizen Scientist ambassadors can be valuable instruments helping environmental educators to fully utilize Citizen Science within their programs. These ambassadors can broaden and diversify the audience reached and support environmentally sound community goals.

Conservation Attitude and Behavior Changes

Citizen Science allows participants to build their view of the project they are involved in and its impact on the community and wider world rather than viewing it exclusively through the eyes of science (Price & Lee, 2013). These individuals are left with an increased appreciation and knowledge of science, nature and the impact of their own daily choices. Environmental educators want to believe this will lead to increased awareness, changes in behavior, and more support for conservation initiatives. However, this may not always be the case. A pre and post-survey assessment of participants in the Birdhouse Network Citizen Science project did not find any significant attitude changes towards science or the environment. However, for some citizens participation in the project itself qualified as a behavior change. Additionally, some participants in the Birdhouse Network found additional projects to participate in and increased their interaction in local civic issues (Brossard, Lewenstein & Bonney, 2005).

The value of citizen generated data for scientific research is being increasingly accepted. After all, it is enabling research that would otherwise be far too expensive to complete. Citizen Science has also begun to be recognized as a powerful tool in increasing scientific literacy within youth in particular, and communities in general (Powering Citizen Science). Citizen Science has the potential to increase environmental stewardship through its participants and the information they collect. However, little research has been done to determine if those citizens are more likely to engage in further conservation initiatives. As Citizen Science has grown in popularity, numerous projects have begun under the assumption that their project will lead to better environmental stewardship. It only takes browsing a few Citizen Science web pages to see statements like this: "We foster marine stewardship in kids through Citizen Science" (www.reefquest.org) or "Together, We Work Together for The Good of The Planet and Inspire

Change." (www.earthwatch.org). These statements suggest that citizen scientists will become more conscious of their personal actions and choices on a given conservation issue. However, there are few projects in which the connection to attitude and behavior changes has truly been assessed (Toomey & Domroese). Self-reporting participants in a Neighborhood NestWatch program reported very small changes or no changes at all in attitude and behavior, while others said their whole outlook towards the natural world was altered by the experience (Toomey & Domroese).

A study in New York State set out to examine this connection between Citizen Science participation and resulting attitude and behavior changes through focusing on two Citizen Science projects: The Great Pollinator Project and the Earthwatch Coyote Project (Toomey & Domroese, 2013). The authors of the study believed the relationship between participation in Citizen Science and the resulting effects on personal conservation attitudes and behaviors to be a cycle or feedback loop. Wherein participation itself leads to the perception of having done something positive for the environment. This leads to more positive attitudes toward conservation in general and reinforces the motivations that led them to participate in Citizen Science in the first place. Participation in such a project itself is considered a conservation behavior contributing to the participants' desire to engage in more conservation behaviors (Toomey & Domroese, 2013).

Participants in the Great Pollinator Project were recruited as "bee watchers" and trained to record and submit bee visits to flowers (Toomey & Domroese, 2013). Surveys following the project reported the following: 90% of participants reported an increase in appreciation for bees and the natural world, 74% reported more confidence in talking to others about native bees and

55% reported an increased interest in environmental issues in their community. Those who participated in the project for three or four years showed a greater percentage increase in their interest in environmental issues than those who participated for only one or two years. Open-ended questions further demonstrated an increase in interest in native bees. Many responded how impressed they were by the diversity of bees and several commented on being surprised that the bees were not aggressive. These responses would suggest that the experience contributed to positive attitudes toward bees and their place within the ecosystem. When asked about future interest in pollinator conservation activities, 79% said they would talk to others about native bees and 77% said they would be planting pollinator-friendly plants. However, only 34% reported an interest in contributing to pollinator protection campaigns or invertebrate conservation groups. It is important to note that 25% of participants reported that they had previously participated in a Citizen Science project. For this 25%, appreciation of nature and conservation behaviors were already high. However, participation in an additional Citizen Science project reinforced this idea as per the feedback loop proposed by the authors (Toomey & Domroese, 2013).

