Citizen Science as Place-Based Education:

Scientific Inquiry as a Framework for Citizen Science Programs at Grand Canyon Youth

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Abstract

Citizen Science is public participation in scientific research, and has a long history as a data collection method and as an educational tool in science education and environmental education. Grand Canyon Youth is a Flagstaff-based 501(c)(3) that collaborates with scientists annually to collect data with youth on their multi-day educational expeditions on the Colorado and San Juan Rivers in Arizona and Utah. As Grand Canyon Youth's number of programs grow annually, they identified a need for programmatic framework to guide development of their Citizen Science collaborations to achieve both scientific and educational goals. Scientific Inquiry was used as a framework for developing materials for the organization's Citizen Science Stakeholders for three timeframes related to the expeditions: pre, on, and post. Literature emphasizes providing educational materials prior to participating in Citizen Science, allowing inquiry to develop while participating, and for a means to continue to stay updated with projects after participation in data collection. Based on literature suggestions and the identified Citizen Science stakeholders at Grand Canyon Youth, educational materials were produced within the framework to provide a starting point for educational materials. Also provided are additional suggestions for the development of Citizen Science and the materials within the organization. This provides the Grand Canyon Youth's staff with communication materials to continue to grow collaborations and relationships with scientists and other stakeholders, to provide data to contribute to ongoing scientific research, and achieve educational goals by engaging with data collection via Citizen Science.

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Chapter 1: Introduction

1.1 Grand Canyon Youth

In 1998, three Grand Canyon river guides made it their objective to get youth on rivers for an experience that they felt could change youths' lives for the better. Grand Canyon Youth (GCY) is a 501(c)(3) non-profit organization based in Flagstaff, Arizona, that was built on the foundation that all youth, regardless of background, could benefit from time spent on a river. GCY's mission is to "provide youth (ages 10-19) with an experiential education along the rivers and canyons of the Southwest in an effort to promote personal growth, environmental awareness, community involvement, and teamwork among people of diverse backgrounds." Since its founding, many youth participants have stayed in contact with GCY, returning to work as guides, mentors, or volunteers, and frequently choosing their professional fields of study based on their experience with GCY.

GCY has unique attributes that set it apart from other youth-based programs, as the only youth program that offers expeditions on the Colorado River through Grand Canyon. Prior to these expeditions, youth earn a portion of their expedition through community service projects, prepare an educational project of their choice, and contribute to the funds of the expedition through their own earnings. Expeditions are not limited to the Colorado River in Grand Canyon; GCY also offers multi-day expeditions through Cataract Canyon, on the San Juan, and in the past has offered multi day expeditions on the Yampa and Green Rivers. GCY also has a growing single day expedition program that operates on the Verde River. On most expeditions, youth participate in service and science projects. These are in collaboration with entities such as the United States Geological Survey, the National Park Service, and Northern Arizona University.

In terms of multi-day expeditions that collect data for Citizen Science, this practicum focuses on two types of expeditions offered by GCY: Individual, and Group and School Expeditions. Specifically concerning the Individual Expeditions, this practicum focuses on the Partners in Science Expeditions. The Partners in Science Expeditions, since they are individual expeditions are open enrollment, and offered on the Colorado River through Grand Canyon. With two sections of the river offered separately (upper and lower halves), these account for four to six expeditions annually. The Group and School Expeditions are organized by a Trip Coordinator representative, often a teacher, administrator or group leader, and are organized for a club, class, or grade level. Both the Individual Partners in Science and the Group and School Expeditions collect data for GCY's ongoing collaborations with Citizen Science projects. In 2018 and 2019 there were two different ongoing projects, a light trap to capture aquatic insects for monitoring the health of the riparian ecosystem along the Colorado and San Juan Rivers, and an acoustic bat monitoring project to contribute to efforts to establish a species baseline of bats in the Southwest. The Partners in Science expeditions collect data for additional project collaborations that require data collection on the Colorado River in Grand Canyon National Park.

1.2 Place-Based Education

Place-Based Education (PBE) fosters the growth of partnerships between schools and communities to grow capacity for student achievements, and improve a community's environmental quality and the social and economic vitality (Powers, 2004). The Center for Place-Based Learning and Community Engagement defines PBE as an immersive learning experience that "places students in local heritage, cultures, landscapes, opportunities and experiences, and uses these as foundations for the study of language arts, mathematics, social studies, science and other subjects across the curriculum." Priest (1986) also defines Outdoor PBE more specifically as “a method of learning that is experiential, occurs in the outdoors, requires the use of all senses and domains, is interdisciplinary, and is a matter of relationships involving people and natural resources.” In this way, PBE serves as a context for academic subjects across the curriculum. GCY engages with PBE on their expeditions by contextualizing learning while on the river, and applying lessons learned to the larger world.

1.3 Citizen Science

The broad definition of Citizen Science is public engagement and participation in scientific research, where members of the public work with a professional scientist to gather, submit, or analyze large quantities of data that without such large participation, would be difficult to achieve for a scientist alone (Bonney, Phillips, Ballard, & Enck, 2016). Citizen Science continues to grow and become more widespread in practice, according to Bonney et al. (2016), over the last 20 years, thousands of projects engaging millions of participants have originated across the world. As Citizen Science grows in popularity, some have recognized it as a democratization of science; Irwin (1995) describes the goal of Citizen Science to bring the public and science closer together, and introduces terms such as “scientific citizenship” into discussions to involve the public more deeply in scientific dialogues and decision-making, specifically concerning the environment. Bonney et al. (2009) also claims that Citizen Science’s potential is only beginning to be understood in terms of how it can improve scientific literacy while achieving large swaths of data collection.

This idea of improving scientific literacy lends itself to build on what Wals, Brody, Dillon, & Stevenson (2014) identified as the potential for a convergence of disciplines – Science Education (SE) and Environmental Education (EE), with Citizen Science being the interdisciplinary bridge that brings the two together. Participants in Citizen Science engage with the scientific process through their data collection on relevant environmental issues. In this way, Wals et al. (2014) point out that Citizen Science has the potential to bring the SE and EE while contributing to ongoing scientific research.

1.4 Story Mapping

Story Maps use Geographic Information System (GIS) tools to combine geospatial data with visual components such as photos, videos, and text, to engage nontechnical audiences to visualize data or sequential events (GIS Story Maps). Story Maps can be created from existing templates that are designed using ArcGIS Online web application tools, or from template files that are downloadable and can be easily customized (Battersby & Remington, 2013). Implementing Story Mapping in classroom settings provides a means to express the visual and spatial components of concepts, stories, or projects, and offers a platform for simple and compelling ways to engage with spatial data (Battersby & Remington, 2013; Teach with Story Maps).

1.5 Citizen Science as Place-Based Education at Grand Canyon Youth

On most expeditions offered in 2018 and 2019, youth participated in Citizen Science projects by collecting data in partnership with the United States Geological Survey’s (USGS) Grand Canyon Research and Monitoring Center (GCMRC). Occasionally on Group and School Expeditions scientists from GCMRC and Glen Canyon National Recreation Area (GLCA), attend to assist with educational components to the project and with the data collection. Guides are trained on the specific project’s protocols prior to the expedition, and if a scientist is present, they bring additional equipment and supplies if needed. On the Partners in Science expeditions, an additional two to four scientists submit project proposals early in the calendar year, oftentimes working with the National Park Service or an educational institution such as Northern Arizona

University. Youth on Partners in Science assist in this data collection alongside the scientists who submitted proposals and attend the expeditions. In 2019, Partners in Science specific projects included native fish monitoring, tamarisk defoliation surveying, mercury content monitoring via dragonfly larvae, and surveying micro plastic presence and distribution in Grand Canyon.

The emphasis of Partners in Science is engagement and participation in current and ongoing scientific research. On Group and School Expeditions, the emphasis and curriculum foci are not always on biology and ecology. Instead, topics may vary from leadership and personal growth, to art and language arts, or to history, anthropology and archeology. While science is present on almost every expedition with varying curricular foci taught in Place-Based contexts, it is not always the main curricular focus. Citizen Science on GCY's expeditions exists in the context of PBE, while engaging youth with concepts from both SE and EE. With this consistent and significant presence of Citizen Science, coupled with curriculum variability, GCY as an organization identified a need for programmatic development within their Citizen Science collaborations.

1.6 Practicum Purpose and Goals

The purpose of this Practicum is to identify a suitable framework for Citizen Science at GCY to help accomplish educational, scientific, and community goals. As GCY sought development of a framework for their Citizen Science projects, the interdisciplinary nature of these projects as bridges between SE and EE led to the decision to use Scientific Inquiry as a guiding model for this framework.

After identifying a framework, creation of specific educational materials ensured the longevity of the practicum products. In the design of these materials, three timeframes were identified, (1) Pre-Expedition, (2) On-Expedition, and (3) Post-Expedition, involving four stakeholders, (1) Scientists, (2) Trip Coordinators, (3) Guides, and (4) Youth. Educational materials were created for each stakeholder and in each of the three timeframes, and recommendations are provided for their continued development. Additionally, through the creation of a Story Map that shows where GCY collects data for Citizen Science, GCY provides an accessible spatial and visual medium to view past and present projects and contributions to scientific research.

Goals:

1. Identify and create a suitable framework for Citizen Science at GCY.
    - Create materials for three timelines, and four stakeholders within this framework.
2. Identify a medium for GCY stakeholders to learn about Citizen Science projects at GCY.
    - Create a Story Map for both Pre-Expedition introduction and Post-Expedition follow-up.
3. Provide future recommendations to GCY.
    - Specific recommendations for development and evolution of materials and framework.
    - Identify current staff who would be appropriate to engage with identified stakeholders and materials produced from this project.
4. Identify possible applications for other organizations to use similar frameworks in Citizen Science programming.

The following chapters will include an in-depth literature review, description of the materials, and future recommendations. The literature review expands on the concepts of PBE and Citizen Science, and includes in-depth definitions, themes, benefits, and limitations of these concepts. Additionally, the literature review examines critiques and drawbacks of Citizen Science in educational contexts. It concludes by examining Citizen Science as an interdisciplinary bridge between SE and EE.

Following the literature review will be a description of the Practicum products, which include an introduction to the framework and stakeholders, and descriptions of the materials produced with their corresponding Appendix reference. After detailing the Practicum's products, recommendations are provided to GCY for the future development of the specific materials. Additional recommendations identify which current full-time staff members at GCY are most suitable to continue with the development of the materials produced, and to engage with the various communication tools identified in this Practicum. Additional recommendations for other organizations to utilize this framework and broader applications of this framework are acknowledged before a project reflection concludes this paper.

Chapter 2: Literature Review

2.1 Citizen Science

2.1.1 Overview of Citizen Science

The practice of Citizen Science "has a history as long as science itself," seeing as the first people following the scientific method were amateur scientists (Kobori et al., 2016). McKinley et al. (2017) also mention its long history, additionally pointing out the work of amateurs' research making key contributions to the understanding of climate change, geology, electricity, astronomy, and other fields. The historic work of these "amateurs" continues to be referenced today – to track impacts of climate change, scientists currently use Henry David Thoreau's records from the 1950s of the first flowers, leaves, and birds to arrive each spring (McKinley et al., 2017). Currently, three general strands of research utilize Citizen Science as a data collection method, the first being biology, conservation, and ecology, the second being geography, and the third social sciences and epidemiology (Kullenberg & Kasperowski, 2016).

Citizen Science as a method allows scientists to gather large quantities of data where it is difficult to do so, such as large-scale patterns in nature that requires data collection across multiple locations and habitats and over the span of years or even decades (Bonney et al., 2009). Citizen Science has the potential to contribute large amounts of data towards research that can influence policy, address conservation challenges, and provide insights on issues at both local and global scales by enabling science that may be otherwise unfeasible due to scale or practicality (McKinley et al., 2017). To make decisions about land management, scientists at times are subject to the "best available science," which is not necessarily peer-reviewed scientific publications, but rather the best scientific information available to help answer a specific question. Citizen Science can be that available information and help meet diverse informational needs in numerous cases (McKinley et al., 2017). An additional strength of utilizing Citizen Science is the diversity of outcomes, including scientific research, learning, and environmental stewardship behavior. These outcomes vary in their emphasis across projects (Kobori et al., 2016). Edelson, Kirn, Loh, and Murphy (2018) point out that while scientific and educational outcomes are two important benefits of implementing Citizen Science, two misconceptions exist about achieving these outcomes. The first misconception is that if you design a project to achieve one objective, the other is automatically also achieved, and the second misconception is the opposite, that the outcomes are mutually exclusive (Edelson et al., 2018). Their claim is that both can be achieved, but there must be the intention to achieve both to be successful (Edelson et al., 2018).

2.1.2 Contributions to Scientific Research

Not only does Citizen Science have a long history in the practice of science, the practice is also global. Japan and the U.K. have long records of Citizen Science, showing that it was practiced long before making its way as a method into current scientific research in the United States. Some of the longest-running scientific records made by Citizen Scientists are in Japan, where the timing of the cherry blossom has been recorded for 1200 years and has been used in climate reconstructions (Kobori et al., 2016). Japan has numerous ongoing Citizen Science records for natural phenomena, such as a census for sea turtles laying eggs on the beaches that has been ongoing since 1954, an Annual Waterbird Census that has occurred for more than 40 years, and a Dandelion Mapping Survey, which started in 1975 and has surveyed about 74,000 specimens (Kobori et al., 2016). It is also notable that Japan’s oldest monitoring project, the cherry blossoms, centered on a culturally significant event, whereas the more recent projects focus on conservation and are in response to environmental issues. Most of these more recent projects began primarily as educational tools to increase public awareness of the importance of the natural environment (Kobori et al., 2016).

In the United Kingdom, phenology records collected by Citizen Scientists date back to the 17th century, the beginning of natural history observation in the country itself (Kobori et al., 2016). Today, projects such as Nature's Calendar continue to encourage observation of phenology events in the fall and spring nationwide, and approximately 40,000 people across the U.K. volunteer for this project (Kobori et al., 2016). The long history of amateur naturalists recording data on flora and fauna in the U.K. eventually led to the projects studying bird biology and ecology across North America led by the Cornell Lab of Ornithology a century later (Bonney, Phillips, Ballard & Enck, 2016).

In Grand Canyon National Park, Citizen Science has contributed towards specific management goals for the Glen Canyon Dam Adaptive Management Program. In 1997, the Glen Canyon Dam Adaptive Management Program was established to manage the Colorado River as it flowed into Grand Canyon National Park, and to monitor the effects of Glen Canyon Dam. The United States Geological Survey's Grand Canyon Monitoring and Research Center in Flagstaff is the science provider for the adpative management plan (Hamill & Melis, 2011; Melis, Walters, & Korman, 2015). Providing this science has proven to be an essential role in the adaptive management of Glen Canyon Dam; however, scientists immediately faced challenges with data collection due to the nature of many monitoring sites along the Colorado River in Grand Canyon National Park, which were only accessible via two-week-long river trips through the park (Kennedy et al., 2016). Citizen Scientists were recruited to assist in this process: professional river guides, National Park staff, and Grand Canyon Youth have collaborated and contributed data towards this research and monitoring on the Colorado River downstream of Glen Canyon

Dam (Kennedy et al., 2016; Muehlbauer, Lupoli, & Kraus, 2019). This data has directly contributed to the management and operations of Glen Canyon Dam, resulting in experimental flows and releases from the dam toward restoration efforts (Kennedy et al., 2016).

According to Bonney et al., (2016), it is clear that Citizen Science is yielding scientific advancement and results. Bonney et al. (2016) referenced a study by Theobald et al. (2015), which provided a review of the impacts of Citizen Science that fit into a “contributory” category of Citizen Science. Theobald et al. (2015) found 388 unique biodiversity-based projects, with between 1.36 and 2.8 million volunteer participants annually, and yielded 446 scientific publications. Additionally, Theobald et al. (2015) acknowledged that the number of publications likely grows substantially each month. Sharing the contributions of Citizen Scientists and publicly acknowledging their contributions not only lends itself to the idea of promoting Citizen Science as a method, but also has positive effects on participants (de Vries, Land-Zandstra, & Smeets, 2019). According to de Vries et al., (2019), communicating the value of participants contributions has positive impacts on participation in Citizen Scientist, and contributes to learning outcomes; participants stated that seeing the results from the studies that they collected data for helped them to see the bigger picture and increased their understanding of the project overall.

2.1.3 Limitations of Citizen Science

Despite extensive contributions to research and a variety of beneficial outcomes, Citizen Science has its limitations and drawbacks as a data collection method. Theobald et al. (2015) point out that the potential for Citizen Science will likely not be achieved or realized if Citizen Science data does not reach peer-reviewed literature, as the impact of Citizen Science could be much greater realized if it made its way into established modes of scientific research. According to Kullenberg and Kasperowski's (2016) findings, most Citizen Science projects do not have scientific output as their primary goal. However, Kullenberg and Kasperowski's (2016) measurements of "output" were largely focused on publications that cited Citizen Science data, which they acknowledge is but one metric; alternative metrics they suggest are sustainability, learning outcomes, and number of volunteers. This thus limits Citizen Science as a research method – if the primary goal is scientific output, then the methods and data collection must be up to the standards necessary for the participants to be able to collect meaningful data – and necessary training must be given to all participants to ensure consistency and quality (McKinley et al., 2017).

According to Klaver (2008), the primary controversy in employing Citizen Scientists is whether the data they collect has any scientific utility – citing statements that their untrained eyes and hands compromise the quality of work they are contributing to. Data quality is perhaps the most variable component when applying Citizen Science as a data collection method. As Dickerson-Lange, Eitel, Link, & Lundquist (2016) found in using Citizen Science for their research, their methods needed to be structured very specifically to assist in collecting usable data. Quality control is difficult to oversee when employing Citizen Science as a method – and while both scientists and citizens can collect data of equal quality, training is still necessary to ensure consistency in data quality (McKinley et al., 2017). Klaver (2008) also points out that as scientists grow more dependent on the large amounts of data collection made possible by Citizen Scientists, the incentive grows to provide participants with the tools and support to collect data of scientific utility. This means improved training and developing research protocols around participants, building research capabilities, and potentially leading to more substantive participation in scientific research in the long term (Klaver, 2008).

Additionally, in recruiting participants, not all projects draw equal public interest – projects centered on charismatic megafauna such as wolves and bears receive more attention and interest than projects involving plants and smaller animals (McKinley et al., 2017). Matching volunteers to projects present difficulties in ensuring consistency in sampling and quality, in terms of time volunteers can dedicate to a project, the number of samples needed, accessibility of sample sites, and the resulting turnover in volunteers and need for re-training from scientists (McKinley et al., 2017).

2.2 Place-Based Education

2.2.1 Overview of Place-Based Education

Academic and scholarly definitions and goals of Place-Based Education (PBE) can vary, but Smith (2002) identifies five key themes that represent the ways in which PBE can be adapted for diverse purposes and settings: (1) cultural studies, (2) nature studies, (3) real-world problem solving, (4) internships and entrepreneurial opportunities, and (5) induction into community processes. Deringer (2017) identifies four themes of PBE programs as (1) critical thinking and problem-posing education, (2) engagement through community connection, (3) environmental justice, and (4) social justice.

Smith (2002) finds evidence of PBE as early as the early 20th century when French educators had students collect and compile information about their villages and send these results to students in other parts of the country who were doing the same thing. In the United States, PBE emerged from a 30-year foundation of environmental education – building on the work of community-based initiatives and grounded in resources, issues, and values of the local community (Powers, 2004). Pieces of the foundation upon which PBE sits also built the current education structures, most notably stressing “intrinsic motivation” for learning. PBE educators acknowledge that by grounding education within the local community, relevance increases to students and they, therefore, are more engaged (Powers, 2004). According to Deringer (2017), the notable increase in scholarly activity surrounding PBE is in response to a weak U.S. school system – the increase in standardized testing decontextualizes learning and creates a need for schools to consider the importance of community and place in education. PBE responds to this by building on progressive foundations rooted in dynamic processes, and offers important critiques of current systems, contextualizing students' experiences and helping to solve "real-world" problems in their communities (Deringer, 2017).

2.2.2 Benefits of Place-Based Education

PBE invests its participants with a sense of agency – inviting students to be producers rather than consumers of knowledge by engaging them with social and environmental problems and providing relevant knowledge and experiences to allow them to participate in democratic processes and participate in discussions to devise solutions to these problems (McInerny, Smyth, & Down, 2011). One of the strengths of a PBE curriculum is the adaptability to particular characteristics of various places – which helps to overcome the disjuncture seen between students' home lives and their classrooms (Smith, 2002). Getting Smart and Teton Science Schools identify four means of the potential to personalize the type of learning that PBE provides. These are identified as (1) giving students a "voice and choice," in determining what, how, when and where they learn, (2) tailoring learning to each students strengths, needs, and interests, (3) ensuring mastery of high academic standards, and (4) promoting student agency. They additionally identify four goals of PBE as (1) impacting communities, (2) increasing student and teacher engagement, (3) boosting academic outcomes, and (4) promoting understanding of the world around us – claiming that these benefits can impact students, teachers, communities, families, and society as a whole (Getting Smart and Teton Science Schools).

2.2.3 Limitations of Place-Based Education

While imperfect school systems led to the creation of PBE, it has room for improvement and growth as it grows in recognition. Critics of PBE claim that it is oftentimes under-theorized, lacks a critical perspective and fails to make global connections to the locally based pieces of the curriculum (McInerny et al., 2011). McInerny et al. (2011) also draw attention to the perhaps less pleasant side of “place,” pointing out that it is easy to feel an attachment to aesthetically pleasing landscapes, and less so to places that may be wrought with social disturbances, unsafe, or environmentally degraded. Somerville (2007) brings up the additional point that we learn about place through embodied connections – and this is not always pleasant or positive, but at times bittersweet – many children grow up in rural environments that are far from “idyllic” (McInerny et al., 2011). McInerny et al. (2011) offer possible solutions or remedies, pointing out that arguably PBE may encourage students to consider places that they may not feel connected to and identify if the place needs something, ecologically, socially, or economically – but this is difficult to do. In conclusion, McInerny et al. (2011) allude to the need for critical readings of the physical place – the physical, cultural, and social attributes that shape students’ identities in connection to place.

2.3 Citizen Science in Traditional and Place-Based Education Settings

2.3.1 Benefits of Engaging with Citizen Science in Education

It is worth noting that in this review educational contexts are not limited to the classroom. Tyson (2019) in particular looked at a Citizen Science project that investigated the impact of habitat decline on high-elevation bird species and engaged with the National Outdoor Leadership

School's (NOLS) expeditions in the Wind River Range in Wyoming to collect data on Clark's Nutcrackers. Outdoor Adventure Education (OAE) provides a promising potential for Citizen Science – even when the curricula emphasis is not science, oftentimes the curriculum in OAE focuses on self-efficacy and personal and social growth – participation in Citizen Science can build on the emphasis to instilling agency in a scientific context (Tyson, 2019). Specifically, instructors from these courses noted benefits such as the value of the project as a teaching tool. Instructors noticed participants commenting on their heightened observation of birds and other aspects of the ecosystems they traveled through, which can be challenging to get students to key into without tools such as the project that provide the framework for motivations to connect with their surroundings (Tyson, 2019).

Shah and Martinez (2016) found that Citizen Science in the classroom has benefits for students such as increasing community awareness, utilizing critical thinking and problem solving, and gaining practical experience in engaging with science. Youth empowerment, self-efficacy, and ownership are recurring themes in the literature surrounding meaningful Citizen Science projects in educational settings. Citizen Science does have the potential to foster self-efficacy in science. In a study where middle school students participated in a Horseshoe Crab Citizen Science project; there were greater gains in self-efficacy in participants in the project when compared to the control group that did not participate (Phillips, Porticella, Constas, & Bonney, 2018).

2.3.2 Implementations of Citizen Science in Educational Contexts: Key Factors to Success, and Challenges

Ballard, Dixon, and Harris (2017) identified potential for Citizen Science to be used in educational contexts to develop Environmental Science Agency (ESA) in students, which describes the combination of not only understanding environmental science, but also identifying practices of inquiry and developing the belief that the ecosystem is something on which students act upon. Developing ESA is significant because it aligns with core ideas in practices in the Next Generation Science Standards (Harris & Ballard, 2018). Three key processes of Citizen Science were identified that assist in developing ESA, those being (1) ensuring rigorous data collection, (2) disseminating scientific findings, and (3) investigating complex social-ecological systems (Ballard et al., 2017). Fostering ESA reframes goals of conservation education to center around practices that encourage students to act with the tools of science in ways that are purposeful and encourage service of more sustainable social-ecological systems (Ballard et al., 2017).

Harris and Ballard (2018) found that one way to encourage investment in scientific work was for programs to position youth to see themselves as experts by allowing them to take ownership of the data that they collect in some way. Edelson et al. (2018) use terms such as "community empowerment" to discuss the idea of democratizing science, and to make science accessible as a tool for everyone. They also discuss the idea of fostering self-efficacy by publicly recognizing the contributions of Citizen Scientists and providing tools or access to the research that participants can access on their own to build their sense of ownership (Edelson, 2018).

Gray, Nicosia, & Jordan (2012) discuss the need for compromise both in educational contexts and by scientists involved, in order to meet the needs of both to facilitate Citizen Science within an educational context. Classrooms must allow space in their curriculum for embracing the uncertainties and various pitfalls of the scientific process, and in turn, scientists must relinquish some control in their research, while offering structure for using science as a tool in the classroom (Gray et al., 2012). By doing this – it allows learners to make mistakes and reflect in ways that are usually not available to traditional classroom settings (Gray et al., 2012).

Edelson et al. (2018) provide additional suggestions for achieving educational outcomes in implementing Citizen Science, such as providing educators with visualizations of data and providing other teaching and educational tools.

He and Wiggins (2017) identify two possibilities for educators engaging with Citizen Science: Student-Teacher-Scientist-Partnerships (STSP), where the scientist engages directly with the teacher, and cases where this is difficult or not possible. In the case of STSP programs, scientists can provide the supplementary materials and engage directly with the participating students; however, opportunities to engage with STSP programs are less common due to resource limitations. In cases where STSP is not present, He and Wiggins (2017) suggest that the Citizen Science project provide educators with supplementary materials, such as lesson plans, training workshops, and curriculum materials. Zoellick, Nelson, and Schauffler (2012) also looked at STSP programs and identified incorporating a third party such as a university to understand and facilitate balancing the educational and research needs. This coincides with what He & Wiggins (2017) identified for Citizen Science projects that exist outside of formal education settings, such as summer programs, and outdoor education programs. They found that organizations, such as a museum hosting a summer program, serve important roles of adoption of the project, follow-through with participants, and resource availability for educators (He & Wiggins, 2017).

In Tyson's (2019) study that researched Citizen Science in OAE at the NOLS, they identified five primary best practices for implementing Citizen Science projects in these educational settings. They are: (1) was that it is easy to implement in terms of time commitment and necessary equipment, (2) it should be well-aligned with the existing curriculum of the partnering organization (in the case of the study, NOLS), (3) that it focuses on a readily visible subject, (4) there is a compelling need that defines the study, and (5) that it can connect to students' lives outside of backcountry settings (Tyson, 2019). From a programmatic standpoint, these practices provide structure for organizations to begin selecting Citizen Science projects to implement in various educational settings.

The extent to which a project's design addresses education can limit the ability of educators to engage with projects in educational settings. As Bonney et al., (2015) found, projects with scientific purpose as the fundamental goal include procedures, instructions, and background materials such as reading and media resources; however, oftentimes these materials do not include learning objectives or lesson plans. For some educators, these materials may provide a "springboard" for educational purposes, however depending on experience; some may have a harder time using these materials as teaching tools (Bonney et al., 2015).

In Tyson's (2019) analysis of implementing Citizen Science in OAE contexts, the challenges that NOLS instructors reported were typical of most Citizen Science projects. Most notably, time constraints present challenges in educational contexts, but OAE contexts considerably exacerbate this and other challenges by the fact that imminent weather, time needed for travel, and necessary equipment are considerably more limiting than in most educational contexts. NOLS in particular exhibits dedication to their leadership curriculum, and the time necessary for implementation can be lengthy and variable. Thus, when inclement weather is an additional factor, a Citizen Science project has the potential to be considerably low on the list of priorities when risk management needs to take precedent (Tyson, 2019). Additionally, there is the prerequisite that participants feel comfortable in their outdoor settings to effectively dedicate themselves to data collection, adding to the variability of time available for Citizen Science in OAE contexts (Tyson, 2019).

2.4 Citizen Science as an Interdisciplinary Bridge

2.4.1 Connecting Science Education and Environmental Education

Bonney et al., (2016) point out that the goal of Citizen Science is to bring science and the public closer together, consider the possibilities of "scientific citizenship," and to involve the public in the dialogue and decision-making that exist around risk and environmental threats. Wals et al. (2014) build on this by suggesting that Citizen Science serves as the convergence between Science Education (SE) and Environmental Education (EE) – particularly drawing attention to the fact that urgent issues such as climate change, and that science and environmental educators seek to engage the public with these issues. The problem, then, in engaging with these issues via SE and EE that Wals et al. (2014) point out, is that these two disciplines have become increasingly distant. An example of how the two differ, but shows room for convergence, is a lesson in water quality. SE might teach students how to monitor water quality and identify pollutants, and understand means to reduce pollution, whereas EE might involve a behavioral analysis to examine the possible causes of said pollution, and identify means to clean up the pollution (Wals et al., 2014). Thus – both subjects might teach a lesson about water quality, but the goals of the lesson differ, resulting in different lessons altogether.

According to Phillips et al. (2018), behavioral change and stewardship are some of the most sought-after outcomes of engaging with Citizen Science in educational contexts. Being as hands-on as they are, Citizen Science projects are natural vessels for this to occur. However, research is limited to the actual effects and amount of influence participation in Citizen Science has on behavior and stewardship (Phillips et al., 2018). Edelson et al. (2018) discuss how to bring stewardship into context while participating in Citizen Science to inspire curiosity and cultivate the desire to be involved in science in the future – and doing this by connecting to participants' existing interests.

2.4.2 Engaging with Scientific Inquiry

Wals et al. (2014) identified Citizen Science as a possible bridge between the disciplines of SE and EE, supporting emphasis on PBE as an additional enhancement of participants' experience. Ruiz-Mallén et al. (2016) found that after participating in Citizen Science, student participants reported increased understanding of the scientific process after engaging with it in learning about the various steps such as forming questions and hypothesis, determining and using methods, and analyzing the results in real scenarios. As Phillips et al. (2018) point out; the hands-on nature of Citizen Science is particularly well suited for the development of inquiry skills in participants. The bridge between SE and EE forms as participants engage with the scientific process through data collection for research about the environment. Collecting data for local projects engages PBE, as participants engage with their community in a place-based format, combining elements of SE, EE, and PBE in one project.

As Bonney et al. (2015) found, one limiting factor to Citizen Science achieving its learning outcome potential is that most projects do not leave room for the development of Scientific Inquiry in participants. There is potential for participation in Citizen Science to have a greater impact if this is addressed intentionally by providing the time and space for inquiry to develop. There is also the potential for furthering innovation at a systematic level by involving participants with all steps of the scientific process – but formats need development in order to do so (Turrini, Dörler, Richter, Heigl, & Bonn, 2018). Scaffolding the steps of inquiry and providing a guide and other learning resources for participants that walk them through the inquiry process, either in the context of the project or on its own is one possible way to develop inquiry in participants (Edelson et al., 2018). Additionally, providing either professional development or learning tools and resources for teachers to assist them in facilitating learning around Citizen Science would assist in achieving greater educational outcomes (Edelson et al., 2018). The lack of resource and teaching material support perhaps contributes to an additional point that Bonney et al. (2015) made – that the "promise (of achieving learning outcomes) is so far greater than the reality."

Chapter 3: Practicum Products

3.1 Framework

As GCY sought development of a framework to grow their Citizen Science programs within, the interdisciplinary nature of Citizen Science as a bridge between SE and EE led to the decision to use Scientific Inquiry as a guiding model for this framework. Citizen Science on GCY's expeditions exists in the context of PBE, while engaging youth with concepts from both science education and environmental education. Participation in the scientific process via Citizen Science provides the convergence point between SE and EE.

Figure 3.1.1 Diagram of Citizen Science as Interdisciplinary Bridge

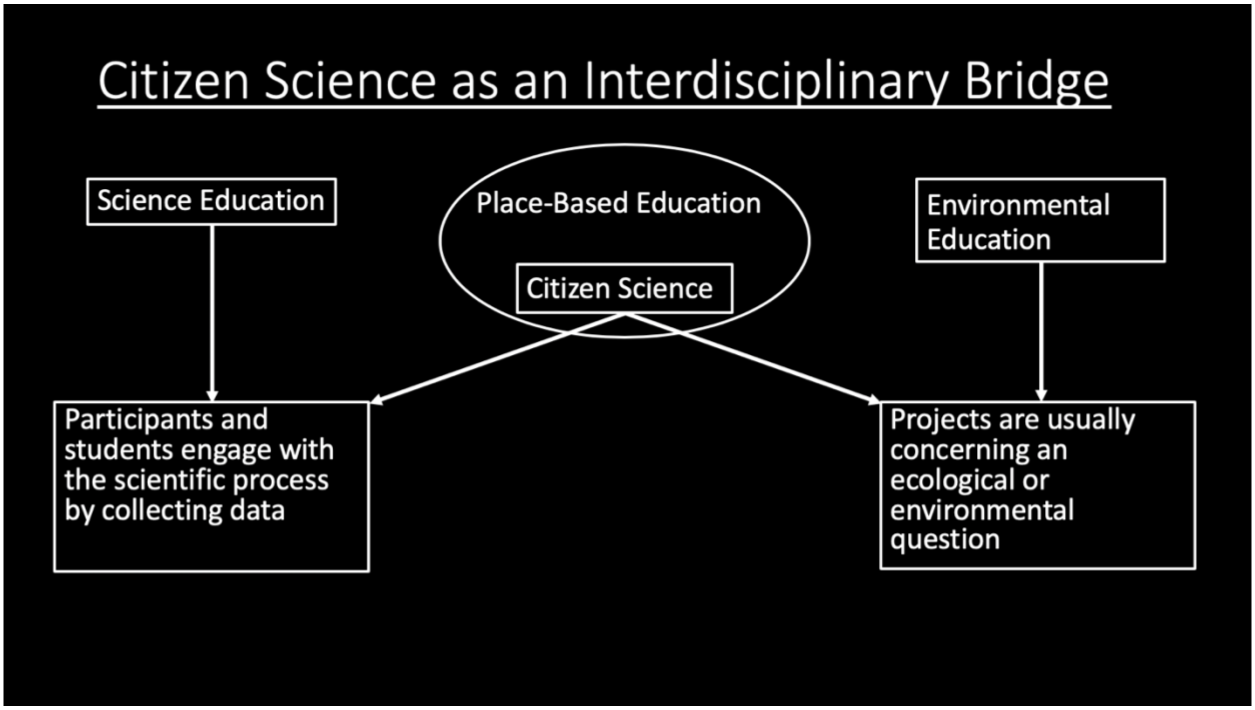

Figure 3.1.1: Diagram showing Citizen Science as interdisciplinary bridge in context of PBE
Diagram by Madeleine Smith

With participation in the scientific process serving as this convergence point between disciplines, the decision was made to use the scientific process to guide the design of the framework and materials. Visual models can be adapted to reflect inquiry, however viewing the scientific process as rigid, decomposable "steps" contributes little to visually scaffolding inquiry, and can distract students from productive inquiry (Tang, Coffey, Elby, & Levin 2010). The eventual decision to make the distinction to use Scientific Inquiry, instead of Scientific Process or Scientific Method, is because models of Scientific Inquiry tend to reflect a non-linear scientific process, such as depicted in Figure 3.1.2.

Figure 3.1.2 Inquiry Model

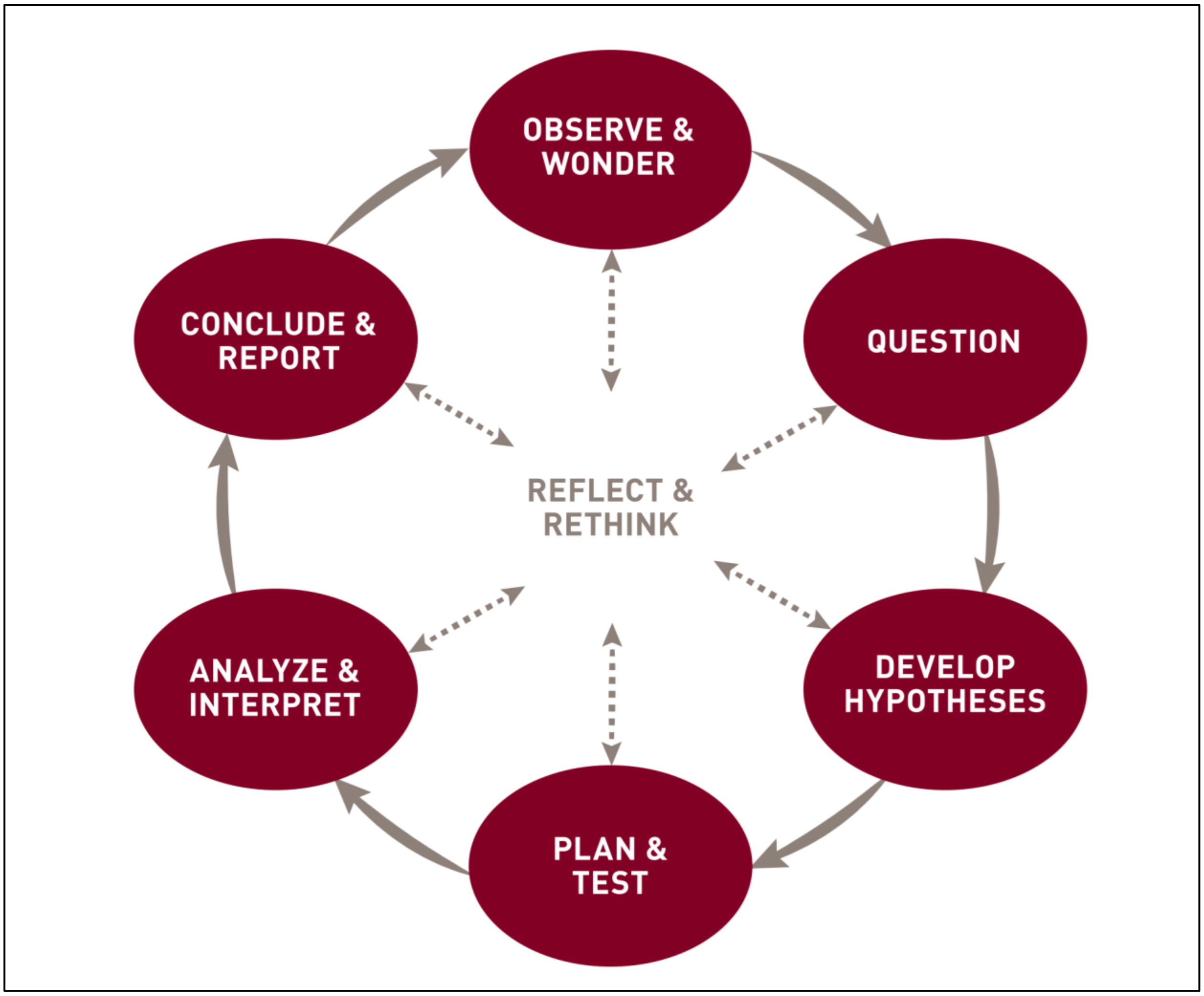

Figure 3.1.2 Model of the Scientific Investigation Process
Figure from Driven to Discover: Facilitator's Guide to Conducting Citizen Science and Science Investigations

After selecting Scientific Inquiry as the most appropriate model for a framework, development of materials to engage participants with more steps of the inquiry process than just data collection began. While reflecting the scaffolding of “steps” in a non-linear format is difficult to do, these materials represent the beginning stages that can evolve to represent non-linear science processes. The following sections begin by introducing the Citizen Science stakeholders at GCY, and the timeframes identified for delivery of materials, before describing each educational material for Citizen Science individually.

3.2 Stakeholders and Materials

3.2.1 Citizen Science Stakeholders at Grand Canyon Youth

Based on the literature recommendations, and who at GCY is involved with Citizen Science, four stakeholders were identified for a Citizen Science framework to be created with their needs in mind: (1) Scientists, (2) Trip Coordinators, (3) Guides, and (4) Youth. Additionally, in establishing a timeline of materials, three timeframes were identified to help clearly lay out when each piece of the materials would be administered. Pre-Expedition, On-Expedition, and Post-Expedition were identified as the three most distinct timeframes for materials to be delivered to stakeholders.

3.2.2 Project Materials

Suggestions from the literature review place extensive emphasis on the three main concepts used to develop the materials in this framework. (1) for organizations, educators, or scientists to provide educational materials to participants prior to the project (2) for facilitators to encourage room for inquiry and environmental science agency (ESA) to develop during the project, and (3) for facilitator’s to provide a post-project update or follow-up to participants. Pre-Expedition materials introduce the projects through scaffolding the steps of scientific inquiry, allowing Trip Coordinators, Guides, and Youth to learn about the project through the Scientist's process, exploring more steps of inquiry than data collection. On-Expedition materials are largely self-guided, encouraging inquiry and ESA to develop based on a specific expedition or individual's needs or interests. Post-Expedition materials provide a medium for an established follow-up, and allow participants to remain connected to their data and the project(s) they contributed to. Additionally, through the creation of a Story Map, GCY provides their community with online tool to access information about current and past Citizen Science projects, in order to learn more about Citizen Science at GCY, or to review the current state of existing projects.

In the Spring and Summer 2020 season, GCY Program Directors intend for a "soft roll-out" of the Citizen Science materials produced in this Practicum. The following table in Figure 3.2.2.1 shows all of the materials produced, but not all of the materials and training to be used in 2020. The Program Directors have selected expeditions to use these materials on in 2020, and will select the materials, training, and the recommendations that they feel most comfortable administering this season. With the recent changes in response to the spread of COVID-19, it is unknown how these materials will be tested in 2020 – seeing as it is unknown which, if any, of GCY's expeditions will be able to proceed in 2020.

Figure 3.2.2.1 GCY Stakeholder Materials

Stakeholders	Pre-Expedition:	On-Expedition:	Post-Expedition:
Scientists	❑ Questionnaires ❑ Engage with school groups (if possible)	❑ Facilitation Expectations (if attending expedition)	❑ End of Season Letter
Trip Coordinators	❑ Intro Letter ❑ PDP Integration ❑ Lesson Plan (optional) ❑ Project Summaries ❑ Story Map	❑ PDP Tools	❑ Newsletter ❑ Story Map
Guides	❑ Intro and PDP ❑ Project Summaries ❑ Season Opener	❑ Science Journal ❑ Explore Box ❑ PDP Expectations	❑ Newsletter ❑ Story Map
Youth	❑ Citizen Science Half Sheet Handout	❑ Science Journal ❑ Data Collection	❑ Newsletter ❑ Story Map

Figure 3.2.2.1 Chart showing the GCY Citizen Science Stakeholders and the Citizen Science expedition materials for three identified timelines.
Chart by Madeleine Smith

3.3 Description of Materials

Following is a list of the materials produced – beginning with Pre-Expedition materials, following with On-Expedition materials, and last is Post-Expedition materials. For each, there is a brief description of the material produced and a reference to its corresponding Appendix when relevant.

3.3.1 Pre-Expedition Materials

3.3.1.1 Scientists

Questionnaires: See Appendix A - C

Prior to 2019, GCY provided youth attending Partners in Science Expeditions with the project abstracts for the specific Partners in Science project collaborations prior to expeditions. When Scientific Inquiry was identified as a framework for Citizen Science at GCY, finding an alternative to the abstracts was selected as an area to begin incorporating this framework prior to the expedition. Questionnaires were sent to scientists on the Partners in Science Expeditions that they completed to produce Project Summaries that were sent to youth. The Questionnaires are a tool that was first administered on the 2019 Partners in Science expeditions. See Appendix A for the first version of the Questionnaire, used to gather responses in 2019. Initial observations from these summaries were that scientists were not providing important information such as the project title and their partnering research entity, but that they were engaged with the questions and responded well to a different style of write-up, they all had complete answers and some included photos. After Partners in Science responses were collected, some initial revisions were made to the Questionnaire, and Appendix B represents the Questionnaire used to collect Project Summaries for the two ongoing Citizen Science projects for GCY in 2020.