Similar results were seen from the Earthwatch Coyote Project (Toomey & Domroese, 2013). During the project, volunteers were taught from experts regarding coyote biology, field ecology, and management practices. Volunteers were then taught how to set up and bait a camera station and to identify coyote tracks and scat. Following the training, volunteers monitored local urban parks for coyote signs. Post survey results indicated that 70% of volunteers had changed attitudes in a positive way while the other 30% indicated no change. When asked how their attitudes changed, 86% selected an option stating coyotes are smarter, more interesting animals

than they had realized. Several volunteers indicated through answers to open-ended questions that they had a better understanding of biases toward coyotes and the impact human encroachment has on coyote habitat and behavior. When asked follow-up questions regarding engagement in a list of eight activities including reducing ecological footprint, raising own environmental awareness, raising others' environmental awareness, and engaging in recreational nature and wildlife activities following the Earthwatch Coyote Project, two-thirds of the volunteers indicated they had done at least four of the eight. 40% of the coyote project participants said participation in other Citizen Science projects was strongly influenced by their experience with the coyote project (Toomey & Domroese, 2013).

These studies demonstrated the efficacy Citizen Science has on conservation attitudes and behaviors. To truly see the long-term impact, case studies would need to be conducted on citizen scientists over the course of many years. However, these studies indicated at least some positive attitude changes as well as the intention for positive behavior changes in most participants. For those who saw little change in attitude and or behaviors, their involvement in the project itself may have been reinforcement for already positive behaviors and attitudes which they already held.

Ultimately an environmental educator will only feel successful if they feel their programs are contributing to positive conservation attitudes and behaviors. Creating a personal connection to science, resources, and issues within a community through citizen science is one possible way to achieve this shift in attitudes and behaviors. For many individuals, the mere act of engaging in Citizen Science could constitute a behavior change, beginning a feedback loop that can lead to further positive changes.

Literature Review Summary

Citizen Science can be as simple as making and sharing an observation or as robust as asking questions and generating data which leads to civic engagement and determines resource management decisions. Citizen Science provides a place for youth, adults and citizens from all backgrounds to learn and do science together while making their communities better places. Youth engagement in Citizen Science provides them with skills to set them up as future leaders and create a healthier more prosperous future.

Citizen Science has exploded from its early days of counting birds on the White House lawn, to countless Citizen Science projects involving millions of people. These projects have local and global impacts answering serious scientific questions and providing hope for the resolution of many environmental issues. Scientists willing to work with educators can create projects not only of scientific value but also have a great educational impact on citizen scientists themselves. The use of technology and incorporation of Citizen Science into the classroom teaches the next generation problem solving, science, leadership, and other skills needed to lead us into a future fraught with difficult environmental and social issues. For most who participate in Citizen Science, there does appear to be an increased desire to practice conservation behaviors and participate in additional projects.

Chapter three outlines the curriculum developed for use with a Citizen Science project working to record the locations of western fireflies. During this curriculum, the firefly was used as an iconic species to represent the beauty of western wetland habitats and create a personal connection to that habitat for students. The curriculum was designed to increase scientific literacy related to fireflies within the Western United States, foster a greater appreciation for the

firefly's wetland habitats and increase conservation behaviors such as minimizing light pollution and pesticide use and conserving water.

Chapter 3

Project Description

Introduction

This chapter describes the capstone project. This project was designed to answer the question: *how can citizen science be used effectively within environmental education in order to foster environmental change?* I have worked with several Citizen Science projects over the years and have witnessed some of their benefits such as increased environmental awareness and citizens making more eco-friendly choices and behaviors. However, I had previously never developed a formal program intentionally designed to do this.

A small Nature Center located in Northern Utah has partnered with entomologists, as well as a local city where fireflies reside, to protect and educate the community about the presence of fireflies, a species most Utah residents do not know exists in Utah. Little is known about these pockets of fireflies in the Western United States. Scientists have yet to answer many questions including exactly what species of fireflies reside in the west. The project relies on Citizen Scientists to report their firefly sightings to allow researchers to map the locations where fireflies are found. A small local Nature Center where I work led annual interpretive firefly viewing walks during the month of June but did little else to expand the project. This capstone project redesigned these firefly walks along with creating several other firefly curricula that can now be utilized year-round. These programs were designed with the intent to impact environmental attitudes and behaviors within the surrounding communities of Northern Utah and Southern Idaho and demonstrate the effectiveness of Citizen Science within environmental education.