A scientist at the United States Geological Survey (USGS) who is involved with the aquatic insect monitoring project provided feedback that the Questionnaires would ensure high-quality science projects – if scientists could answer all of the questions, then the projects were well thought out and were likely to have output of high scientific value. Additional feedback on formatting and certain wording was included and contributed to the final draft of the Questionnaires (See Appendix C). This feedback also contributed to the information that was included in the introduction and cover page for the Questionnaire – such as some annual numbers for GCY, that are intended to inform scientists of the high potential for data collection that GCY can contribute to their project.

Project Summaries: See Appendix D - H

See Appendix D for 2019 Partners in Science Project Summaries. The Questionnaires (Appendix A) were sent out in May 2019, and three responses were received by the June 2019 Partners in Science expeditions. One response was received later in October 2019 due to being a late addition to the summer expedition.

See Appendix E for the Acoustic Bat Monitoring Project Summary. The Questionnaire (Appendix A) was sent in July 2019, and the response was received in September 2019. This Project Summary was gathered via the same Questionnaire as in Appendix D, but without the Partners in Science information, since it was not to be used for these expeditions exclusively, but also on the Group and School Expeditions.

See Appendix F for the Aquatic Insect Monitoring Project Summary, completed by the USGS scientist providing feedback about the Questionnaires. Appendix F includes the comments and suggestions in parentheses provided by the scientist as they filled out the Questionnaire. This Questionnaire (Appendix B) was sent in December 2019 and the response was received in January 2020, and omitted the Partners in Science specific information.

After receiving two Project Summaries for 2020, GCY identified the Acoustic Bat and Aquatic Insect Projects as two certain ongoing projects the 2020 season. The scientists answers returned in varying formats, so it was decided that re-doing the formatting so that the two visually matched would be beneficial. The two responses were edited and placed into templates for a final product to be used in the following Pre-Expedition materials. See Appendix G for the final Bat Project Summary and Appendix H for the final Aquatic Insect Project Summary.

3.3.1.2 Trip Coordinators

Intro to Citizen Science Handout: See Appendix I

See Appendix I for a short handout to send to Trip Coordinators prior to their expeditions, informing them of the history of Citizen Science at GCY, and that on their expedition they will be collecting data as part of GCY's ongoing collaborations with scientists. This provides a short description of Citizen Science at GCY, and what to expect from GCY prior to their expedition and on their expedition concerning Citizen Science. This could be transferred to a format such as the body of an e-mail, or remain as a standalone handout to be sent to Trip Coordinators with other Pre-Expedition materials.

Program Development Packet Goal Integration: See Appendix J

The Program Development Packet (PDP) is an online-shared document that the Program Directors at GCY use to communicate and identify themes, goals and activity planning for each expedition. Trip Coordinators access and fill out the PDP prior to their expedition, and identify a theme, such as natural sciences, three goals based on this theme, and activity plans for their expedition. In this format, they can express any support from guides or supplies from GCY they may need in order to implement their theme, goal, or activities.

Citizen Science is not currently included in the PDP, even though data collection occurs on most multi-day expeditions. To determine a means to integrate Citizen Science in the PDP, all of the themes and goals Trip Coordinators identified for all expeditions in 2019 were reviewed to select the five most common themes. A list of their related goals for each theme was also created, and the final list of five themes included any subheads or associated language from goals that related to the identified larger themes. For each of these themes, a short paragraph is included relating participation in Citizen Science to each (see Appendix J). This provides a context for introducing Citizen Science as a learning platform to support various interdisciplinary expedition themes such as personal growth, stewardship, and team building, in addition to natural and environmental sciences.

Lesson Plan: See Appendix K

See Appendix K for an optional lesson plan that is recommended for GCY provide to Trip Coordinators prior to their expeditions. The lesson plan uses adapted lessons from both the National Aeronautics and Space Administration's (NASA) Education Guide and The University of Minnesota's Drive to Discover Facilitator's Guide to Conducting Citizen Science and Science Investigations. The lesson plan also provides an activity for how to potentially introduce the Project Summaries to their students should they choose to do so.

Project Summaries: See Appendices G and H

The Project Summaries are sent to Trip Coordinators either to be handed out to their students in a format of their own choosing, or to be used in the lesson plan as it provides an activity to incorporate and introduce them to their students. See Appendices G and H for the final Project Summaries sent to Trip Coordinators for 2020.

Story Map: See Appendix L

A Story Map was identified as a suitable web-based format for anyone interested in Citizen Science at GCY to learn about current projects and any past projects they have been involved with. The Story Map includes map frames of all of GCY's multi-day river expeditions that participate in Citizen Science (see Appendix L for screenshots of the maps). Additional frames show the individual river sections where youth collect data for each project, and provide descriptions of the Citizen Science projects GCY is collecting data for in 2020. These descriptions are from the Project Summaries in Appendix D, G, and H, and can include links to websites or publications that feature this data when available.

3.3.1.3 Guides

Introduction and Program Development Packet

Guides receive access to view the same PDP that the Trip Coordinators fill out prior to their expeditions. They can then access the expedition's theme and goals, and associated Citizen Science information (Appendix J) for the expeditions that they are guiding. This is also a place for guides to be informed prior to their expedition of any expectations for assistance with facilitation of lessons or activities from the Trip Coordinator.

Project Summaries

It is recommended that Project Summaries (Appendices G and H) be sent to the guides prior to the beginning of the expedition season, so that guides are able to familiarize themselves with the background information for the projects prior to their expeditions. They are also able to request additional information about Citizen Science protocols, or do independent research prior to their expeditions. With every guide receiving the same Citizen Science Pre-Expedition background information as Trip Coordinators; it establishes a baseline of information for all facilitators of the expedition all have access to.

Field Staff Season Opener

The Season Opener is an event held at GCY prior to the beginning of their expedition season. GCY invites, but does not require, all field staff to attend this event, which goes over organizational information, and Citizen Science is one of the topics covered. Historically, this includes a demonstration of data collection by scientists associated with the project. This event is an opportunity for GCY to present to guides the materials related to Citizen Science, explain how their participation in Citizen Science contributes to scientific research, and provide a time for guides to ask questions about the projects. This is also an opportunity to bring up "crew talks" that guides give on the river to describe the different series of "crews" that youth rotate through on the river, such as cook crew and clean-up crew. "Science" is one of these crews – and GCY has an opportunity to give guides expectations for this crew talk, and identify mentioning the On-Expedition materials as a part of this crew talk.

3.3.1.4 Youth

Citizen Science Handout: See Appendix M

Youth receive Pre-Expedition information such as packing lists, and what to expect on their expedition, and since Citizen Science is a part of most expeditions, this Pre-Expedition information format was identified an appropriate place to include information about Citizen Science. Being that Citizen Science specific information previously was not shared with youth prior to their expedition; the proposed handout now provides an expectation to be participating in Citizen Science, as well as a brief description of what participation in Citizen Science at GCY means. See Appendix M for a half-page handout to be sent to youth prior to their expedition with materials such as their packing list and other Pre-Expedition information.

3.3.2 On-Expedition Materials

3.3.2.1 Scientists

Facilitation (if attending expedition)

If scientists are able to attend the expedition, their role currently is to assist in facilitating data collection and provide additional educational support. Currently, this supports the framework and materials developed in this Practicum. My recommendation is to continue to communicate with scientists about expedition expectations. Part of the reason for having the scientists themselves fill out the questionnaires in the Pre-Expedition materials is for scientists to see GCY's educational expectations for youth participation in Citizen Science. By including scientists as a key part of this Pre-Expedition information process, they establish the baseline of information about their projects and are aware of the framework in which GCY is sharing this information with other stakeholders. It also allows them to see how collaborations with GCY produce a method for data collection as well as a method for the dissemination of information about their research.

3.3.2.2 Trip Coordinators

Program Development Packet

As GCY continues to use these materials on their expeditions and refine them as need be, the Program Development Packet can evolve to reflect the Trip Coordinator's expectations for Citizen Science while On-Expedition. This could mean requesting additional lesson plans or activities specifically pertaining to Citizen Science, or science more generally. Since Natural Sciences are not a theme of every expedition, it is unrealistic to prescribe additional science activities for every expedition, when Citizen Science is already taking place. The PDP has the potential to be a place for Trip Coordinators to request activity plans or time for guides, the scientist, or themselves to talk more extensively about Citizen Science generally, or the projects specifically while on the expedition.

3.3.2.3 Guides

Science Journal: See Appendix N

See Appendix N for the initial pages of the Science Journal. This includes Project Summaries for all stakeholders on the expedition to reference, as well as discussion questions for guides to refer to while on their science "crew" night of the expedition, if this is something the Trip Coordinator requests of them, or if it is a material they wish to engage Youth with. The discussion questions are within the same format as the Questionnaires and Project Summaries, following scaffolding the steps of Scientific Inquiry. Each step has 1-3 discussion questions, providing guides with a resource that allows them to engage deeper with the projects without needing extensive scientific backgrounds.

Explore Box

GCY already has a resource for On-Expedition interaction with science, called the "Explore Box." It is recommended that as the Science Journal evolves, the Explore Box be the place where the journal is kept on all expeditions. Materials such as relevant guidebooks, science tools, identification cards, and other educational materials related to natural sciences can be added to the Explore Box as supplementary science materials.

Program Development Packet

As stated earlier, the PDP has the potential to be a place for Trip Coordinators to request activity plans and guide support for educational activities. This access prior to their expedition gives guides opportunity ahead of time to either request educational materials from GCY, or plan their own activities and request support for implementation. As these materials and this framework becomes more engrained, the Trip Coordinators On-Expedition will be responsible for the follow-through of any expressed activities or discussions from the PDP to more deeply explore the Citizen Science projects, but this place can be where Trip Coordinators can communicate or request the need for additional guide support.

3.3.2.4 Youth

Science Journal: See Appendix N

The Science Journal (see Appendix N) is primarily intended as a tool for youth and guides to interact with together on their expeditions. Youth are able to engage with the discussion questions, interact with the materials in the Science Journal as it continues to grow, and explore the project summaries for more information on the projects if they are interested. This specific resource is more self-guided than any of the other materials produced in this Practicum – acting as a resource for guides to allow room for inquiry to develop but also as a means for individual youth to more extensively learn about the projects if they are interested. Again, since Natural Sciences are not a theme of every expedition, it is unrealistic to prescribe that every expedition to interact with the Science Journal in the same way.

Data Collection

The most consistent piece of this framework is the data collection itself. Whether or not stakeholders interact with any of the Pre-Expedition or On-Expedition materials, data is collected on expeditions for the Citizen Science projects. As mentioned previously, youth rotate through a series of "crews" each night of their expedition, and science is one of these crews, in which a smaller group of youth with one guide collect data for the Citizen Science projects. For the purpose of expedition consistency and for this project – there is no need for this to change. However, GCY recognizes that daytime projects are easier for all stakeholders to engage with than projects that require data collection at night.

Currently, the Aquatic Insect and Acoustic Bat Projects both require data collection to be done after nighttime, and for the devices to be left for an hour before taking them down. Oftentimes, guides report setting up the monitoring devices with the youth present and assisting, but then taking them down later themselves since the youth are getting ready for bed, or are already in bed. However, this is the time where the results from the night's data collections can actually be seen; this is when the recordings of the bat species flying past are collected and can be viewed, and when the insects that were attracted to the light traps are transferred to their bottle containers. While it is again unrealistic to prescribe that every expedition require youth on the science crew to be present for this part of the data collection process – youth's presence in the second part of the data collection process can be encouraged and emphasized when deemed appropriate. It is also important to recall as Tyson (2019) acknowledged, in order for Citizen Science to take place in Outdoor Adventure Education contexts, the prerequisite of participants comfort in their outdoor setting impacts their ability to dedicate themselves to collecting data. GCY youth at times are on their first river trip or camping and sleeping outside for the first time – and their comfort and ability to manage themselves has to come first before they can be expected to participate in data collection, particularly at night after long and active days.

As GCY continues to grow their collaborations with scientists, finding projects that collect data during the day presents an ideal opportunity to engage youth with the entire data collection process on their expedition. This is not to say that nighttime projects should not be considered or included, but rather to simply continue to seek out projects where data collection takes place during the day. This is already something that GCY recognizes – and two recommendations were identified: (1) to continue to seek projects and collaborations where data collection can either be done in one sitting, and does not require leaving for an hour at night, or (2) to find projects that collect data earlier in the day before dark. This is to provide youth with the opportunity to participate in the entire data collection process when possible.

3.3.3 Post-Expedition Materials

3.3.3.1 Scientists

End of Season Letter: See Appendix O

At the end of GCY's season, after compiling data for number of youth and number of expeditions, it is recommended that a short follow-up letter be sent to scientists, thanking them for their collaboration, and sharing GCY's numeric data with them. This informs them of how many youth were collecting data, and creates a pre-season and post-season set communication with scientists. This follow-up will also have some brief questions asking scientists to share any project updates with GCY, and in turn, GCY disseminates this information to anyone involved with their organization. This provides scientists with another reason to collaborate with GCY for their research – GCY not only assists them in their data collection methods, but also in the informal dissemination of their research throughout their project. This is also an opportunity to GCY to request to be sent any publications that result from this project, should access to the articles be granted.

3.3.3.2 Trip Coordinators, Guides, and Youth

Newsletter

GCY already sends a seasonal newsletter, called "The Ripple Effect." For a Post-Expedition follow-up, it is recommended that after the end of season information has been gathered from scientists, Citizen Science be a focus of one edition of the newsletter. The newsletter is sent to all stakeholders at GCY, and these stakeholders are not limited to Citizen Science stakeholders, but this is also an opportunity for donors, parents of youth, board members, and anyone who receives GCY communications to learn about GCY's annual contributions to scientific research. Potential information to include could be a list of the projects, to show the diversity of scientific research that GCY contributes to, as well as some numbers and statistics, such as how many youth went on expeditions and collected data, or how many expeditions collected data. This requires some record keeping, but has potential to improve the quality of Citizen Science at GCY for all stakeholders. GCY gives scientists an additional avenue to share their research with the public, and it requires little extra work on their part. Trip Coordinators, Guides, and Youth are able to see the big picture of their contributions to the project(s) they collected data for, and are able to follow it after their expedition concludes. Additionally, from an organizational perspective, GCY is able to publicly convey their contributions to scientific research, and the diversity of their scientific collaborations.

Story Map: See Appendix L

Lastly, the Story Map can serve as both a Pre-Expedition and Post-Expedition information sharing method for GCY. After the follow-up letters are sent to scientists and their responses are received, the Story Map can be updated if needed, and publications or articles published can be attached for anyone who visits the Story Map to view. This again serves the purpose of providing an additional avenue for scientists to disseminate their research, particularly if their publications can be shared on the Story Map. Even without access to these, participants are able to revisit the project information, and GCY is able to provide updates of their project collaborations. Not only does this utilize literature recommendations to make the research more meaningful to participants, but it also allows GCY as an organization to show its contributions to scientific research over the years in a visual and spatially engaging format.

Chapter 4: Recommendations, Further Applications, and Reflections

4.1 Recommendations

The materials produced in this Practicum represent an initial list of materials I recommend that GCY begin implementing and utilizing as Citizen Science continues to be a part of their expeditions. GCY's mission is to promote personal growth, environmental awareness, community involvement, and teamwork among people of diverse backgrounds on their expeditions. Citizen Science has a widely acknowledged potential ability to contribute to personal growth, environmental awareness, community involvement, and teamwork. I recommend that the Citizen Science framework be a consistent component of discussion behind implementing these goals in GCY's mission.

Each of the materials in this Practicum was developed with recommendations from the literature in mind – such as scaffolding scientific inquiry in the science summaries to walk participants through the entire project from start to finish, involving them in more than one part of the inquiry process (Edelson et al., 2018). Recommendations in the literature for educators to have access to tools to introduce Citizen Science led to the lesson plan, and incorporating the Project Summaries in the lesson was based on recommendations that not all teachers will know how to use Citizen Science materials as a teaching tool (Bonney et al., 2015). Perhaps the hardest part to "enforce" is the development of inquiry and ESA while on expeditions, which may simply need the time to evolve as Guides, Trip Coordinators, and the GCY staff engage with the materials themselves and Citizen Science framework becomes an engrained part of the conversation in their mission.

The Program Development Packet (PDP) is a place where the connections between GCY's mission, contributions of Citizen Science, and specific expedition goals expressed by the

Trip Coordinator can begin to connect, and perhaps eventually become an engrained part of these communications prior to expeditions. Although the addition of Citizen Science brings something new to an established version of the PDP that may be challenging to navigate at first, it is recommended for this PDP integration to become an established piece of Pre-Expedition Materials where various stakeholders are able to see how Citizen Science contributes to GCY's mission and to a group's expedition goals.

The Science Journal has some of the greatest potential to evolve organically as youth and guides interact with it on expeditions as an educational resource and a creative outlet. The discussion questions themselves have room to expand as Guides and Youth interact with them. As Guides refer to them, they should provide feedback on questions that prompted lively discussion, or questions that did not. Additionally, guides can add to these questions as with either questions that they come up with, or even questions that Youth have asked them. This process may take time as Guides and those interacting with these materials become familiar with them, but this is how the materials can eventually evolve to reflect an original and representative voice to the GCY Citizen Science Stakeholders. To build on the interdisciplinary nature of GCY's expeditions, the Explore Box and the Science Journal can work together to become a key component of Citizen Science participation On-Expedition. The materials associated with these two core pieces could grow beyond identification cards and guide books, but also include art supplies and environmental literature such as poems and short essays about the places where GCY offers expeditions.

The Story Map will continue to be updated as necessary, but not by Grand Canyon Youth. This will continue via collaboration with Northern Arizona University. However, someone must communicate the information in the Story Map that must be changed, added, or updated. The Story Map and the post-season newsletter is recommended be shared with the entire community surrounding GCY – Citizen Science Stakeholders, but also donors, board members, and parents of youth.

GCY proposed one of the Practicum's goals be to recommend who among their current staff was the most appropriate to continue to engage with the materials produced in this Practicum. However, due to the nature of the materials and stakeholder communications, identifying one staff member was not practical. Considering certain staff already work closely with Trip Coordinators or Guides, multiple GCY staff were identified based on who is already in frequent communication with each stakeholder. Due to external communications nature of the Post-Expedition materials, a stakeholder addition to this chart is the Grand Canyon Youth Community – encompassing all who engage with the organization in any capacity.

Figure 4.1.1 GCY Staff and Stakeholder Communications

STAKEHOLDER	GCY LIAISON	COMMUNICATIONS
Scientists	Partners in Science: National Program Director Other/Ongoing: Flagstaff Program Director	❑ Sending and collecting Pre-Expedition Questionnaires ❑ Sending and collecting Post-Season Letter and Questions
Trip Coordinators	Program Directors	❑ Sending materials to Trip Coordinators ❑ Integrating PDP Goals
Guides	Field Staff Director	❑ Sharing Citizen Science Project info ❑ Facilitating training opportunities (Season Opener)
Youth	Guides	❑ Supporting Science "Crew" ❑ Interacting with Science Journal ❑ Explore Box
Grand Canyon Youth Community	Communications Director	❑ Citizen Science Newsletter ❑ Story Map information (in collaboration with NAU)

Figure 4.1.1 Chart showing Stakeholders, and the associated position at GCY who is recommended to be in communication with them throughout the season.
Chart by Madeleine Smith

The final recommendation from this practicum is for GCY to incorporate a visual of an inquiry model into the materials produced in this Practicum. The Questionnaires and corresponding Project Summaries represent the most succinctly scaffolding models of Scientific Inquiry of the recommended materials. While it is difficult to produce these materials to represent a non-linear format, incorporating non-linear visuals will be a key component to conveying the non-linearity of Scientific Inquiry. The model used in Figure 3.1.2 was identified as a possible model for GCY to adapt and create a unique model specific to the organization. This model could also be included in the Explore Box to go on expeditions as a laminated handout for guides and Citizen Science facilitators to refer to and ask youth to identify where in the inquiry model they believe the project is currently. It could be used as a discussion or dissemination tool, incorporated into the Project Summaries, included in the Story Map, and serve as a visual guide for the inquiry process. Moreover, it provides an additional facilitation tool to engage participants with more steps of inquiry than the data collection process. Because the intention is for this to be an organization-specific visual, I have not placed it into any of the materials produced. I recommend that the GCY staff and stakeholders ensure that visually and linguistically it reflects the nature and mission of the organization, before implementing it into the materials produced in this Practicum. The beginning stages of an organization-specific model adapted from Figure 3.1.2 for GCY to incorporate can be seen in Figure 4.1.2.