This chapter details the capstone project, the rationale behind it, how it was executed, its setting, audience, and proposed timeline. The project consists of online presentations to engage more citizens with the project and increase the number of sightings reported. There was also an online elementary school curriculum designed to pique the interest of children and, in turn, create Citizen Scientists of that child's entire family. Kindergarteners in particular were targeted through the creation of a field trip curriculum aligned to Utah Science with Engineering Education (SEEd) standards. In-person guided firefly walks were restructured to contain a Citizen Science activity within the walk. Additional programs were also developed to reach the community through school STEM nights and community fairs. Details on the project as a whole, as well as each individual curriculum, are outlined in this project description.

Project Overview and Rationale

The firefly project now has a strong foothold within Utah. Entomologists are now looking to further expand the project to determine where fireflies are located throughout the rest of the Western United States. Being situated near the Utah Idaho border, the Nature Center is in a prime location to try and expand the project into Idaho. This capstone project was to create a comprehensive firefly curriculum guide for use by the Nature Center with targeted programs to reach schools, families, adults, and community organizations. This guide was designed to both raise awareness of the presence of fireflies, but also create more citizen scientists to report firefly sightings particularly within Southern Idaho. If successful, these programs will increase knowledge and awareness of western fireflies and their wetland habitat resulting in an increase of firefly sightings throughout Utah and Idaho.

Audience and Setting

Everyone can be a Citizen Scientist no matter their age, background, or ethnicity. This creates a large and diverse audience to reach. Fireflies are charismatic creatures that create a sense of wonder by lighting up and turning ordinary landscapes into something extraordinary. The vast majority of the Nature Center's audience is not aware of the existence of fireflies in their home state. Often Nature Center staff hear comments like, "I miss seeing the fireflies I saw growing up in the Midwest or the Eastern United States"

Programming through the Nature Center was used to reach a diverse audience through a variety of different settings. Programming was conducted throughout Cache County, Utah, and Franklin County, Idaho. These programs are twofold: community programs designed for adults and families and school programming. The project utilized both community and school programming to reach the largest audience possible. In particular, efforts were made to reach out to community organizations and school teachers within Franklin County, Idaho in order to expand the firefly project into Idaho where, to date, there are very few sightings. To reach such a broad audience, the curriculum guide includes programs for five different settings including an online presentations (due to the COVID-19 outbreak in-person programs were not always possible) to be sent to libraries and community groups such as Audubon chapters, 4-H groups, Rotary and Kiwanis clubs, etc. An online lesson curriculum for elementary students, their families and teachers was also created for use during the COVID-19 quarantine as part of the Nature Center's staying home initiative.

In addition to online resources, June firefly viewing walks were restructured, a kindergarten field trip curriculum was developed and a firefly centered activity for use at

community fairs and school STEM nights was created. A more detailed description of each of these program curricula follows.

Project Format

For entomologists studying fireflies, the most beneficial aspect of this project was to reach Idaho residents in order to generate more sighting data. This was a challenging task due to the stay at home order in effect at the time within the state of Idaho. This necessitated the need for online training and curricula that could be completed inside the home. The online materials were done in two parts for this project. The first was an online presentation geared toward adults. This presentation provides a background about the natural history and life cycle of fireflies, when and where to look for them, and how to record and submit sightings. The online presentation was developed to reach community organizations such as Audubon, Kiwanis, and Rotary clubs. Secondly, an online lesson plan geared toward elementary school students was developed and posted on the Nature Center's website as part of the center's staying home, COVID-19 initiative during the month of May 2020. It was also sent to elementary school teachers within the Franklin County Idaho school district. Nature Center staff have observed the enthusiasm children exhibit while learning about insects. By engaging children, the curricula will reach the entire family through the experience of one child. The goal is to aid in the search for Idaho fireflies by broadening our base of Citizen Scientists.

For the past 4 years, annual firefly viewing walks have been conducted every night for a week in June at a local city park. City residents, in particular, have become very aware and proud of the fireflies located in this park. The city and its residents are already making changes to raise further awareness for the fireflies and the wetland habitat they represent through setting aside the

natural wetland area that is the park and working with the Nature Center to design and install interpretive signage about fireflies as well as the annual firefly walks. In past years this program consisted of learning a few facts about fireflies and enjoying seeing them. This project provides a more structured program that is more engaging through the inclusion of Citizen Science. In this restructured program participants begin the night with an interpretive guided walk introducing the firefly, their habitat, life cycle etc. Once it is dark enough to begin seeing fireflies participants are invited to spend 10-15 minutes observing and recording firefly flash patterns. Participants are usually couples and families. Thus, the program needed to be fun and educational for the whole family, prompting them to continue looking for fireflies in other locations for the duration of the firefly season. Following the flash pattern recording the night is concluded with a call to action to report any future firefly sightings and to consider what actions they might take to protect fireflies and wetlands. This is the only program offered by the center in which participants are actually able to see real-life glowing fireflies. In my experience, there is something about seeing an animal in person which creates a personal connection between animal and viewer evoking a stronger desire to protect it and preserve that sense of awe created by viewing an animal like a glowing firefly. Therefore, I saw the greatest impact on behaviors and attitude change emerge from this program.

Nature Center staff also attend many school STEM nights and community fairs and have the capacity to reach a large audience through this setting. The style of these programs is a table or booth space with some sort of short activity or game for families and children to engage in using STEM skills. The audience for this program is again mostly families, however, the setting is much different. In this setting participants only have 5-10 minutes to engage in a learning

activity usually in an indoor setting such as a school gym. STEM guidelines were used to combine science, technology, engineering, and math into an activity teaching children and their families how to become and think like a Citizen Scientist. The short time this audience has to engage with environmental educators made this a challenging program to develop. To bring nature and Citizen Science indoors, a portable "firefly box" which simulates wetland habitat and firefly flash patterns was constructed. Participants are then able to engage in a quick mock Citizen Science project by recording the flash patterns seen within the box. Following this activity participants are invited to pick a card with a dilemma related to human impacts on wetland habitats. After reading the card they picked, they are prompted to pick a responding action i.e how they would respond in each particular dilemma. An example dilemma is:
You are on a walk on a trail through a local protected wetland with your friend and his dog. Your friend takes his dog off leash and lets the dog run off trail through the protected area. What would you do?

A) Do nothing
B) Run off trail after the dog.
C) Ask your friend to call the dog back and put the dog back on leash.
D) Do something else

Successful interaction with this activity should inspire families to not only report firefly sightings, but also to reconsider household behaviors which may impact wetlands.

The last part of the curriculum guide is a field trip plan for kindergarteners aligned to Utah's new SEEd standards. In this curriculum kindergarteners use cameras to document the flora and fauna found within a plot of wetland home to firefly. Following this, the students study how these organisms get the things they need to survive from the surrounding wetlands and each

other through two more activities focused on the food web and habitat interactions. A second curriculum was designed to be used by teachers in school following this field trip or as a stand alone in case of inclement weather or for schools unable to arrange the field trip portion. The school portion of the curriculum focuses on human impacts on wetlands and fireflies by exploring the effects our decisions have on wetland ecosystems. This kindergarten curriculum would be implemented the entire school year with any kindergarten classes planning field trips to the Nature Center. The curriculum focuses on wetland preservation using fireflies as the iconic species of our local wetland ecosystems. Unfortunately, it is unknown at this time when in-person field trips will be able to resume. Therefore, it is unlikely this program will take place this year. However, the curriculum is prepared and ready for use in future years. Acquainting students at a young age with fireflies and the importance of wetlands should help to spread and raise awareness among their siblings, friends and parents aiding in increasing environmental awareness and positive conservation behaviors towards both fireflies and wetlands.

Timeline

Due to firefly biology and their short lifespan, they are only visible in the night sky for a short timespan here in the west, usually from late May or early June to early July. This influenced the timeline of my project. The month of May was focused on providing online presentations to community groups located within Franklin County, Idaho, as well as posting online resources and training for both elementary school students, teachers, and adult community members interested in participating in the project. The first two weeks of May was devoted to creating the online presentation and resources and scheduling presentations. Brief surveys (see Appendix A)were sent for use by Nature Center staff to those who participated in these programs

following firefly season to evaluate changes in their conservation attitudes and behaviors. This followed a similar pattern to research done on conservation attitudes of participants involved in the Great Pollinator Project and Earthwatch Coyote Project (Toomey, 2013).