Figure 4.1.2 Adapted Inquiry Model for GCY

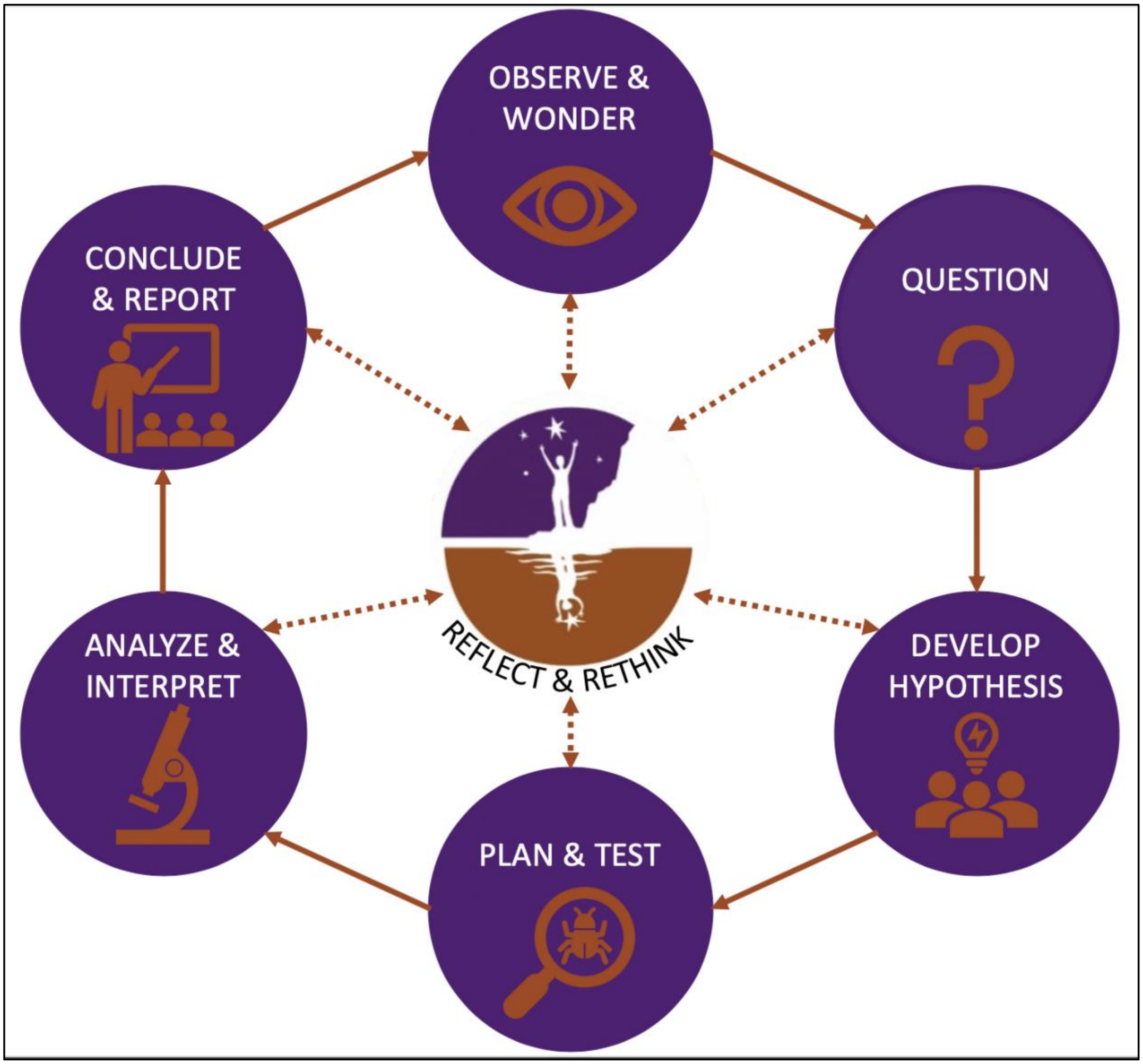

Figure 4.1.2 Diagram of Inquiry Model adapted from Driven to Discover: Facilitator's Guide to Conducting Citizen Science and Scientific Investigations
Adaptation of model by Madeleine Smith

4.2 Further Applications

While the materials produced in this practicum are largely organization-specific, the guiding principles behind the materials are widely applicable to other organizations. The literature places heavy emphasis on educational materials, inquiry development, and post-project follow-up. At GCY, these three components became the three pieces of the timeline, with educational materials representing Pre-Expedition, inquiry development representing On-Expedition, and identifying possible avenues for Post-Expedition follow-up. Other organizations that offer experiential education and wish to use Citizen Science as an educational tool would benefit from keeping these three timeframes in mind, and identify which stakeholders are the most appropriate for producing materials within these three timeframes.

Revisiting the literature, as noted by Edelson et al. (2018), two misconceptions exist about achieving educational and scientific outcomes through Citizen Science: that if you design a project to achieve one outcome, the other is automatically achieved, and the opposite, that the two outcomes are mutually exclusive. Both are attainable, but it requires the intention to achieve the two. He & Wiggins (2017) identify mediating organizations as serving an important role in communication to participants, providing resources for educators, and participant follow-up with project updates. Edelson et al. (2018) recommend organizations or the project developers themselves provide a tool or a means for participants to access project information on their own, to build on their sense of ownership – such as a Story Map. The potential for Citizen Science to achieve perhaps the two most sought-after educational goals (stewardship and inquiry development), lies in creating room for inquiry to develop while participants gather data, as Turrini et al. (2018) point out the need for formats to be developed to engage participants with more steps of scientific inquiry than the data collection process. Edelson et al. (2018) identify one possible means of developing inquiry as scaffolding the steps of inquiry so that participants are walked through the process, and this can either be in the context of the project (such as in the project summaries) or on its own, (such as in the Science Journal). Additionally, as pointed out by Tang et al. (2010), incorporating non-linear scientific process models focuses attention on more authentic scientific inquiry, such as the models in 3.1.2 and 4.1.2.

The specific materials may or may not be applicable to other organizations, but many of the materials were created referencing concepts from the literature review and adapting them to fit the needs of the organization. What other organizations can apply from this practicum is the identification of their stakeholders, and the three timeframes Pre, On, and Post. The specific materials are largely up to the discretion of the organization. Many of the materials produced, such as Questionnaires, Project Summaries, the Lesson Plan, and the foundations of a Science Journal, could serve as starting points and a variety of organizations could adapt them for their own purposes. Additionally, useful resources for creating or building on lesson plans exist, ones used for this Practicum were the National Aeronautics and Space Administration's Planet Hunters Education Guide, and Driven to Discover: Facilitator's Guide to Conducting Citizen Science and Science Investigations – these two resources have lesson plans and activities that can be adapted for organizational or classroom needs.

4.3 Project Reflection

This project began with the goal to review existing frameworks and see what other similar organizations were doing in terms of Citizen Science, only to find out that this was almost non-existent, or so different that it was not applicable to GCY. The expeditions themselves are unique – and the fact that they incorporate Citizen Science on almost every expedition is even more unique. Upon realizing this, it became apparent that this would be a more original design, and would have to rely heavily on literature recommendations – but that was what revealed the framework. Citizen Science may have a long history in the world of scientific research, but as an educational tool has unique challenges and requires careful consideration for successful implementation.

As Grand Canyon Youth continues to grow as an organization and Citizen Science continues to be a part of their expeditions, this framework can guide the evolving processes among their stakeholders. GCY can continue to position themselves as a Citizen Science facilitating organization, capable of balancing both scientific and educational outcomes for their Citizen Science stakeholders. The framework seeks to foster relationships with Scientists, grow Guide potential as facilitators and communicators of science, empower Trip Coordinators to incorporate science in interdisciplinary settings, and ultimately, engage Youth with science in a unique format to inspire curiosity, develop inquiry, and empower their sense of Environmental Science Agency.

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Appendices

Appendix A

Science Questionnaire: Partners in Science 2019

P.O. Box 23376 Flagstaff, AZ 86002 Phone: 928.773.7921 Fax: 928.774.8941
info@gcyouth.org www.gcyouth.org

Hello _____,

Thank you for your interest in being a science representative on a Partners in Science program! This program has been around for 15 years and is a collaboration between Grand Canyon Youth (GCY) and the United States Geological Survey (USGS). The goal of this program is to connect youth to the Colorado River through Grand Canyon National Park through participation in actual scientific research. This program is open to youth from across the country and includes specific outreach to underserved/underrepresented youth. Each half has 15 youth and a Trip Coordinator, a volunteer for GCY with experience working with young people. There are also guides and potentially other scientists like yourself.

In an effort to provide the best educational experience for our participants we ask that you share with us a 2-page summary following the scientific inquiry method. See questions below.

You'll also get a follow-up email from our National Program Director, Jordan Robinson with questions about your dietary and camping equipment needs. There is also some training required to participate on our youth programs. Please don't hesitate to reach out with any questions and we look forward to meeting you.

Kind regards,

Emma Wharton
Executive Director

Science Project Summary Overview

Background

At GCY, we are excited to have Madeleine Smith a M.S. Candidate in the Applied Geospatial Sciences with the NAU Department of Geography, Planning, and Recreation as a practicum student at GCY. Her project is to create a citizen science framework for GCY.

The goal of this practicum is to provide a framework for GCY to utilize for their citizen science projects that can be used on all programs with the goat to ensure best practices and continuity among GCY's programs. For the upcoming partners in science expeditions, we want to engage the scientists on these expeditions in order to test the beginning stages of this framework. We plan to reinforce scientific inquiry while on program. Through this, we hope to observe what effect this may have on student engagement and quality of data collection. We are grateful for the learning opportunities that you as scientists bring to these expeditions, and it is a goal of ours to strengthen this partnership to serve both youth and scientists alike.

Project Outline

Following is an outline of what we hope to test on these expeditions for the sake of achieving GCY's goals of inspiring curiosity and sharing the relevancy of these citizen science projects with participants. In the hopes of instilling these goals, the model is thus not phrased or outlined to be explicitly aligned with the "scientific method," but rather to reflect an inquiry-based model. Please share the answers to the questions below for your topic and feel free to include photos or links to videos or other background material. This will then be shared with the youth participants and guides prior to the program.

1. What is the initial research question/observations? (Question/Background)
2. What do we already know/think the answer may be? (Background/Hypothesis)
3. How are we going to try to answer this question? (Methods/Test)
4. What have we learned so far/what are we hoping to learn? (Conclusions)
5. What management or policies do you hope to address or change with this research? (Dissemination)
6. Are there additional follow-up questions that resulted from this project?

Appendix B

Science Questionnaire: Ongoing Projects 2020

P.O. Box 23376 Flagstaff, AZ 86002 Phone: 928.773.7921 Fax: 928.774.8941
info@gcyouth.org www.gcyouth.org

Hello,

Thank you for your interest in collaborating with Grand Canyon Youth to help complete your research! We have been working with scientists to collect data on our expeditions for the last 20 years. In 2019 we had 1,093 youth join us on 76 expeditions on the Colorado, San Juan, and Verde Rivers, most of which participated in Citizen Science. A guiding principle of our mission is our commitment to inspiring curiosity. Projects like yours help us to fulfill this mission and contribute to science in a way that develops stewardship within our participants.

We have developed a model that uses scientific inquiry to frame all of our collaborator's projects. This format will help introduce your project to Trip Coordinators, youth, and guides, and ensure an authentic integration of Citizen Science with the participants expedition experience.

We ask that prior to implementing this project on expedition, you provide us with some information about your project following our framework – this includes a short questionnaire that outlines your project within the scientific method. These can be brief, 500-700 words is an ideal length, and please define any scientific terms used. Additionally, feel free to attach photos, graphs, and any supplementary attachments! We have also provided an example of one of these questionnaires that has already been filled out for reference.

Our collaborations with scientists are important to us, and through involving you in this Pre-Expedition process we hope to continue to build on these collaborations, to inspire scientific literacy and curiosity within our youth, and to plant the seed for future projects. Thank you again!

Please include the title of your project, your name, and name of your research entity.

500-700 words

Define scientific terms

Include pictures and graphs, or any other supplementary information!

- Are you, or someone involved in this project, available to connect with Grand Canyon Youth groups prior to their expedition?

1. Observation:

We noticed _______ and wanted to know _______

2. Question: What are the initial research question and observations?

3. Hypothesis: What do we already know, and what do we think the answer may be?

4. Methods: How are we going to try to answer this question?

5. Conclusions: What have we learned so far, and what are we hoping to learn?

6. Dissemination: What management or policies do you hope to address or change with this research?

7. Are there additional follow-up questions that resulted from this project?

Appendix C

Science Questionnaires: Final Template

GRAND CANYON YOUTH discover your nature

P.O. Box 23376 Flagstaff, AZ 86002 Phone: 928.773.7921 Fax: 928.774.8941
info@gcyouth.org www.gcyouth.org

Hello,

Thank you for your interest in collaborating with Grand Canyon Youth to help complete your research! We have been working with scientists to collect data on our expeditions for the last 20 years. In 2019 we had 1,093 youth join us on 76 expeditions on the Colorado, San Juan, and Verde Rivers, most of which participated in Citizen Science. A guiding principle of our mission is our commitment to inspiring curiosity. Projects like yours help us to fulfill this mission and contribute to science in a way that develops stewardship within our participants.

We have developed a model that uses scientific inquiry to frame all of our collaborator's projects. This form will help introduce your project to Trip Coordinators, youth, and guides, and ensure an authentic integration of Citizen Science with the participants' expedition experience.

We ask that prior to implementing this project on expedition, you provide us with some information about your project following our framework – this includes a short questionnaire that summarizes your project within the scientific method.

A few things about the project summaries:

- These are going to be shared with youth, Trip Coordinators, and guides, so please define any scientific terms that you may use!
- These can be brief; the entire document can be 500-700 words, roughly.
- Feel free to attach any photos, graphs, or supplementary attachments!
- We have provided an example for reference.

Our collaborations with scientists are important to us, and through involving you in this Pre-Expedition process, we hope to continue to build on these collaborations, to inspire scientific literacy and curiosity within our youth. Thank you!

Project Name:	
Research Entity:	
Your Name (and anyone else's names involved in the project you wish to include):	
Are you, or someone else involved in this project, able to connect with Grand Canyon Youth participants prior to their expedition?	
Observe & Wonder:	We noticed _____ and wanted to know _____.
Question: What are the initial research questions?	
Develop Hypothesis: What do we think the answer may be?	
Plan & Test: How are we going to try to answer this question?	
Analyze & Interpret: What have we learned so far?	
Conclude & Report: What are potential applications of this research for resource managers?	
Reflect & Rethink:	

Are there additional follow-up questions that resulted from this project?	

Appendix D

Project Summaries: Partners in Science 2019

Project Name: The Dragonfly Mercury Project
Partnering Entity: The National Park Service
Liaison: Kat Ko, katherine_ko@partner.nps.gov
DMP Contact: Colleen Flanagan Pritz, colleen_flanagan_pritz@nps.gov

1. ***What is the initial research question/observations? (Question/Background)***

The Dragonfly Mercury Project (DMP) investigates mercury as an environmental toxin. This study was created by the National Park Service (NPS), U.S. Geological Survey (USGS), and University of Maine to research the status of mercury pollution across the nation. We want to know where there are high or low concentrations of toxic methylmercury, what factors might contribute to higher concentrations, and how we can mitigate the effects of mercury pollution.

2. ***What do we already know/think the answer may be? (Background/Hypothesis)***

We already know that mercury is a common pollutant worldwide. There are natural sources of mercury (i.e. volcanoes) and man-made sources (i.e. coal-fired power plants and mining). We also know that mercury can travel hundreds of miles in the air and end up in seemingly pristine places, like national parks. In addition, there can be a variety of factors that affect how much toxic methylmercury accumulates in an ecosystem. We suspect that certain environments are more susceptible than others to accumulating toxic mercury.

3. ***How are we going to try to answer this question? (Methods/Test)***

This study involves collecting dragonfly larvae for mercury analysis. Dragonfly larvae are biosentinels for mercury pollution: this means that the amount of mercury found in the larvae is a good indicator of the overall health of an ecosystem. Dragonfly larvae were chosen for this study because they are easy to collect, they are found on every continent except Antarctica, and they prey on other aquatic insects, therefore bioaccumulating toxins like mercury in their bodies.

We collect 10-15 dragonfly larvae at a site, measure their body length, and identify them down to family. We fill out a tag for each larvae and ship them to the USGS lab for mercury analysis. We also take note of characteristics at the sampling site, such as geology, elevation, and vegetation. This information will help scientists identify trends between mercury pollution and certain site characteristics.

4. *What have we learned so far/what are we hoping to learn? (Conclusions)*

The results of the DMP thus far have found that mercury concentrations in dragonfly larvae are highly variable across the nation. Sources of mercury emissions, such as power plants, are not the sole dictator of how much mercury ends up in an environment. Instead, factors like larval body size, dragonfly family, and habitat type can affect how sensitive a site is to mercury accumulation. The DMP will continue to investigate links between site and larval characteristics and mercury concentration.

Since the project's launch in 2009, over 100 parks and 4,000 citizen scientists have contributed more than 10,000 hours of service to the DMP. The power of citizen science has helped this project grow and gather data from all over the nation in a short amount of time. We are hoping to continue expanding the project, engaging more youth, and collecting more data in places we haven't been able to reach yet.

5. *What management or policies do you hope to address or change with this research? (Dissemination)*

The data produced by the DMP will inform resource managers of potential risk regarding mercury in the environment. This project can help managers and agencies make decisions to safeguard human and wildlife health. The DMP also serves to connect people to parks. We hope to encourage people to visit their public lands and take care of the world in which they live. This research serves to bring attention to the issue of global mercury pollution while engaging citizen scientists and inspiring an age of activism and stewardship.

6. *Are there additional follow-up questions that resulted from this project?*

The DMP will continue investigating what specific site and larval characteristics are related to mercury concentrations. We are waiting for the 2018 and 2019 data to be published; then, we will know about mercury concentrations at our sites in Glen Canyon and the Grand Canyon! The DMP is also exploring the educational and citizen science opportunities that emerge from this kind of project, such as creating teaching materials about mercury and investigating what makes citizen science programs successful.

Establishing a Baseline of the Distribution of Microplastics in the Grand Canyon

Michaela Miller

1. ***What is the initial research question/observations? (Question/Background)***

Around the world, plastics of many types and sizes are polluting aquatic ecosystems. Microplastics, plastic particles less than 5mm in size and typically invisible to the naked eye, are a huge part of plastic pollution. Plastics are created to make a wide variety of products used by humans daily, yet the way plastics are made that make them so useful for humans also allow results in plastics staying in aquatic environments for long periods of time. Microplastics can be formed from larger plastic items breaking down into smaller pieces. They can also be formed from fibers that come off of synthetic clothing items (like your favorite Patagonia fleece!) after washing that pass through waste water treatment plants. So although we have benefited from the use of plastics as a society, the improper disposal and overuse of plastics over time has led to them accumulating in oceans, rivers, streams, and other aquatic environments around the world.

Consequently, plastics and microplastics have been found in all major oceans as well as a number of other terrestrial and freshwater environments. In the ocean, the ecological effects and dangers plastic impose on marine life are well studied. Rivers are known to transport plastics and other man-made trash to the ocean; however, the distribution of microplastics and their effects on freshwater ecosystems is not well studied. In order to inform our understanding of this issue, a necessary first step is to examine the problem as a whole. The Grand Canyon and the Colorado River that flows through it are both intrinsically and ecologically important, and well-studied. However, the extent of microplastic pollution in this area is not well studied. In order to inform our understanding of this issue in the Grand Canyon, a necessary first step is to establish a baseline documenting the extent of the distribution of microplastics throughout Grand Canyon.

2. ***What do we already know/think the answer may be? (Background/Hypothesis)***

A previous study documented microplastic particles in surface waters at a few different locations throughout Grand Canyon. Since microplastics sink over time, the next step in assessing the distribution of microplastic particles would be to test for microplastics in sediment along the river. We hypothesize that microplastic particles will be much higher in sediment than in surface waters since they are known to sink over time.

3. ***How are we going to try to answer this question? (Methods/Test)***

In order to test for microplastics, we are going to collect multiple samples throughout our trip down river. We will collect two sediment samples at each location. One sample we will save to analyze later in the lab. The other sample we will process right there in the field at camp using a density separation method. Since plastic particles are much lighter than sediment, if we mix the sediment sample with a hyper-saline solution then the plastic particles will float to the top. After the plastic particles are floated to the top and suspended, we will pour the suspended particles and water into a hand-powered vacuum system to filter out the microplastics. Once filtered, the microplastics will be left on a filter paper and we will be able to examine, count, and record any microplastics left on the filter and present in the sediment by using a ‘field microscope’ constructed from an iPad with a microscope lens attachment.

4. What have we learned so far/what are we hoping to learn? (Conclusions)

We have learned that microplastic particles are present in Grand Canyon, but we do not know the extent of the problem or how they are distributed. By sampling the sediment at multiple locations, we are hoping to learn the just how much microplastics are distributed here to possibly identify potential sinks and sources of microplastics. Once we figure out how they are distributed, we can establish a baseline to base future monitoring off and be able to see if microplastics are increasing or decreasing over time in Grand Canyon.

5. What management or policies do you hope to address or change with this research? (Dissemination)

As previously stated, the first step to addressing the problem is understanding the extent of the problem. With this study our main goal is to document the extent of the problem in this critically important area, which is an important first step in making any management or policy decisions.

6. Are there additional follow-up questions that resulted from this project?

After we establish a baseline of the extent of microplastics in Grand Canyon, potential sources and sinks of microplastics may be revealed. From there, additional follow-up questions that result from this project would be to examine any ecological impacts that microplastic pollution may cause.

Distribution and Abundance of Native and Non-Native Fishes

Jan Boyer

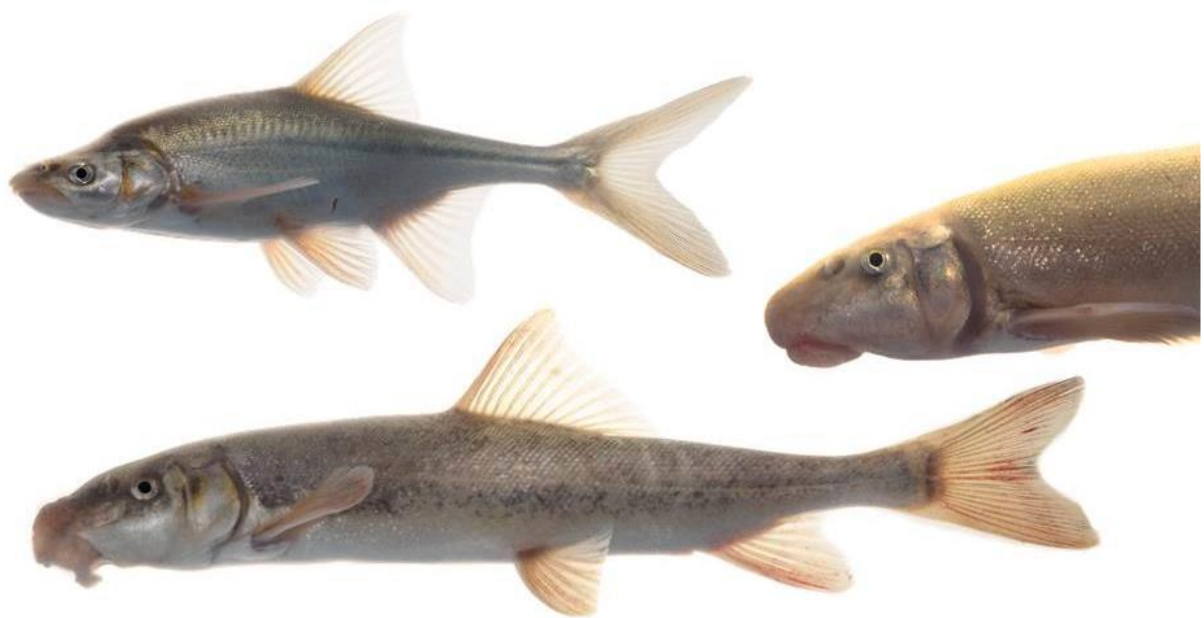
1. ***What is the initial research question/observations? (Question/Background)***

Background: The Colorado River in Grand Canyon is a heavily altered ecosystem. Glen Canyon Dam has changed flows by eliminating spring floods but increasing daily variation in flow as the dam is hydropeaked to generate electricity. Scientists have recently found that this hydropeaking reduces the abundance of aquatic invertebrates that many fish feed on. Water is released from near the bottom of Lake Powell, so the dam has made the river colder and clearer. Nonnative fish including rainbow trout, brown trout, common carp, and channel catfish have been introduced to the river and compete with or predate on native fish.

Unnatural cold, clear water due to Glen Canyon Dam

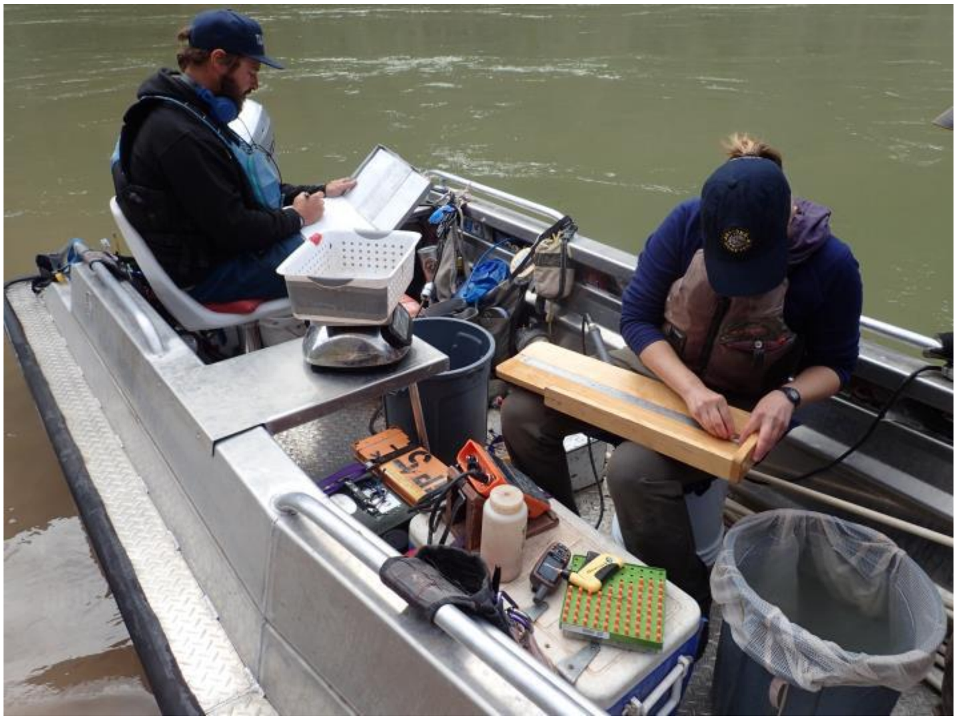
A more natural, turbid, Colorado River: tributaries periodically supply some silt to the Colorado, but the river is still less turbid than it was historically.

These changes are a challenge for native desert fish – these fish evolved in a Colorado River that was warm and silty, had massive spring floods that built sandbar and backwater habitat, and did not have predators such as catfish. However, despite these alterations, native fish have managed to persist in the Grand Canyon. The Grand Canyon holds the world's largest population of Humpback Chub, an endangered fish that exists only in the Colorado River. Flannelmouth Sucker are thriving in the canyon, and Bluehead Sucker and Speckled Dace are also present.



Native fish of the Grand Canyon: Humpback Chub, Bluehead Sucker, Flannelmouth Sucker

Scientists monitor fish in the Grand Canyon in order to track changes in fish populations, understand how current dam operations and environmental conditions are affecting fish, and try to learn if there are any actions we can take to help native fish. Recovery actions that have occurred in the past have included translocations of Humpback Chub to new tributaries to help these fish expand their range, artificial floods (High Flow Events, HFEs) at Glen Canyon Dam meant to mimic historic floods and rebuild sandbars, and nonnative fish removal. A recovery action that is occurring now is low steady flows on weekends, commonly referred to as "bug flows". The changing water levels caused by hydropeaking reduce aquatic invertebrate abundance by drying out eggs laid in shallow water. The low steady flows on weekends will keep eggs laid on these days underwater, improving survival and hatching success. We hope that bug flows will also benefit native fish populations by providing more insect food for fish.



Scientists measuring fish caught in hoop nets on a fish monitoring trip

Open spillways at Glen Canyon Dam during a high flow event (artificial flood)

Given this background, our two main research questions are:

a. How does the geographical distribution (i.e., where?) and relative abundance (i.e., how many?) of native and nonnative fishes compare to past years?

b. Do experimental bug flows (implemented summer 2018 and 2019) improve fish growth, condition, or abundance?

2. What do we already know/think the answer may be? (Background/Hypothesis)

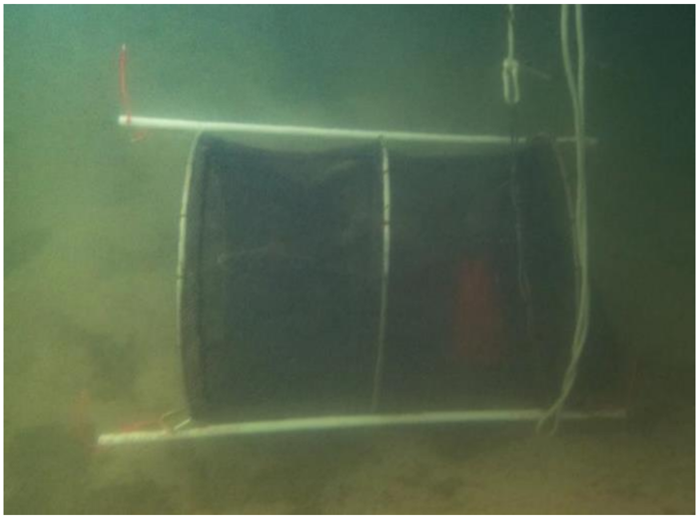
a. Nonnative rainbow trout will be the most abundant fish in Marble Canyon, but downstream of the Little Colorado River, increasing numbers of native fish will be captured. Native fish numbers will continue to increase, as has been observed in recent years.

b. Bug flows will increase fish abundance, growth, and condition by providing additional food resources.

3. How are we going to try to answer this question? (Methods/Test)

Hoop nets will be the primary method used to sample fish (photos: setting a hoop net, a hoop net underwater). Fish enter hoop nets to get bait (if we bait nets) and also because they like the cover and safety nets provide! We will set hoop nets near camp each afternoon or evening, leave them overnight, and pull them in the morning to see what we caught.

Setting a hoop net



A Hoop net underwater

We may also use seines or angling to capture fish that we cannot capture with hoop nets. Different fish sampling techniques work better or worse for different species, so using a variety of techniques gives us a more complete picture of the fish in the Grand Canyon.

For all sampling techniques, we will record the amount of time that we sampled (time hoop net was in water, time spent angling, etc.). We can the calculate catch per unit effort (CPUE; number of fish caught/time spent sampling), which gives us a relative measure of fish abundance (how many fish are there?).

We will record the species, length, and weight of all captured fish. We will also scan fish for PIT tags, and give untagged fish a PIT tag. PIT tags are small tags with a unique ID that lets us identify individual fish (If any of you have dogs, they may have PIT tags implanted under their skin so that vet clinics or shelters can identify them if they get lost). If tagged fish are recaptured, we can use tag information to learn about growth and movement of fish. After we record these data, fish will be released back into the river.

Our sampling methods are very similar to the methods used by several science agencies working in the Grand Canyon (U.S. Geological Survey, U.S. Fish and Wildlife Service, Arizona Game and Fish). This consistency is important because it will let us compare our data with data collected on other trips.

4. ***What have we learned so far/what are we hoping to learn? (Conclusions)***

In recent years, scientists have documented increasing numbers of native fish (Flannelmouth Sucker, Humpback Chub, Bluehead Sucker, Speckled Dace), particularly in Western (downstream) areas of the Grand Canyon. Grand Canyon Youth trips were actually some of the first to observe increasing numbers of Humpback Chub in the Western Grand Canyon – several science agencies subsequently added hoop net sampling in the Western Grand Canyon to better understand Humpback Chub distribution, and have now published several papers in scientific journals describing Humpback Chub range expansion.

However, fish distribution and abundance is always changing, so we continue to monitor fish distribution and abundance to better understand how the Grand Canyon's fish assemblage changes in response to changing environmental conditions.

Bug flows are a new experiment, and we don't yet know how they are affecting fish. Invertebrate scientists have preliminary data showing that 2018 bug flows increased aquatic invertebrate abundance. This increased food availability (many fish eat these aquatic insects) may help fish too. However, because many factors (temperature, turbidity, presence of predators) in addition to food availability affect fish growth and condition, we don't know if bug flows will benefit fish.

In 2019, one thing we hope to learn is how bug flows are affecting fish. Experimental flows meant to improve aquatic invertebrate egg survival and abundance may benefit fish by providing more food – we may see increases in fish abundance, growth, or condition (modified length/weight ratio, condition is a measure of how fat a fish is).

5. ***What management or policies do you hope to address or change with this research? (Dissemination)***

If bug flows benefit fish, we may be able to encourage the Bureau of Reclamation to continue low steady flows in future years, or even increase the number of days that bug flows occur in future years.

6. ***Are there additional follow-up questions that resulted from this project?***

We'll answer this question at the end of the trip/project!

Tamarisk Beetle Activity in Grand Canyon

Nat Bransky

1. ***What is the initial research question/observations? (Question/Background)***

Tamarisk (*Tamarix spp.*) are invasive, Eurasian shrubs that were introduced to the United States in the early 1820's for ornamental purposes. Much of the tamarisk encroachment we see today was sparked during the early 1900s, when large dams were built throughout the Southwest, creating an environment in which tamarisk thrive. They are characterized by a deep tap root that allows them use more groundwater than native species, salty foliage that transforms soil chemistry and makes it less inhabitable for other plants, and rapid rates of seed dispersal that allow them to largely replace native vegetation throughout an expansive area. Tamarisk is abundant along the Colorado River, which provides water and hydroelectric power for several million people in central Arizona and southern California.

Land managers have implemented various efforts to stop the spread of tamarisk. The most recent is the release of the tamarisk beetle (*D. carinulata*). Repeated defoliation of tamarisk by the tamarisk beetle can lead to mortality of the shrub due to nutrient depletion, though the documented rates of tree mortality have varied greatly between study areas. We are interested in documenting the effects of the tamarisk beetle on tamarisk in Grand Canyon. Through our data collection and analysis, we hope to answer the following questions: in what areas of Grand Canyon are tamarisk the most susceptible to beetle attacks? Where, and to what extent, is tamarisk dying due to defoliation?

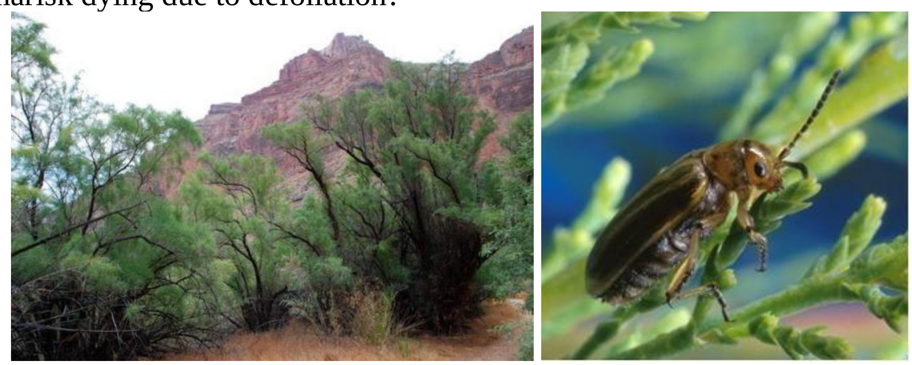


Figure 1. Healthy tamarisk trees (left) and the tamarisk beetle (right).

2. ***What do we already know/think the answer may be? (Background/Hypothesis)***

Previous studies show that tamarisk beetle abundance is related to the size of tamarisk stands (i.e. groups of trees) and how well stands are connected to one another. In Grand Canyon, it is expected that we will observe more beetles and more brown foliage from beetle attacks while we are outside of the inner gorge. This is because the steep cliffs and thin riverbanks within the inner gorge restrict tamarisk growth to smaller, more separated stands, therefore lowering beetle activity.

3. ***How are we going to try to answer this question? (Methods/Test)***

Each evening in camp, we will perform a net sweep on tamarisk foliage to catch, identify, document, and release tamarisk beetles and other arthropods. This is done by raking a net multiple times along the leaves of a tree, then documenting what is caught in the net. Also, Nat Bransky will be collecting visual observations of tamarisk defoliation adjacent to the boat every 0.5 miles.

Figure 2. Defoliated tamarisk in the Glen Canyon National Recreation Area.

4. ***What have we learned so far/what are we hoping to learn? (Conclusions)***

So far, we understand some of how spatial patterns in tamarisk stands relate to beetle activity. For example, large stands that are close together are known to support higher rates of tamarisk beetle activity, such as defoliation. However, we are hoping to learn more about what these patterns might look like in the Grand Canyon.

5. ***What management or policies do you hope to address or change with this research? (Dissemination)***

Understanding where beetle impacts are the greatest, as well as where tamarisk is the most (and least) adversely affected by the beetle, helps land managers determine where to best focus their restoration efforts. For example, an area that is repeatedly defoliated and is showing signs of tamarisk death would be in less need of removal efforts than an area that sees little beetle activity and has thriving tamarisk.

6. ***Are there additional follow-up questions that resulted from this project?***

Ultimately, this project has an objective of determining the utility of satellite data in detecting defoliation events of tamarisk by the beetle. After we collect our ground-based observations along the Colorado River, these data will be compared to satellite imagery in the Remote Sensing and Geoinformatics Lab at Northern Arizona University. Satellite data allow scientists to make observations without physically visiting a place. Understanding how well these types of data can be used to detect defoliation opens a method for monitoring tamarisk that can be useful to other scientists and land managers.

Appendix E

Project Summary: Acoustic Bat Monitoring

Science Project Summary Overview – Citizen Science Based Acoustic Bat Monitoring Project

1. What is the initial research question/observations? (Question/Background)
   What are the spring, summer, and fall distributions of species susceptible to white-nose syndrome (WNS) (see attached species list) in this presumed WNS-free area within Glen Canyon National Recreation Area (GLCA), and how do these change over time?
   Are bat conservation efforts improved by involving citizen scientists in bat monitoring and education efforts?
   Will data collections yield high quality data that can be used to influence management decisions?

2. What do we already know/think the answer may be? (Background/Hypothesis)
   Distribution data on bat species susceptible to WNS is greatly lacking in many areas of North America including GLCA; therefore, we implemented this citizen science study to fill data gaps, engage the public in bat conservation, and inform future management decisions.

3. How are we going to try to answer this question? (Methods/Test)
   Citizen scientists and GLCA Biological Science Technicians will use bio-acoustic hardware (Wildlife Acoustics SM4BAT FS) and software (https://sonobat.com/) to collect and analyze acoustic recordings. All acoustic recordings will be entered into the National Park Service Bats Acoustic Survey Database (v. 1.7) and North American Bat Monitoring Program (NABat) Bat Population Database. Data collections will contribute to a statistically robust dataset that will enable researchers to make inferences about bat species distribution and threats on a local, regional, and continent-wide scale.

4. What have we learned so far/what are we hoping to learn? (Conclusions)

Between 2016 and 2018, citizen scientists collected 47,152 acoustic call files within GLCA, 21,645 of which were identified to species. Sonobat software (https://sonobat.com/) was used to confirm presence of the following bat species susceptible to WNS: big brown bat (*Eptesicus fuscus*; EPFU), Yuma myotis (*Myotis yumanensis*: MYYU), long-legged myotis (*M. volans*; MYVO), western small-footed myotis (*M. ciliolabrum*; MYCI), Brazilian free-tailed bat (*Tadarida brasiliensis*; TABR), silver-haired bat (*Lasionycteris noctivagans*; LANO), California myotis (*M. californicus*; MYCA), fringed myotis (*M. thysanodes*; MYTH), spotted bat (*Euderma maculatum*: EUMA), and pallid bat (*Antrozous pallidus*; ANPA).

Citizen scientists recorded the first GLCA record of the greater mastiff bat (*Eumops perotis;* EUPE) and confirmed presence of the following species: Allen's big-eared bat (*Idionycteris phyllotis*; IDPH), hoary bat (*Lasiurus cinereus*; LACI), and canyon bat (*Parastrellus hesperus*; PAHE).

Young and old citizen scientists are generally very interested in learning about bio-acoustic technology and learning how they can further bat conservation efforts.

5. What management or policies do you hope to address or change with this research? (Dissemination)
   We hope to develop an efficient and effective citizen science based bat monitoring and education program that can easily duplicated by federal and non-federal entities to promote bat conservation efforts.

6. Are there additional follow-up comments/questions that resulted from this project?
   Question:
   The San Juan River region has yielded the greatest species richness among all sites surveyed. How will WNS influence species richness along the San Juan and Colorado Rivers? Will significant differences in species richness result between these two major tributaries?

Comments:

If correctly deployed, Wildlife Acoustics SM4BAT FS acoustic recorders can yield useful, high quality recordings. SM4BAT FS tutorial videos (https://www.wildlifeacoustics.com/products/song-meter-sm4bat/videos) provide useful training to increase data collection success. I recommend all GCY river rafting guides view these videos prior to implementing data collections.

Wildlife Acoustics Echo Meter Touch 2 handheld detectors are very effective teaching tools, but may not produce high quality recordings. Echo Meter Touch 2 tutorial videos (https://www.wildlifeacoustics.com/products/echo-meter-touch-2/tutorial-videos) provide useful training to increase user experiences. I recommend all GCY river rafting guides view these videos prior to implementing data collections.

Appendix F

Questionnaire Feedback and Project Summary: Aquatic Insects

GRAND CANYON YOUTH
discover your nature

P.O. Box 23376 Flagstaff, AZ 86002 Phone: 928.773.7921 Fax: 928.774.8941
info@gcyouth.org www.gcyouth.org

Hello,

Thank you for your interest in collaborating with Grand Canyon Youth to help complete your research! We have been working with scientists to collect data on our expeditions for the last 20 years. In 2019 we had 1,093 youth join us on 76 expeditions on the Colorado, San Juan, and Verde Rivers, most of which participated in Citizen Science. (Scientist's Comment: Love the numbers!) A guiding principle of our mission is our commitment to inspiring curiosity. Projects like yours help us to fulfill this mission and contribute to science in a way that develops stewardship within our participants.

We have developed a model that uses scientific inquiry to frame all of our collaborator's projects. This form will help introduce your project to Trip Coordinators, youth, and guides, and ensure an authentic integration of Citizen Science with the participants expedition experience.

We ask that prior to implementing this project on expedition, you provide us with some information about your project following our framework – this includes a short questionnaire that outlines your project within the scientific method. These can be brief, 500-700 words is an ideal length, and please define any scientific terms used. Additionally, feel free to attach photos, graphs, and any supplementary attachments! We have also provided an example of one of these questionnaires that has already been filled out for reference.

Our collaborations with scientists are important to us, and through involving you in this Pre-Expedition process we hope to continue to build on these collaborations, to inspire scientific literacy and curiosity within our youth, and to plant the seed for future projects. Thank you again!

Please include the title of your project, your name, and name of your research entity.

(Scientist's Comment: Consider making this part of the form. I only eally know what to do here by following the mercury projects example. Ie: What is your project name? Who are the primary contacts?)

500-700 words

Define scientific terms

Include pictures and graphs, or any other supplementary information!

(Scientist's Comment: Remove from here since you mention it clearly in the description above)

- Are you, or someone involved in this project, available to connect with Grand Canyon Youth groups prior to their expedition?

  (Scientist's Comment: Good question but I'm not sure where in this form to answer it.)

Project name: Aquatic insect light trap monitoring

Partnering entity: Grand Canyon Monitoring & Research Center / United States Geological Survey

Contacts: Anya Metcalfe (ametcalfe@usgs.gov), Ted Kennedy (tkennedy@ugs.gov), Cheyenne Szydlo (cszydlo@usgs.gov)

Observation:

We noticed a lack of insects in Grand Canyon *and wanted to know* why that was

Aquatic insects are a fundamental component of a healthy river ecosystem. Most aquatic insects spend their juvenile life stages (egg, larva, pupa) in the river and their winged adult life stage flying along the riparian corridor. Most aquatic insect monitoring programs collect aquatic insects during their juvenile life stages by sampling the benthic zone – the river bottom. However, it is challenging to access the bottom of the river in large and swift rivers like the Colorado and San Juan rivers. To overcome this problem, we designed a sampling protocol that targets the winged adult life stage of aquatic insects. Using this new protocol, we teamed up with river guides and Grand Canyon Youth to sample large rivers of the southwest and monitor aquatic insect populations.

Question: What are the initial research questions?

What aquatic insects live in these rivers? How abundant are these taxa? Do different rivers have different insect communities? How do different water temperatures affect insect species richness (number of unique species) and abundance (measured as total insects captured per hour)? How do different flows, including managed flows released from dams, affect insect communities and abundance?

Hypothesis: What do we think the answer may be?

We predict that aquatic insect communities are affected by water temperatures and flows in rivers. We expect that we will see differences in aquatic insect species richness and abundance in different rivers and in response to variation in environmental conditions.