Guided Firefly walks took place the nights of June 18-23, 2020 beginning at 9 pm. Sighting data in this location is not useful as scientists are already well aware of this location. Instead, participants recorded and monitored flash patterns using similar methods to those used by the Massachusetts Audubon Society's Firefly Watch program during these walks (Firefly Watch Citizen Science Project, 2020). The same before and after surveys were given to walk participants for the Nature Center to analyze the program.

The curriculum for school STEM nights, community fairs, and kindergarten field trips was completed by August of 2020. These curricula will be implemented throughout the fall and winter of 2020 as well as the spring and summer of 2021 through the Nature Center.

Project Description Summary

In summary, this project consisted of curriculum for five distinct programs to be implemented through the Nature Center. These programs were designed to introduce everyday citizens to the presence of fireflies using Citizen Science as a means to create a connection to fireflies. The program aims to provide participants the desire to make everyday choices which will protect western fireflies and their habitats. Two of these programs, online training for community organizations and an online elementary school curriculum, were implemented immediately during the month of May 2020 to recruit and prepare community members for the beginning of the firefly season. Nightly guided firefly walks occurred in June. Educational

programming about the unique western firefly will continue throughout the next year through STEM nights, community fairs and kindergarten field trips.

The end goal of this capstone project is to effectively use Citizen Science within environmental education to create positive changes in the conservation attitudes and behaviors of its participants. Meeting this goal through this specific series of programs can be measured by an increased interest in and actions taken toward protecting fireflies and their wetland habitat.

Chapter Four

Conclusion

Introduction

The purpose of this capstone project was to create a curriculum that would tie in an existing Citizen Science project to foster appreciation and awareness of fireflies and their habitat within Northern Utah and Southern Idaho. Over my professional career, I have had the opportunity to be involved with numerous Citizen Science projects. I have enjoyed working as both a wildlife field researcher and an environmental educator. Citizen Science provides a crossroads where the two can meet and mutually benefit each other. Scientists are benefited by the collection of a wider data set and Citizen Scientists themselves may change the way they think or interact with their environment (Pandya & Dibner 2018).

The Citizen Science project I was involved in however, never had any sort of formal or organized education program developed for use alongside the project. The benefits of Citizen Science are many including; ties to STEM and inquiry-based learning methods for children, development of critical thinking and problem-solving skills, increased participation in community civics, and positive shifts in conservation attitudes and behaviors. All the benefits of Citizen Science also positively benefit the profession of environmental education. Therefore, formally pairing the two together within a focused environmental education curriculum is a natural fit.

My capstone project was to create environmental education programs built around an ongoing firefly Citizen Science project and targeted toward various demographics of the community. These programs were implemented through a local Nature Center where I work. The Nature Center already conducted annual firefly walks so expanding this into additional programming tied directly to the Citizen Science project seemed like a natural fit. Through the creation of these programs I believe I have answered the question: *how can citizen science be used effectively within environmental education to foster environmental awareness?*

Within each program, I tried to create a connection between fireflies and the importance of their habitat; wetlands. Fireflies are just one small part of the wetland ecosystem. If we hope to change behaviors and attitudes within our communities it cannot be just about fireflies. This project was designed to not only teach about the fireflies but also to impart the bigger picture; the importance of protecting wetlands. In the United States we have lost over 50% of our Wetlands since the American Revolution at a rate of 60 acres per day (Dahl, 1990). One third of federally listed endangered species rely on wetlands for survival (Dahl, 1990). Wetlands also provide water storage and filtration. Creating a connection to our wetlands was important because this project is not just about gathering firefly sightings. For Citizen Science to be an effective environmental education tool, it needs to be used in a way that sparks the desire within individuals to change and take actions which benefit the environment as a whole. This project used the firefly as an icon to build an effective environmental education program which fosters awareness of local wetlands and the plight of the western firefly.

The following chapter summarizes my conclusions following this capstone project including project limitations and extensions, future use, benefits to the environmental education profession and ties to the literature reviewed in chapter two.