Methods: How are we going to try to answer this question?

Working with Citizen Scientists allows us to have an effective monitoring program where light trap samples (see photo) are constantly being collected. Light traps consist of rectangular plastic containers (17 · 28-cm opening, and 7 cm deep) with a fluorescent light placed on the short edge of the container. Within 1 h after sunset on each night of a river trip, collectors place light traps within 3 m of the river's edge, pour 250 mL of 95% ethanol into the trap, and turn on the fluorescent light. After 1 h of deployment, collectors turn off the light, transfer the contents into a 250-mL plastic bottle, label the sample, and recorded sample location, open and close times, and weather conditions on an associated data sheet. At the laboratory in Flagstaff, a team of scientists methodically goes through these samples making sure that each sample and its associated data are of high quality. Samples are then looked at under a microscope by a scientist. Each individual insect is identified, counted, and recorded on a datasheet. Data are then entered into a computer database where they can be queried, imported into statistical software, and used to answer questions.

Figure 1. Citizen scientists collecting a light trap sample along the Colorado River in Grand Canyon

Conclusions: What have we learned so far?

We have been monitoring in Grand Canyon and on the San Juan Rivers using light traps since 2012 – and we have learned a lot! In Grand Canyon, we've learned that aquatic insect communities downstream of Glen Canyon Dam have much lower species richness than insect communities downstream of other dams in the western United States. We think that this might be due to a dam management practice known as "hydropeaking" in which water is released through dam turbines in response to peak power demand. Hydropeaking creates a daily "artificial intertidal zone" that is lethal for aquatic insect eggs (Figure 2). Data collected by citizen scientists in Grand Canyon helped us come to this conclusion, because sections of river that have "high tide" at dusk (when insects are laying eggs) have lower midge abundance than sections of river that have "low tide" at dusk (Figure 3).

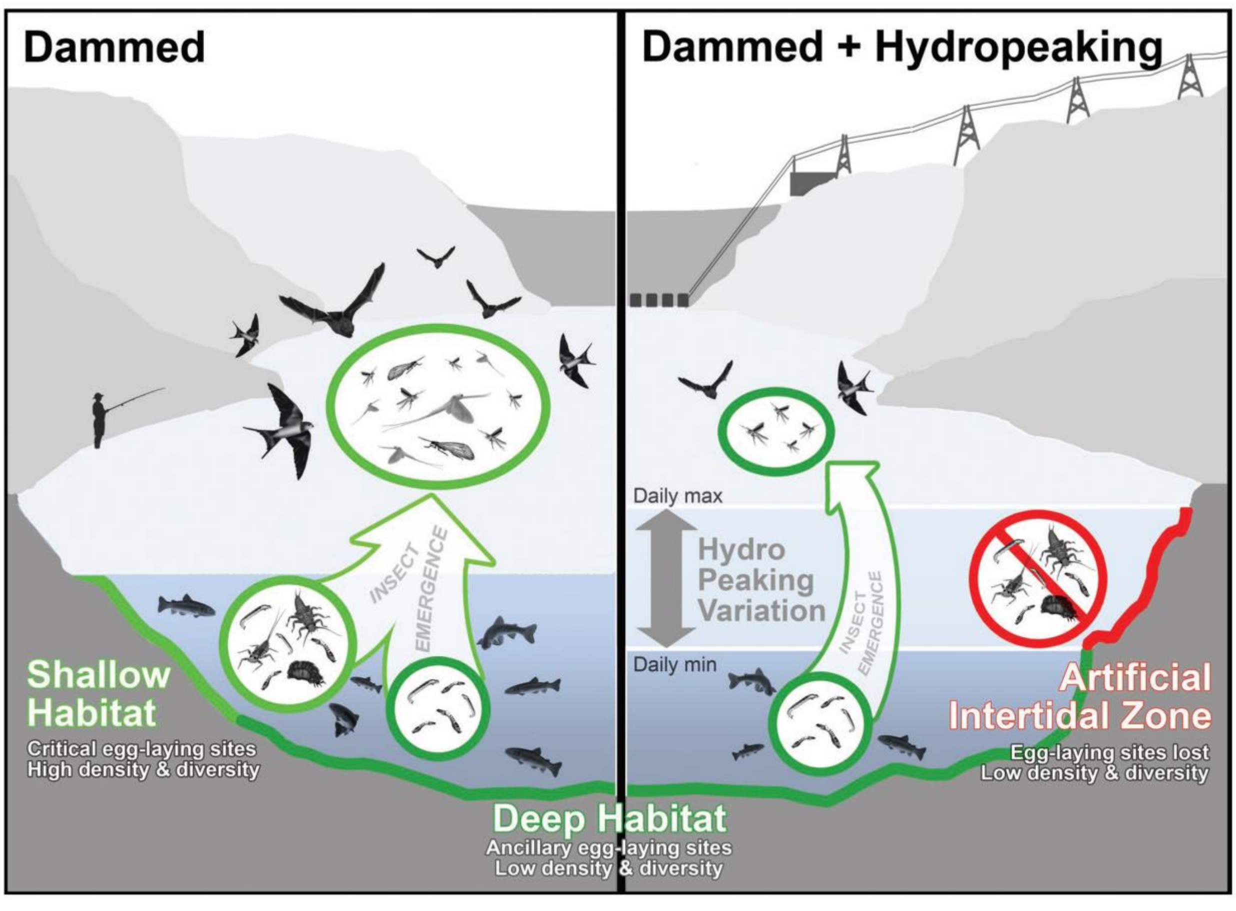


Figure 2. Rivers without hydropeaking practices likely provide better habitat for aquatic insects that lay their eggs along the rivers edge

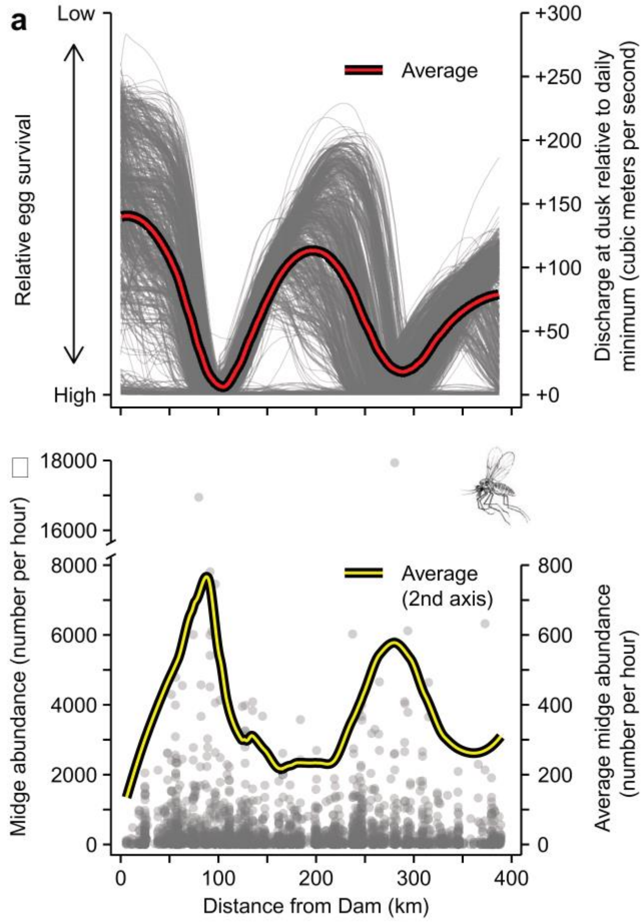


Figure 3. The abundance of midges captured in light trap samples in Grand Canyon in 2012-2015 was greatest in sections of river that had low tide at dusk. Eggs laid along the rivers shore at high tide get exposed to air when the tide drops, leading to desiccation and mortality.

Dissemination: What management or policies do you hope to address or change with this research?

(Scientist's Comment: I technically can't answer this question as a USGS employee! As scientists, we should go into every investigation trying to answer specific questions. We should not go into any kind of project "hoping" to address or change management. That's bias! I would be more comfortable with phrasing along the lines of: What are potential applications of these data for resource managers? Or, more specifically along the lines of dissemination: Have any publications or reports resulted from these data collections?

In 2018, stakeholders of the Glen Canyon Dam Adaptive Management Program initiated an experimental flow regime from Glen Canyon Dam. The experiment is informally known as “bug flows.” Bug Flows were released from May to August in 2018 and 2019. They are different from regular hydropeaking flows because they include 48 hours a week, Saturday and Sunday (when hydropower costs less) when flows are released at a low and steady discharge.

The following publications that use citizen science light trap data have been disseminated:

Scientific Journals and Publications

Metcalfe, A., Kennedy, T., Marks, C., Smith, A., Muehlbauer, J. (In review) Spatial genetic structuring of a widespread aquatic insect in the Colorado River Basin: evidence for *Hydropsyche oslari* species complex. Resubmitted to *Freshwater Science* with revisions June 2019.

Metcalfe, A., Muehlbauer, J., Kennedy, T., Yackulic, C., Dibble, K., Marks, C. (In review) Water temperature and flow determine the distribution of a common aquatic insect (*Hydropsyche* spp.) in the highly regulated Colorado River Basin. Submitted to Functional Ecology October 2019.

Metcalfe, A., Muehlbauer, J., Ford, Morgan, & Kennedy, T. 2020. Bug Flows: Don’t count your midges until they hatch. The Boatman’s Quarterly Review 32(4): 8-11.

Metcalfe, A. 2018. Aquatic insect distribution in the Colorado River Basin. Masters Thesis. Northern Arizona University. Available from Proquest (<https://search.proquest.com/docview/2051910485)

Metcalfe, A., Kennedy, T., & Fritzinger, C. 2016. Moth Mystery Hour. The Boatman’s Quarterly Review 27(4): 15-16.

Metcalfe, A., Kennedy, T., & Muehlbauer, J. 2016. Phenology of the adult angel lichen moth (Cisthene angelus) in Grand Canyon, USA. The Southwestern Naturalist 61: 233–240. DOI: 10.1894/0038-4909-61.3.233

Kortenhoeven, E., Muehlbauer, J., & Kennedy, T. 2016. Hydropower waves, insect eggs, and citizen science: whats up with the aquatic food base in Grand Canyon? The Boatman’s Quarterly Review 29(3): 19-22.

Metcalfe, A., Kennedy, T. & Muehlbauer, J. 2016. Angel lichen moth abundance and morphology data, Grand Canyon, AZ, 2012. US Geological Survey Data Release. DOI: 10.5066/F7154F5S

Kennedy, T., Muehlbauer, J., Yackulic, C., Lytle, D., Miller, S., Dibble, K., Kortenhoeven, E., Metcalfe, A., & Baxter, C. 2016. Flow management for hydropower extirpates aquatic insects, undermining river food webs. BioScience 77: 561–575. DOI: 10.1093/biosci/biw059.

External media coverage

USGS (2019) Podcast about Citizen Science. “Outstanding in the Field: Citizen Science – Your Data in Action” <https://www.usgs.gov/media/audio/outstanding-field-ep-2-citizen-science-your-data-action>

Arizona PBS (2019) Documentary about the future of Grand Canyon National Park. https://azpbs.org/2019/02/beyond-the-rim-the-next-100-years-of-grand-canyon-national-park/

National Geographic (2016) At 17 million tears old, Grand Canyon still has lessons to teach. <https://video.nationalgeographic.com/video/short-film-showcase/00000156-e673-dbd5-add6-fff3e6d30000>

Scientific American (2019) Article about conducting aquatic ecology research in Grand Canyon. https://www.scientificamerican.com/article/re-engineering-the-colorado-riverto-save-the-grand-canyon

Associated Press, picked up by The New York Times, The Washington Post, US News and World Report, and others (2018) Story describing the Bug Flows experiment <https://apnews.com/accec230d442406fa7bedf4af219c5d1>

Bureau of Reclamation (2018) Official press release describing Bug Flows experiment https://www.usbr.gov/newsroom/newsrelease/detail.cfm?RecordID=62133 13)

Undark Magazine (2018) Essay about conducting aquatic ecology research in Grand Canyon https://undark.org/article/wilo-doyle-colorado-river-insects/

National Public Radio KNAU (2017) Story about *Cisthene angelus* paper. <https://www.knau.org/post/earth-notes-angel-lichen-moths>

Science Magazine (2016) Scientific reinterpretation of the BioScience hydropeaking paper. http://science.sciencemag.org/content/353/6304/1099

Arizona Daily Sun (2016) Story about BioScience hydropeaking paper. http://azdailysun.com/news/local/dam-management-plan-aims-to-boost-native-fishbugs/article_8f2a949c-03ee-5f96-86b4-eda52fd0ffbf.html

National Public Radio KNAU (2016) Story about BioScience hydropeaking paper. http://knau.org/post/study-hydropower-decimates-aquatic-insects-coloradoriver#stream/0

High Country News (2016) Reinterpretation of BioScience hydropeaking paper. https://www.hcn.org/issues/48.12/new-measures-could-reduce-glen-canyon-damsimpact-on-the-grand-canyon-a-bit

Columbia Basin Fish & Wildlife News Bulletin (2016) Summary of BioScience hydropeaking paper. http://www.cbbulletin.com/436660.aspx

American Fisheries Society (2016) Summary of BioScience hydropeaking paper. https://fisheries.org/2016/05/citizen-science-reveals-how-river-food-webs-areaffected-by-hydropower-practices/ =

Conservation Magazine (2016) Summary of BioScience hydropeaking paper. http://conservationmagazine.org/2016/05/simple-trick-make-dams-less-damagingriver-ecosystems/

USGS (2016) Official press release for BioScience hydropeaking paper. <https://www.usgs.gov/news/river-food-webs-threatened-widespread-hydropowerpractice>

Oregon State University (2016) Official press releases for BioScience hydropeaking paper. https://today.oregonstate.edu/archives/2016/may/hydropeaking-river-waterlevels-disrupting-insect-survival-river-ecosystems

BioScience (2016) Editor's choice selection for BioScience hydropeaking paper. <http://bioscienceaibs.libsyn.com/hydroelectric-dams-kill-insects-wreak-havoc-withfood-webs>

Are there additional follow-up questions that resulted from this project?

The decision by managers to implement Bug Flows in 2018 led us to a very important follow-up question: Do stable flows increase aquatic insect abundance and diversity in Grand Canyon?

Appendix G

Project Summary: Final Acoustic Bat Monitoring Project

Project Name:	Citizen Science Based Acoustic Bat Monitoring Project
Research Entity:	Glen Canyon National Recreation Area
Your Name (and anyone else's names involved in the project you wish to include):	Lonnie Pilkington
Are you, or someone else involved in this project, able to connect with Grand Canyon Youth participants prior to their expedition?	
Observe & Wonder:	We noticed the spread of White Nose Syndrome, and wanted to know how it might affect Southwest bat species. White Nose Syndrome (WNS) is a wildlife disease that affects hibernating bats and has killed millions of bats primarily in the northeast/eastern United States. Recently, WNS has been shown to be spreading westward due to the social nature of bats. Currently, there is a lack of understanding of the distribution of bat species in the Southwest, therefore if WNS makes its way to the Southwest, it will be difficult to understand how it is affecting Southwest bats. No bats have yet been found to have White-Nose Syndrome in Glen Canyon National Recreation Area as of yet, but the park does provide habitat to known susceptible species. This research is an effort to document bat species distribution and behavior to better prepare for the potential arrival of WNS in the Southwest.
Question:	What are the spring, summer, and fall distributions of bat species that are susceptible

What are the initial research questions?	to white-nose syndrome in this presumed white-nose syndrome-free area within Glen Canyon National Recreation Area, and how do these change over time? Are bat conservation efforts improved by involving citizen scientists in bat monitoring and education efforts? Will data collections yield high quality data that can be used to influence management decisions?
Develop Hypothesis: What do we think the answer may be?	Distribution data on bat species susceptible to white-nose syndrome is greatly lacking in many areas of North America including Glen Canyon. Therefore, we implemented this citizen science study to fill data gaps, engage the public in bat conservation, and inform future management decisions.
Plan & Test: How are we going to try to answer this question?	Citizen scientists and Glen Canyon Biological Science Technicians will use bio-acoustic hardware and software to collect and analyze acoustic recordings. All acoustic recordings will be entered into the National Park Service Bats Acoustic Survey Database and North American Bat Monitoring Program Bat Population Database. Data collections will contribute to a statistically robust dataset that will enable researchers to make inferences about bat species distribution and threats on a local, regional, and continent-wide scale.
Analyze & Interpret: What have we learned so far?	Between 2016 and 2018, Citizen Scientists collected 47,152 acoustic call files within Glen Canyon, 21,645 of which were identified to species. Sonobat software was used to confirm presence of 10 bat species susceptible to white-nose syndrome. Citizen scientists recorded the first GLCA record of the greater mastiff bat Citizen scientists confirmed the presence of the following species: Allen's big-eared bat, hoary bat, and canyon bat

	Young and old citizen scientists are generally very interested in learning about bio-acoustic technology and learning how they can further bat conservation efforts.
Conclude and Report: What are potential applications of this research for resource managers?	We hope to develop an efficient and effective citizen science-based bat monitoring and education program that can easily duplicated by federal and non-federal entities to promote bat conservation efforts.
Reflect and Rethink: Are there additional follow-up questions that resulted from this project?	How will white-nose syndrome influence species richness along the San Juan and Colorado Rivers? Will significant differences in species distribution result between these two major tributaries?

Appendix H

Science Summary: Final Aquatic Insect Monitoring

Project Name:	Aquatic Insect Light Trap Monitoring
Research Entity:	Grand Canyon Monitoring and Research Center / United States Geological Survey
Your Name (and anyone else's names involved in the project you wish to include):	Anya Metcalfe, Ted Kennedy, Cheyenne Szydlo
Are you, or someone else involved in this project, able to connect with Grand Canyon Youth participants prior to their expedition?	
Observe & Wonder:	We noticed a lack of insects in Grand Canyon and wanted to know why that was. Aquatic insects are a fundamental component of a healthy river ecosystem. Most aquatic insects spend their juvenile life stages (egg, larva, pupa) in the river and their winged adult life stage flying along the riparian corridor. Most aquatic insect monitoring programs collect aquatic insects during their juvenile life stages by sampling the benthic zone – the river bottom. However, it is challenging to access the bottom of the river in large and swift rivers like the Colorado and San Juan rivers. To overcome this problem, we designed a sampling protocol that targets the winged adult life stage of aquatic insects. Using this new protocol, we teamed up with river guides and Grand Canyon Youth to sample large rivers of the southwest and monitor aquatic insect populations.
Question:	What aquatic insects live in these rivers? How abundant are these taxa? Do different rivers have different insect communities?

What are the initial research questions?	How do different water temperatures affect insect species richness (number of unique species) and abundance (measured as total insects captured per hour)? How do different flows, including managed flows released from dams, affect insect communities and abundance?
<u>Develop Hypothesis:</u> What do we think the answer may be?	We predict that aquatic insect communities are affected by water temperatures and flows in rivers. We expect that we will see differences in aquatic insect species richness and abundance in different rivers and in response to variation in environmental conditions.
<u>Plan & Test:</u> How are we going to try to answer this question?	Working with Citizen Scientists allows us to have an effective monitoring program where light trap samples (see photo) are constantly being collected. Light traps consist of rectangular plastic containers (17 · 28-cm opening, and 7 cm deep) with a fluorescent light placed on the short edge of the container. Within 1 h after sunset on each night of a river trip, collectors place light traps within 3 m of the river's edge, pour 250 mL of 95% ethanol into the trap, and turn on the fluorescent light. After 1 h of deployment, collectors turn off the light, transfer the contents into a 250-mL plastic bottle, label the sample, and recorded sample location, open and close times, and weather conditions on an associated data sheet. At the laboratory in Flagstaff, a team of scientists methodically goes through these samples making sure that each sample and its associated data are of high quality. Samples are then looked at under a microscope by a scientist. Each individual insect is identified, counted, and recorded on a datasheet. Data are then entered into a computer database where they can be queried, imported into statistical software, and used to answer questions.