Project Ties to Literature

During the development of this project I tried to keep in mind the concepts expressed in the literature review and use these concepts wherever possible. These concepts included aligning to Science, Technology, Engineering and Math (STEM) standards, using technology to reach youth participants and increasing civic engagement. As I developed my capstone project, I kept these ideas in mind and tried to incorporate them into my programming wherever possible.

Conservation Attitudes and Behavior Changes

As an Environmental Educator, I like to think my programs make a difference by impacting the way people think about and behave toward the environment around them. While I have no definitive way of knowing the long-term impact of this project on those who participated, Toomey (2013) indicated that the majority of individuals who participate in Citizen Science felt their attitudes toward the environment shifted in a positive way. Toomey (2013) stated that for many engagement in a Citizen Science project itself constitutes a behavior change. I found this to be true of my own project. Many participants had never sought out the opportunity to become involved in Citizen Science prior to attending one of my firefly programs. For these individuals attending and participating in an educational program that included Citizen Science opened their eyes to the possibilities of Citizen Science. Many participants commented they

planned on sharing what they learned with others, modifying behaviors at home, or seeking out other Citizen Science opportunities.

Retaining Citizen Scientists

Each Citizen Science project has its own unique challenges and advantages. The firefly project relies on individuals to report sightings within their communities. Education is critical to inform the general public about the project and our need for their help. This made the project a natural fit to create an education curriculum for. The project does not require a large time commitment or the retention of repeat volunteers which can be one of the hardest parts of a Citizen Science Program (West & Pateman, 2016). The firefly project does however, rely on citizens to be ambassadors of the project in order for data to be collected. Therefore, the same principles discussed by West and Pateman (2016) of creating projects which fit the motivations and wants of the community still applies. For most participants in the firefly programs the motivation was just to learn more about fireflies or in the case of our guided walks to see them. I found this to be a strong motivator. Fireflies are charismatic creatures that people seem to easily connect with and enjoy learning about creating the motivation to want to learn more.

Incorporating Citizen Science into Inquiry-based STEM learning

The literature regarding the use of Citizen Science within STEM and inquiry-based learning was particularly impactful while designing this project. According to Edelson (2012), hands-on scientific observation of the entire scientific process is necessary in order for the growth of critical thinking skills.

Designing inquiry-based school programs aligned to STEM standards that allowed observation of the entire scientific process was not possible. However, STEM and Citizen Science is about learning by doing, which I was able to accomplish through this project and kindergarten students were able to engage in a large portion of the scientific process on field trip visits. According to Condon and Wichowsky (2018) STEM shows students how to apply the scientific method in everyday life and focuses on real-world applications. Since students cannot see real fireflies and report them during an hour-long field trip or during a school STEM Night, it took some creativity to introduce the Concept of Citizen Science. To meet this need, kindergarten field trip students examined and recorded the number and diversity of plants and animals found within a plot of known firefly habitat. These observations will prove useful down the road to researchers studying firefly habitats. The students' observations are then recorded in iNaturalist allowing students to revisit and analyze the data they gathered at any time.

Collins (2014) stated that while not all classrooms will be able to incorporate Citizen Science to the same degree it does prove to be a better alternative to traditional science. I found this statement to be particularly meaningful as not all schools are able to attend an onsite field trip. In order to bring Citizen Science to the classrooms of students and teachers unable to come to an onsite field trip I developed a classroom curriculum which can be used as a stand-alone curriculum or as a follow up to an onsite field trip. This provided kindergarten teachers with an alternative to traditional science education.

Inquiry-based learning should trigger a student's curiosity and place some responsibility for their learning on the student (Condon & Wichowsky, 2018). Conducting these programs

through a Nature Center means staff have limited time with our students. Nature Center staff set the stage for students and classroom teachers to continue the inquiry process following these programs. I noticed this in particular among children who attended our guided firefly walks. Part of the walk included time to become a Citizen Scientist by observing and recording firefly flash patterns. I was amazed to see the details the youth participants picked up on during this observation. With very little prompting children were able to use the details they observed to formulate their own inquiries and conclusions regarding firefly behavior as well as the human impacts to this behavior.

Diversifying Participation and Technology Use

The firefly project relies on reaching a wide and diverse audience in order to gather the most data. Traditionally Citizen Scientists came predominantly from a white middle class background (Herodotou, Aristeidou, Sharples, 2018). The use of technology has been shown to be an effective way to diversify the reach of Citizen Science. In particular, technology is appealing to youth Citizen Scientists (Land-Zandstra, Devilee, Snik, Buurmeijer & Broek, 2015). While the resources of the Nature Center limit the use of technology during in-person programs, I was able to utilize the iNaturalist app as part of the Staying Home Curriculum. Since nearly all youth have access to a cell phone or other electronic device using a digital app such as iNaturalist was an easy way to recruit younger Citizen Scientists. Additionally technology such as video conferencing allowed programming to continue to a diverse range of community groups that otherwise would not have been possible during the COVID-19 pandemic.

Civic Engagement

According to Condon and Wichowsky (2018) over 40% of states are so focused on STEM engagement that they fail to include civic education. Integrating civic engagement into science curriculum can improve learning outcomes in both subject areas. I was excited to see many adult participants in these programs express the desire for changes in local regulations and laws to decrease light pollution, pesticide use and other environmental concerns. This demonstrates that Citizen Science can bring science and civics together by engaging participants in activities meant to address shared community problems as discussed in the literature review (Condon & Wichowsky, 2018). I felt that the use of inquiry-based learning within youth curriculum led many youth to also come to the conclusion that civic engagement was necessary to change community behavior. For example, youth noticed the tire tracks from trucks spraying pesticides to kill mosquitoes within firefly habitat and came to the conclusion that this was a civic issue the community needed to address.

Literature Ties Summary

The firefly programs conducted so far have proved to support many of the key points within the literature review. Through this project, participants are able to engage in hands-on science in a situation relevant to their local community. This participation led to a desire to increase civic engagement and modify environmentally harmful behavior within the communities Citizen Scientists live in.

Project Implications

This project could have a wide range of implications for both science and education, however, it may take several years of use to see these implications. Scientifically, the data collected on flash patterns will become more relevant each year allowing for comparison between years. Once we have a historical basis to draw on, this data can be used to determine fluctuations within the firefly population at the park where tours were conducted, as well as the effects of temperature, weather patterns, and human impacts such as construction and additional light pollution. As these programs continue year after year more individuals will be reached leading to the collection of more sighting data.

The implications for environmental education are harder to quantify. However, I did see an increase in knowledge pertaining to fireflies as well as an increase in the use of Citizen Science. Conversations with participants in this program indicate that they did experience an increase in knowledge and planned to either seek more Citizen Science opportunities, modify behaviors and or become more civically engaged on issues pertaining to local wetlands. Implementation of this project through future years will continue to increase environmentally friendly actions and civic engagement within communities as a whole particularly pertaining to wetland protection. This will lead to a shift in conservation attitudes and behaviors within our communities as a whole.

Project Limitations and Extensions

This project was largely limited due to two factors. First, the short length of the firefly viewing season late May through early July and the nature of the fireflies themself. Second, the

COVID-19 pandemic severely limited the individuals who could be reached through in person programming.

Due to the pandemic fewer firefly programs were conducted than I would have liked. Digital platforms such as Zoom made it possible to reach Rotary and 4-H clubs. However, I was unable to reach other audiences including local libraries. This being the case an online firefly activity guide was created as part of the Nature Center's COVID-19 staying home initiative. This guide was posted on the Nature Center's website and social media as well as sent to local elementary school teachers. These curricula generally reach approximately 200 families a week, however, it is hard to know exactly how many families and children used this curriculum and I found it difficult without the personal interaction I've grown accustomed to during onsite programs. These programs yielded only two reports of firefly sightings both of which turned out not to be credible populations. Continued annual use of these programs will produce more credible sightings in the future as we continue to expand our Citizen Science base.

A smaller limitation will be the accuracy of data collected during these programs. Nature Center staff leading the programs will need to work closely with participants, particularly children to ensure the data is as accurate as possible. After several years of data collection data outliers will be easily determined at which point Nature Center staff can decide if this is due to inaccurate reporting by our Citizen Scientists. Data outliers which are known to be caused by reporting errors can be discarded. Using this method to determine reporting errors still allows us to make Citizen Science accessible and inclusive for all of the program participants. Citizen

Scientists including children will still be able to engage in hands-on science regardless of their scientific observation abilities.