<table>
<tr><td></td><td>
Figure 1. Citizen scientists collecting a light trap sample along the Colorado River in Grand Canyon</td></tr>
<tr><td><u>Analyze & Interpret:</u>

What have we learned so far?</td><td>We have been monitoring in Grand Canyon and on the San Juan Rivers using light traps since 2012 – and we have learned a lot! In Grand Canyon, we’ve learned that aquatic insect communities downstream of Glen Canyon Dam have much lower species richness than insect communities downstream of other dams in the western United States. We think that this might be due to a dam management practice known as “hydropeaking” in which water is released through dam turbines in response to peak power demand. Hydropeaking creates a daily “artificial intertidal zone” that is lethal for aquatic insect eggs (Figure 2). Data collected by citizen scientists in Grand Canyon helped us come to this conclusion, because sections of river that have “high tide” at dusk (when insects are laying eggs) have lower midge abundance than sections of river that have “low tide” at dusk (Figure 3).</td></tr>
</table>

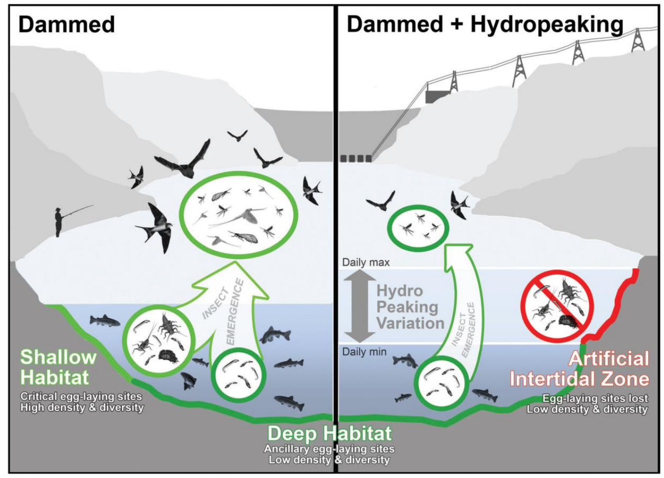


Figure 2. Rivers without hydropeaking practices likely provide better habitat for aquatic insects that lay their eggs along the rivers edge

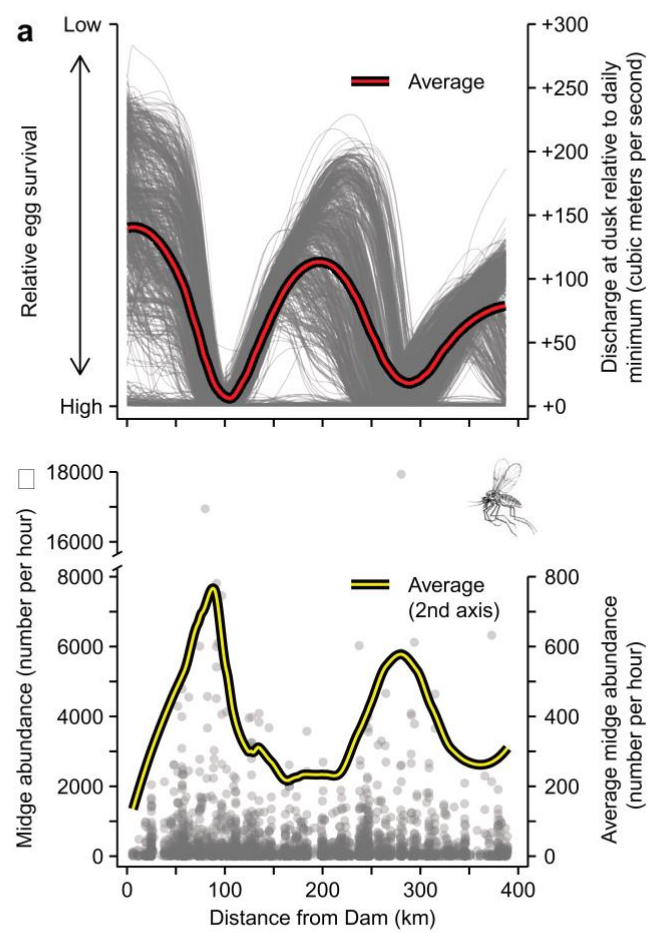


Figure 3. The abundance of midges captured in light trap samples in Grand Canyon in 2012-2015 was greatest in sections of river that

	had low tide at dusk. Eggs laid along the rivers shore at high tide get exposed to air when the tide drops, leading to desiccation and mortality.
Conclude & Report: What are potential applications of this research for resource managers?	In 2018, stakeholders of the Glen Canyon Dam Adaptive Management Program initiated an experimental flow regime from Glen Canyon Dam. The experiment is informally known as "bug flows." Bug Flows were released from May to August in 2018 and 2019. They are different from regular hydropeaking flows because they include 48 hours a week, Saturday and Sunday (when hydropower costs less) when flows are released at a low and steady discharge.
Reflect & Rethink: Are there additional follow-up questions that resulted from this project?	The decision by managers to implement Bug Flows in 2018 led us to a very important follow-up question: Do stable flows increase aquatic insect abundance and diversity in Grand Canyon?

Appendix I

Trip Coordinators Intro to Citizen Science

GRAND CANYON YOUTH
discover your nature

P.O. Box 23376 Flagstaff, AZ 86002 Phone: 928.773.7921 Fax: 928.774.8941
info@gcyouth.org www.gcyouth.org

Hello _____,

It's now time to talk about the Citizen Science projects that will be a part of your expedition at Grand Canyon Youth. Over the past 20 years, GCY has been involved with about 40 different Citizen Science projects, collaborating with research entities to collect data for such as the Grand Canyon Research and Monitoring Center, National Park Service and Northern Arizona University. GCY collaborates with science organizations to provide an opportunity for youth to engage with a Citizen Science project on most overnight expeditions. Data collected on these expeditions is sent to scientists to be used in their ongoing scientific research.

Citizen Science is public participation in scientific research, where members of the public work to gather large quantities of data that would be otherwise difficult for scientists to collect alone. At GCY, Citizen Science provides a place-based learning experience for youth to engage with scientific research On-Expedition. Youth participate in the scientific method and are actively engaged in various steps of inquiry. Citizen Science serves as a unique, interdisciplinary bridge between science education and environmental education, bringing the two together through experiential, place-based learning.

While the theme of your expedition may not be natural sciences, engagement with Citizen Science can enhance other learning areas youth will be engaging with on your expedition. We have developed a model that uses scientific inquiry to frame these Citizen Science projects. This provides a consistent introduction of projects to Trip Coordinators, youth, and guides, and translates it into an approachable the format for discussing and participating in these projects while on your GCY expedition.

The next step in this process is to assist you in connecting this aspect of your expedition with your program's theme – ensuring authentic integration of Citizen Science of youth's expedition experience. In the Program Development Packet, we will assist in integrating Citizen Science with your expedition's goals where it is appropriate. We will also send you summaries of the projects that you will be collecting data for on your expedition to give you some information about these prior to your expedition. There is an optional lesson plan included, which has an activity using the science summaries for you to use if you wish. These summaries were completed by scientists working on these projects, and were designed to be shared with youth, guides, and Trip Coordinators.

A Science Journal will be included in your On-Expedition Citizen Science materials. This journal includes discussion questions to engage with, and shortened project summaries. We hope you use this tool to encourage inquiry and scientific agency on your expedition!

Appendix J

Program Development Packet Integration

Program Development Packet Goals: Citizen Science contributions to expedition goals

List of goals and related sub-goals:

1. Stewardship
    a. Storytelling/art/poetry
    b. Reflections
    c. Connection to place
2. Personal Growth
    a. Leadership skills
    b. Responsibility
    c. Develop observation skills
    d. Reflections
    e. Identify new capacities in self
    f. Discuss and give presentations
3. Team Building and Communication
    a. Effective communication
    b. Group relationships
4. Power of Place/Place-Based Education
    a. Connection to place
    b. More knowledgeable about place
5. Learn about the river’s ecology/environmental learning
    a. Think global, act local

b. Citizen Science

c. River as a living thing

Goals and corresponding Citizen Science connections for PDP: How citizen science connects to your expedition's specific goal(s)

1. Stewardship
   a. Citizen Science is one form of stewardship, as youth will participate in ongoing scientific research by collecting data on their expedition. Many forms of stewardship exist – and youth are encouraged to reflect on what these may be throughout the expedition as they paint, draw, write, photograph, play music, or journal throughout their experience.
2. Personal Growth
   a. Through participation in Citizen Science, youth are actively contributing to ongoing scientific research, and contributing data that is used in ecosystem monitoring, and in some cases, influences policy in a way that hopes to enhance the ecosystem and environment. While collecting data, youth will learn new skills, and engage with questions asking about their involvement and contributions to this project, and how to apply what they have learned to their own personal interests.
3. Team Building and Communication
   a. On your expedition, youth will rotate through a series of "crews" or "teams" each night. One of these teams involves collecting data for an ongoing scientific research project that GCY contributes to. Youth will work together to engage with scientific research, sharing what they learn with the group.

4. Place
    a. Through Citizen Science, youth will engage with some specific and at times very small parts of the ecosystem – such as aquatic insects. Through engaging with some of these smaller systems within the ecosystem, youth continue to foster their connection to the greater place through their experiences.
5. Environment
    a. The Citizen Science projects that youth will be participating in are primarily concerned with the immediate environment and the health of the ecosystem – but some of the data collected contributes to national databases that help inform effects of climate change, and other global environmental health concerns.

Appendix K

Lesson Plan

Introduction to Citizen Science Lesson Plan

Grand Canyon Youth

1. Goal of Lesson:
    a. Introduce Citizen Science as a method for research and explore connections between Citizen Science and various forms of environmental stewardship.
2. Three Objectives of Lesson:
    a. Establish basic definition of Citizen Science among participants and introduce GCY's Citizen Science projects
    b. Identify observations and questions as fundamentals for scientific research
    c. Connect youth's own interests to environmental stewardship
3. Audience:
    a. Middle School – High School students
    b. Previous relevant information can be little scientific background to extensive
    c. Environmental literacy stage – can be highly variable
    d. Learning expectations:
        i. Develop baseline understanding of what Citizen Science is
        ii. Understand fundamentals of scientific research and identify observations, questions, and the early stages of hypothesis as these fundamentals
        iii. Explore concepts of environmental stewardship and the various forms that stewardship can take

4. Duration:
    a. 45-60 minutes
5. Location:
    a. Classroom/indoor setting – whiteboards or other similar sharing tools are helpful for some of these activities. This lesson plan does not require the use of technology such as PowerPoint – but feel free to supplement equipment and tools however you see fit!
    b. This can absolutely be done outside! Weather permitting and at the personal preference of activity facilitator(s). Additional tips on conducting this lesson in an outdoor setting can be found in the following section.
6. Equipment:
    a. Citizen Science project outlines (attached in email) print enough copies for groups of 3-5 to get one of the outlines or both, this depends on how much time facilitator wants to dedicate to this lesson and project introduction.
    b. Paper and pencils/colored pencils for Middle School groups are encouraged for drawing activity but not necessary. One to two sheets of paper per group is sufficient.
        i. If done outside in a large enough space, where it is appropriate and no damage to environment will take place (sand box, large dirt area empty of vegetation, sandy beach, etc.), sand/dirt drawings would work also to remove need for extra paper!

c. Sticky notes or small notecards are good if you choose to incorporate “I Wonder” board – “I Wonder” activity can be done without the board – but it creates a fun visual to engage with!

d. If done outside – facilitator may want to utilize a form of a portable whiteboard of sorts for both their recording purposes and for the “I Wonder” board.

   i. If you remove the top of a rubber storage bin (or have anything with a large and relatively flat surface) and tape a large sheet of paper to it, this can work very well as a makeshift whiteboard!

7. Management and Safety Considerations:

   a. If done outside – consider group management and establishing perimeters/boundaries for when groups split up into smaller discussion circles.

8. Content and Methods:

   a. Pre-Engage: Lesson introduction (<5 minutes)

      i. Introduce participants (if necessary)

         1. If participants do not know each other, an introduction circle that relates to this lesson could be going around and saying your name, and a favorite subject in school or hobby.

      ii. Reminder of GCY introduction

         1. We are going on a Grand Canyon Youth expedition on ____ River for dates ____ through ____!

         2. On this expedition, we will be contributing to scientific research, by participating in what is called Citizen Science.

3. Citizen science: is public participation in scientific research, where any members of the public can assist in collecting large quantities of data that would be difficult for scientists to gather by themselves.

iii. Goals of lesson: learn about Citizen Science and the projects we will be participating in, how these contribute and connect to research and environmental stewardship, and how youth's interests can also relate to environmental stewardship.

b. Engage: (5-10 minutes)

i. Divide participants into groups of 3-5

1. Middle school: draw a scientist – and share what about the drawing indicates that they are a scientist.
2. High school or for a little more challenge: describe a scientist – discuss what makes them a scientist.
3. All groups: share these drawings/descriptions – what do the different groups drawings and descriptions have in common?
    a. Facilitator can either begin to record these onto a white board or on a piece of paper to revisit later.
    b. Some common themes that should emerge are making an observation, asking a question, and figuring out how to answer the question.

c. Ask: what is the scientific method? Entire group works together to name off all of the steps and facilitator can write them down:

i. Observation
ii. Question
iii. Hypothesis
iv. Methods
v. Analysis
vi. Conclusions and sharing

4. Facilitator: here is where you can bring up the scientific method, or scientific inquiry as the process and practice of science. Therefore, anyone who engages with and participates in the process of science, is a scientist.

c. Explore: (15-20 minutes)

i. Remaining in their groups, facilitator hands out Citizen Science project outlines provided by Grand Canyon Youth. Depending on how much time facilitator wishes to dedicate to this activity, you can either give all groups all of the outlines or divide the outlines of the projects among the groups. We recommend at least one outline of each project be handed out, so that the entire group is introduced to each project.

1. In groups, go over the project outlines, helping each other to understand any new concepts, and working together to pull out the fundamentals of each project.

2. Each group shares and the entire group discusses – what are the initial observations? What are the questions? Facilitator can again record these on a white board or on a piece of paper to revisit later.

d. Explain: (5-10 minutes)

   i. This can be done to whatever extent the facilitator feels comfortable explaining Citizen Science – we have provided some talking points and explanations, but this is probably the hardest section to facilitate unless you are familiar with Citizen Science and these projects!

      1. Citizen Science at GCY

         a. Some scientists need large amounts of data to be collected, and sometimes over the span of multiple seasons/years.

         b. Some scientists need large amounts of data collected in hard to access places – like on a river that would require 3+ days in the field.

         c. Partnering with Citizen Scientists allow scientists to collect large amounts of data in sometimes hard to access places that would otherwise be very difficult for them to collect on their own.

         d. In 2019, GCY led 76 expeditions on the Verde, San Juan, and Colorado Rivers – most of which collected data for Citizen Science, which is a huge contribution to scientific research.

      2. Current Citizen Science Projects at GCY:

a. This lesson plan is designed to be able to introduce any and all Citizen Science projects at GCY, so no project-specific information is included in the lesson plan – so we encourage you to review the attached project outlines to gain an understanding of the projects you will be collecting data for on your expedition, and pulling out as many points as you feel comfortable discussing in this portion.

b. Some key points we encourage visiting that don't require extensive knowledge of the projects and subject areas themselves are the observations and research questions, and the dissemination and follow-up questions. This is to create a clear connection that science begins with observations and questions, but also often results in even more questions.

c. Another point we encourage you to highlight is that this science and this data has goals for contributions to management – this will be addressed in the following section in talking about environmental stewardship. These projects often have goals to contribute to a growing understanding of the places you will be visiting on your expedition, so as to know how to best protect and support them. This is important to recognize that science is meant to be shared and learned from by everyone – not just the scientists who are asking these questions!

e. Elaborate: (10-15 minutes)

   i. "I Wonder" Board

   ii. If science begins with an observation and a question – what are some that we have? This is a good time to brainstorm briefly about what kinds of questions youth or scientists can have – about anything! They can either pertain to the projects or to youth's own interests, and we encourage youth to ask questions outside of the realm of traditional "science" – ask questions about people, places, art, music, animals, etc.

   iii. Have each student write down (this is where sticky notes come in!) a sentence following a structure such as "I noticed _____ and I wonder ______."

   iv. Have youth compile their sticky notes based on general areas – are some of these questions about biology/ecology? Are others social? Are some about art? This is where the "I Wonder" board starts to form.

   v. Introduce environmental stewardship as responsible use and protection of the environment – can elaborate more if facilitator wants to spend more time here!

   vi. Remember the pieces towards the end of the Citizen Science project outlines that talked about addressing policy and management. If this scientific research can be considered environmental stewardship since it asks questions about the places in order to inform their protection – what are other forms of stewardship that relate to youth's interests? What areas from the "I Wonder" board can relate to stewardship?

1. A local example we like to use is art – such as Amy Martin, a Flagstaff photographer who uses her photographs as a form of environmental stewardship.
2. Encourage students to recognize their roles as Citizen Scientists in the scientific process – but also to think creatively about stewardship and how to be an environmental steward – even if they aren't a scientist!

f. Evaluate: (5-10 minutes)

i. Revisit scientist drawings and descriptions: would you change anything or add anything to these?

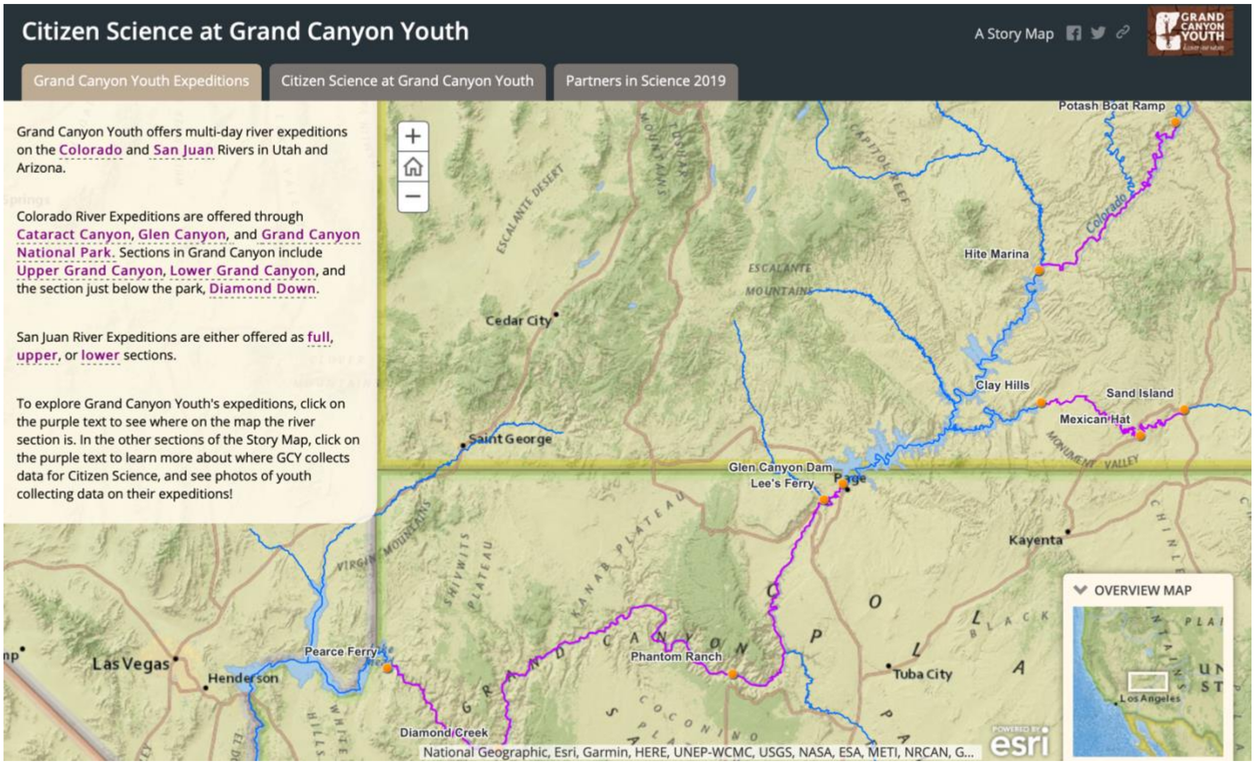
ii. How would you draw or describe a Citizen Scientist? An environmental steward?

iii. These themes of engagement in the scientific method and various forms of environmental stewardship will be re-visited and re-examined on your GCY expedition – and we encourage you to visit our suggestions as per how Citizen Science compliments and builds on your specific group goals as expressed in your Program Development Packet!

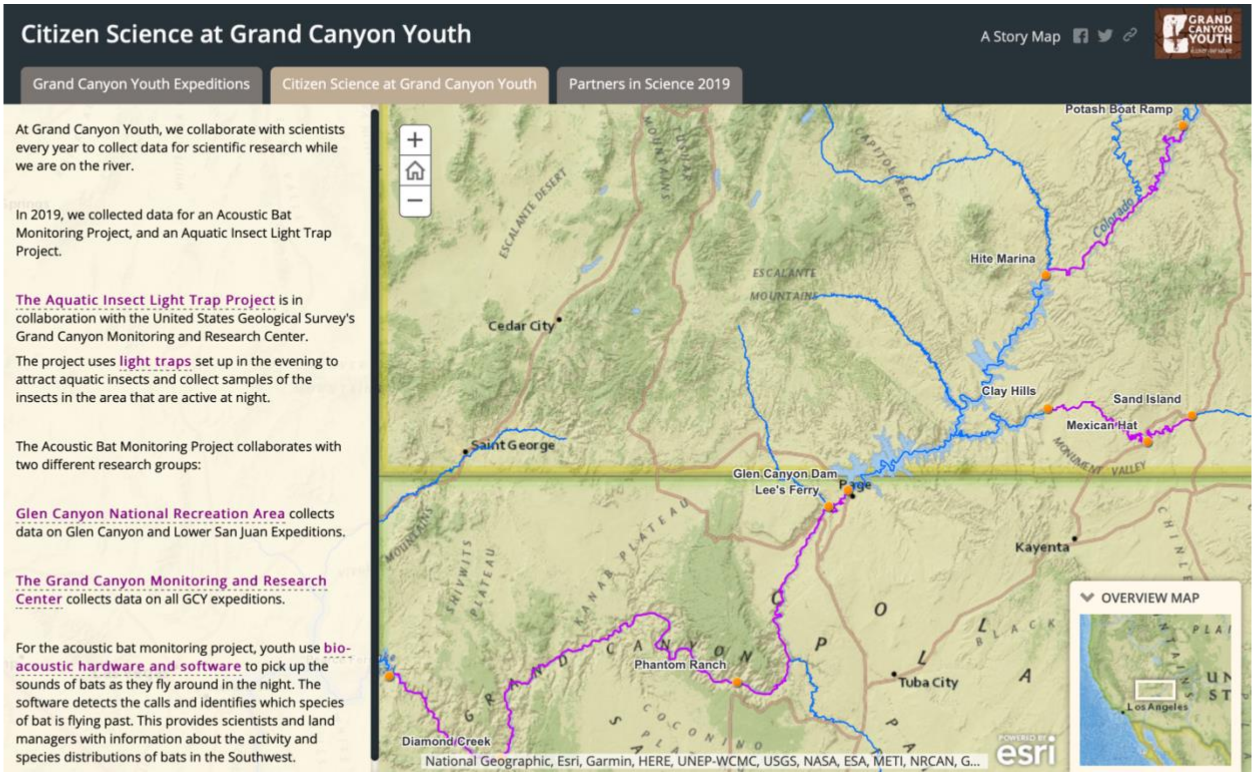
Appendix L

Story Map Screenshots

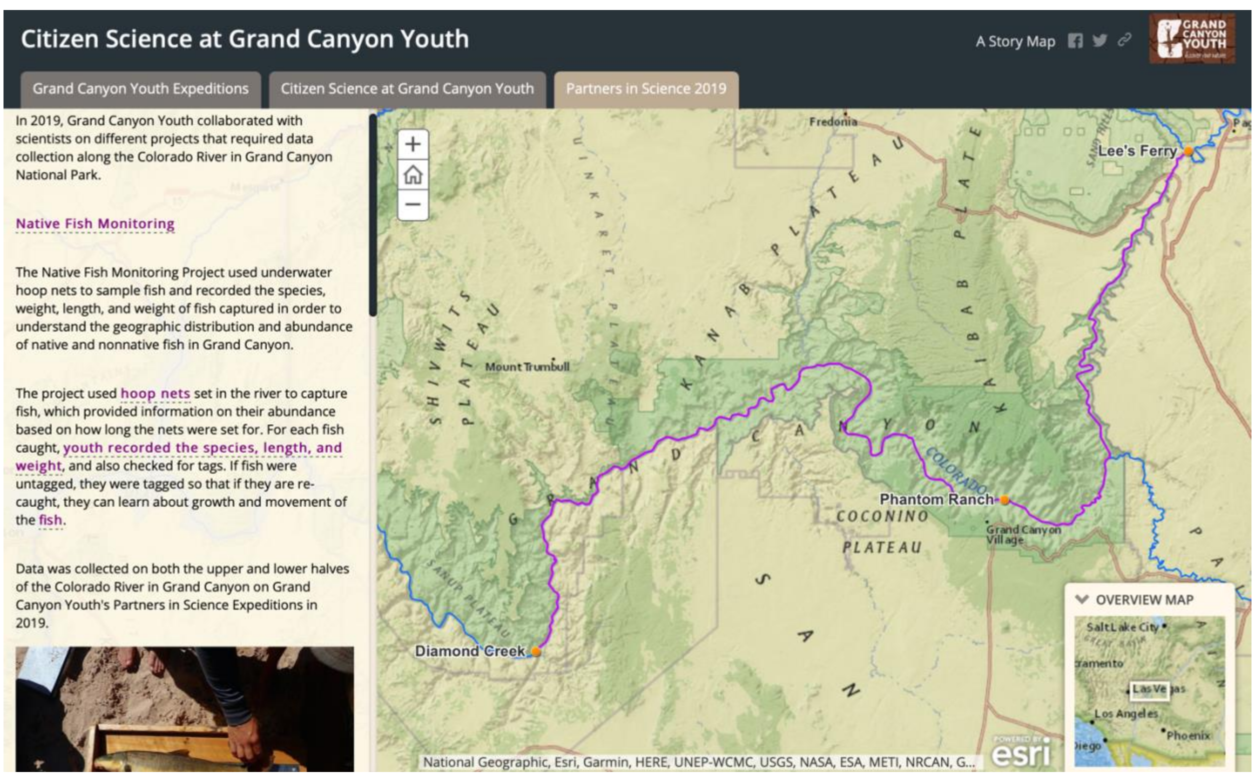
Story Map URL:
http://grail.maps.arcgis.com/apps/MapSeries/index.html?appid=7e94bdaab6ae4372ac78da5718f251ba



Screenshot of Introduction page of Story Map Series for Citizen Science at Grand Canyon Youth



Screenshot of Ongoing Citizen Science Projects of Story Map Series at Grand Canyon Youth



Screenshot of the Partners in Science page of Story Map Series

Appendix M

Youth Citizen Science Half Sheet

Yay Science!