Educationally the benefits noticed included; increased engagement during programing, participants leading their own learning through inquiry and a wider more diverse audience. Remarks from program participants would imply that many did experience positive shifts in conservation attitudes and the desire to engage in environmentally friendly behaviors either through personal decisions or increased civic engagement. Children participating in any of these programs are practicing skills that aid them as future community members and leaders.

Recommendations for Future Use

These programs are now in place for use in following years. Certain programs created for this project will continue year-round including kindergarten field trips, school STEM nights and community fairs. Other programs developed for this program including annual firefly walks will be used annually during firefly season. Programs such as the online "Staying Home" program can be adapted for onsite in-person programming in future years allowing individuals a more personal and engaging experience. With continued use of these programs, I am confident more firefly populations will be verified in coming years.

After researching and seeing the benefits of including Citizen Science within environmental education programming, I also plan to include more citizen science into my other environmental education programs within the National Forest. One idea I hope to implement in the future is a teacher training workshop on how to use Citizen Science effectively in the classroom. If school teachers learn the benefits of Citizen Science and ways to include it within

their science curriculum, future generations may be better equipped to deal with the myriad of environmental, social and economic issues they are sure to face(Condon & Wichowsky, 2018).

Benefits to Environmental Education

As environmental educators our goal is to provide our communities with the tools and information needed to make the best decisions regarding our natural resources possible. This project allows information regarding fireflies to reach a far wider audience than previously. The inclusion of Citizen Science provides a meaningful and personal connection to the resource in this case fireflies and wetlands.

I found this to be particularly impactful for children. I believe kids learn best by doing and this is also the concept behind STEM learning. Through this project in addition to learning about fireflies, children were able to participate in either real-life or simulated scientific data collection. In addition, they can now contribute to the firefly project by becoming ambassadors of the project and sharing their learning experiences with friends and family. This increases the reach and diversity of the project. Exposure to Citizen Science while young also provides a solid scientific foundation for them to use as adults and future leaders within their communities.

Several adult participants expressed the desire for local government to address the issues faced by fireflies and wetlands. This demonstrates that Citizen Science can be used effectively within environmental education programs and foster the desire for environmental change. This project effectively combined environmental education and Citizen Science to reach a far larger audience than was previously reached as well as provide the motivation for positive change within communities. In addition to benefiting everyday citizens, this project will aid scientists in

discovering new firefly populations and learning more about the life and habits of the western firefly.

Summary

In conclusion, I believe this project has demonstrated that Citizen Science can be used effectively within environmental education to foster environmental change. Not only can Citizen Science based environmental education programs foster this change, they also provide many additional benefits to both scientists, educators and students. Programs effectively using Citizen Science foster the skills and motivations needed to provoke this change at an individual and community level.

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Appendix A

Firefly Post-Program Survey Questions:

1. Did you know we had fireflies in the Western U.S. before participating in this program?

   Yes/No

2. How likely are you to share what you learned tonight with friends, family and coworkers?

   A) Absolutely I'll be sharing with everyone I know

   B) I'll probably share with a few people

   C) I probably won't be sharing with anyone

3. How likely are you to participate in future Citizen Science Projects?

   A) I'll be actively looking for other Citizen Science Projects to be involved with right away!

   B) I'll probably be more likely to be involved if something comes my way.

   C) Citizen Science isn't for me

4. Will you be more likely to make choices to benefit our wetlands following this program

Yes/No

If you answered yes please check any you feel you will be more likely to do

A) Purchase naturally based pesticides/fertilizers and other lawn/garden care products.
B) Be more cautious about my contribution to light pollution i.e. only using light when I need it not over lighting etc.
C) Support/vote for laws & policies which protect wetlands and/or be more civically engaged in environmental issues.
D) Minimize my carbon footprint through other actions such as water conservation, recycling, minimizing plastic consumption etc.

5. Do you feel your attitude towards fireflies and wetlands have changed at all following this program? Why or Why not?

6. Any additional comments?