On your upcoming expedition at Grand Canyon Youth, you will have the opportunity to collect data for scientific research as a Citizen Scientist!

Citizen Science is when members of the public – like you – assist scientists in collecting large amounts of data that would be difficult for them to do by themselves, such as on a river expedition that requires 3-4 days in the wilderness.

You will have at least one opportunity to participate in the scientific research project, and your guides will teach you about the data collection process when you are on the river.

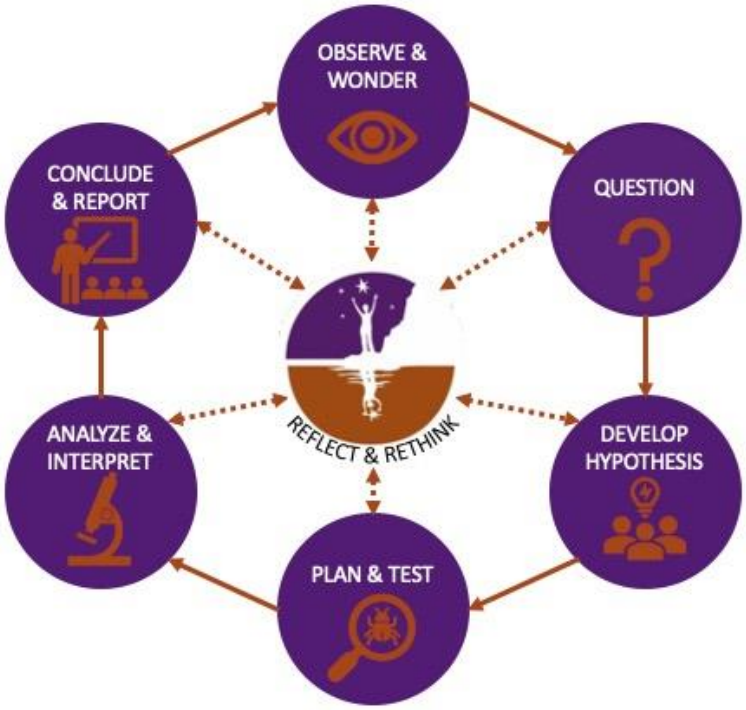
We hope you are as excited as we are to interact with science! You will get to learn about the observations and questions that led to the project, and collect data to be analyzed by scientists Scientists use this data to inform land management, and as a Citizen Scientist, you get to contribute to their project. Science is all about asking questions, so if you have any before, during, or after your expedition, ask away!

Appendix N

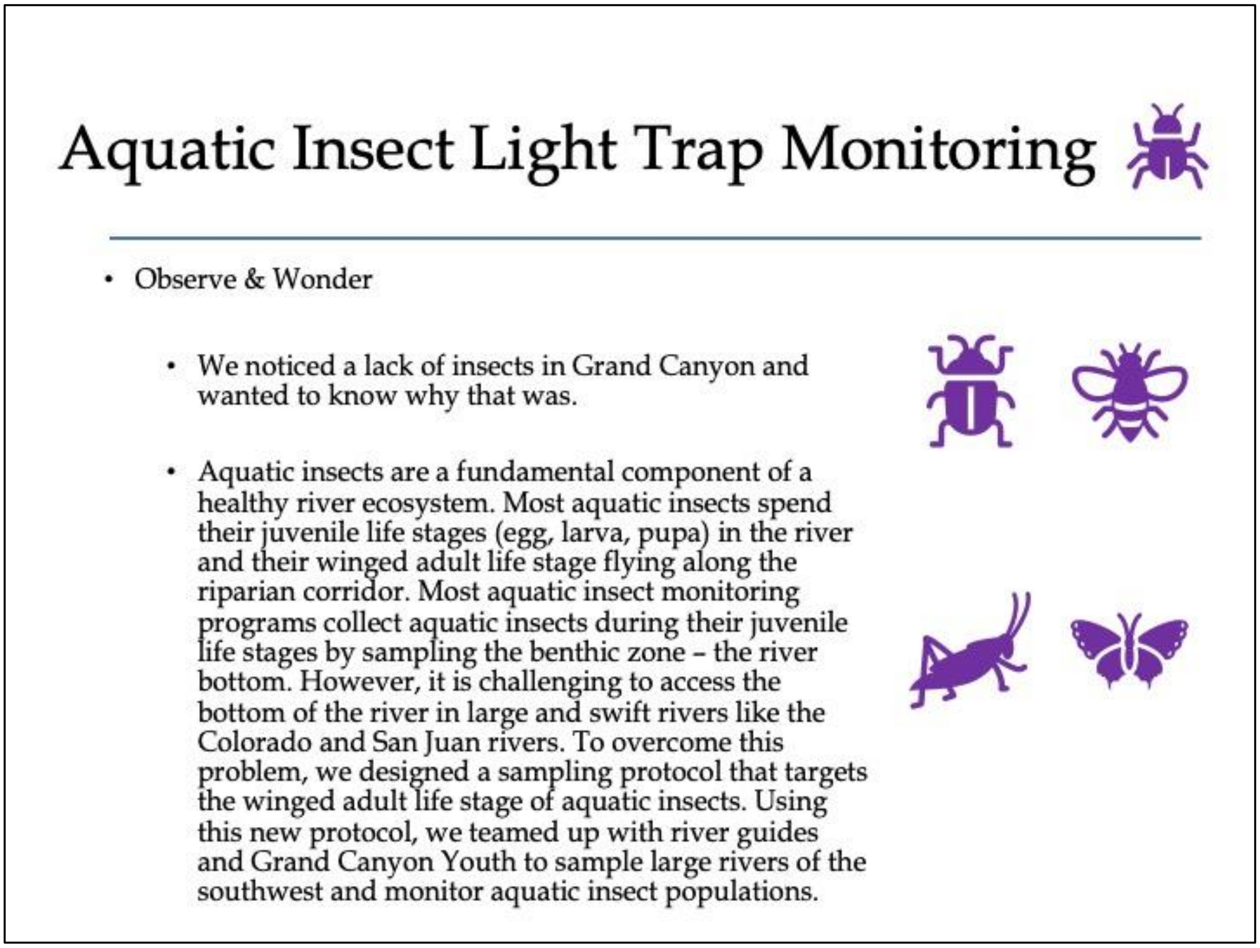
Science Journal Pages

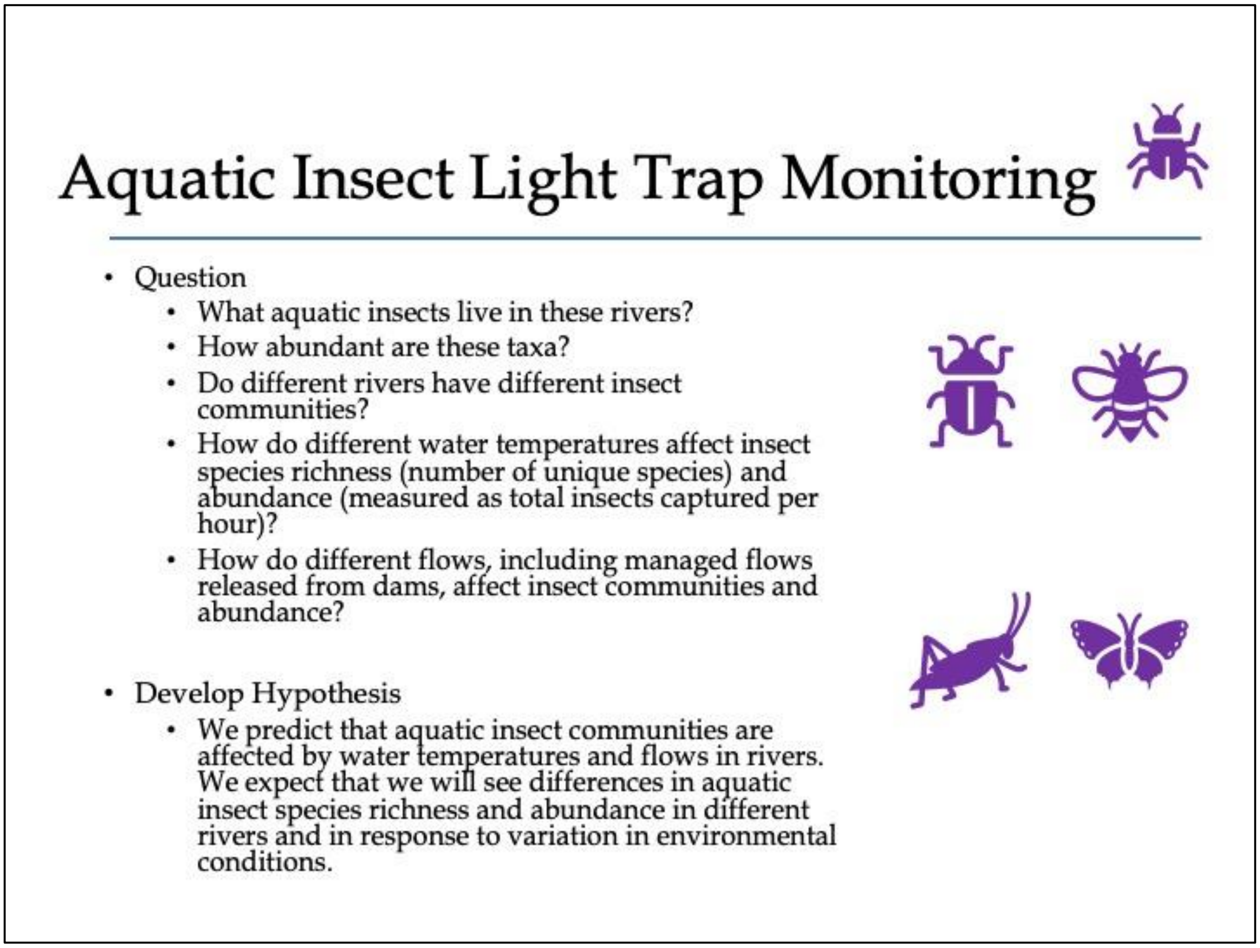
Grand Canyon Youth
Science Journal

GRAND
CANYON
YOUTH
discover your nature


OBSERVE & WONDER
QUESTION
DEVELOP HYPOTHESIS
PLAN & TEST
ANALYZE & INTERPRET
CONCLUDE & REPORT
REFLECT & RETHINK


Aquatic Insect Light Trap Monitoring
• Grand Canyon Monitoring and Research Center
• United States Geological Survey


Aquatic Insect Light Trap Monitoring
• Observe & Wonder
• We noticed a lack of insects in Grand Canyon and wanted to know why that was.
• Aquatic insects are a fundamental component of a healthy river ecosystem. Most aquatic insects spend their juvenile life stages (egg, larva, pupa) in the river and their winged adult life stage flying along the riparian corridor. Most aquatic insect monitoring programs collect aquatic insects during their juvenile life stages by sampling the benthic zone – the river bottom. However, it is challenging to access the bottom of the river in large and swift rivers like the Colorado and San Juan rivers. To overcome this problem, we designed a sampling protocol that targets the winged adult life stage of aquatic insects. Using this new protocol, we teamed up with river guides and Grand Canyon Youth to sample large rivers of the southwest and monitor aquatic insect populations.


Aquatic Insect Light Trap Monitoring
• Question
• What aquatic insects live in these rivers?
• How abundant are these taxa?
• Do different rivers have different insect communities?
• How do different water temperatures affect insect species richness (number of unique species) and abundance (measured as total insects captured per hour)?
• How do different flows, including managed flows released from dams, affect insect communities and abundance?
• Develop Hypothesis
• We predict that aquatic insect communities are affected by water temperatures and flows in rivers. We expect that we will see differences in aquatic insect species richness and abundance in different rivers and in response to variation in environmental conditions.

Aquatic Insect Light Trap Monitoring

- Plan & Test
  - Working with Citizen Scientists allows us to have an effective monitoring program where light trap samples (see photo) are constantly being collected. Light traps consist of rectangular plastic containers (17 · 28-cm opening, and 7 cm deep) with a fluorescent light placed on the short edge of the container. Within 1 h after sunset on each night of a river trip, collectors place light traps within 3 m of the river's edge, pour 250 mL of 95% ethanol into the trap, and turn on the fluorescent light. After 1 h of deployment, collectors turn off the light, transfer the contents into a 250-mL plastic bottle, label the sample, and recorded sample location, open and close times, and weather conditions on an associated data sheet. At the laboratory in Flagstaff, a team of scientists methodically goes through these samples making sure that each sample and its associated data are of high quality. Samples are then looked at under a microscope by a scientist. Each individual insect is identified, counted, and recorded on a datasheet. Data are then entered into a computer database where they can be queried, imported into statistical software, and used to answer questions.

Aquatic Insect Light Trap Monitoring

- Plan & Test
- Figure 1. Citizen scientists collecting a light trap sample along the Colorado River in Grand Canyon

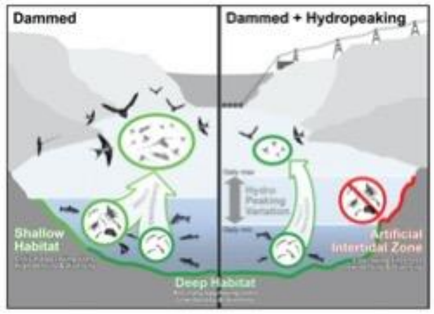
Aquatic Insect Light Trap Monitoring

- Analyze & Interpret
  - We have been monitoring in Grand Canyon and on the San Juan Rivers using light traps since 2012 – and we have learned a lot! In Grand Canyon, we've learned that aquatic insect communities downstream of Glen Canyon Dam have much lower species richness than insect communities downstream of other dams in the western United States. We think that this might be due to a dam management practice known as "hydropeaking" in which water is released through dam turbines in response to peak power demand. Hydropeaking creates a daily "artificial intertidal zone" that is lethal for aquatic insect eggs (Figure 2). Data collected by citizen scientists in Grand Canyon helped us come to this conclusion, because sections of river that have "high tide" at dusk (when insects are laying eggs) have lower midge abundance than sections of river that have "low tide" at dusk (Figure 3).

Aquatic Insect Light Trap Monitoring

- Analyze & Interpret

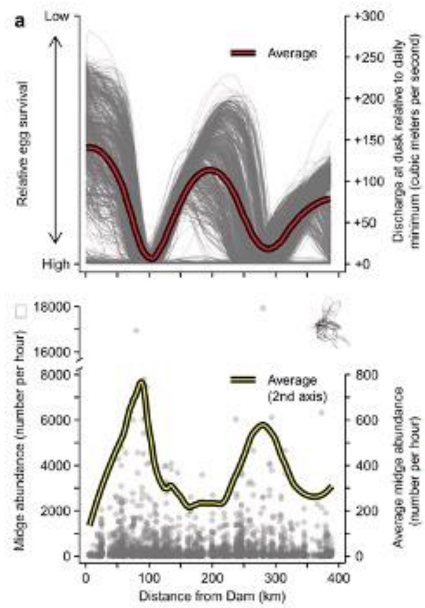
- Figure 2. Rivers without hydropeaking practices likely provide better habitat for aquatic insects that lay their eggs along the rivers edge

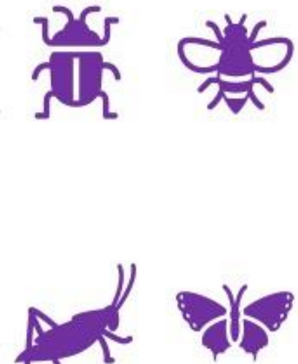


Aquatic Insect Light Trap Monitoring

- Analyze & Interpret

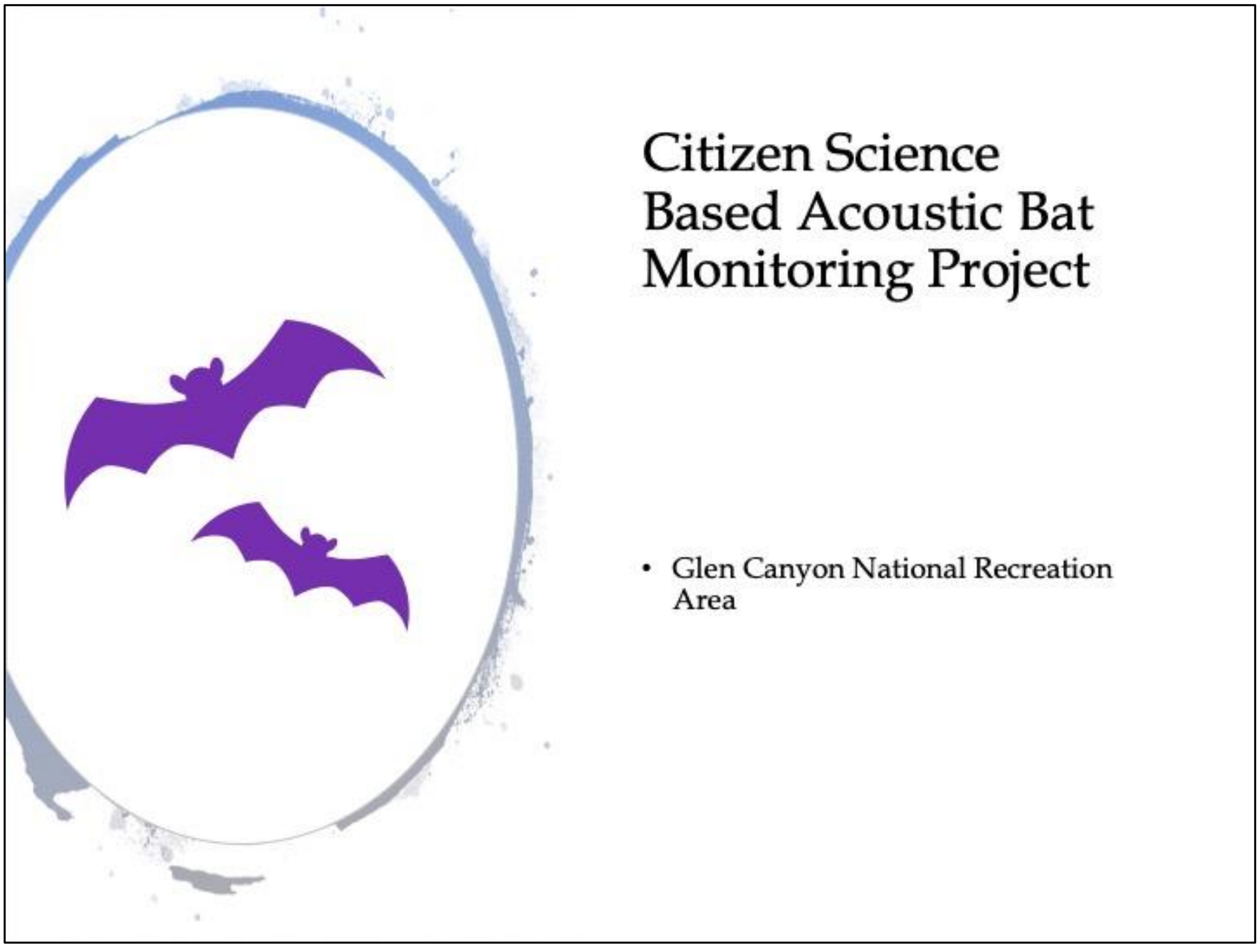
- Figure 3. The abundance of midges captured in light trap samples in Grand Canyon in 2012-2015 was greatest in sections of river that had low tide at dusk. Eggs laid along the rivers shore at high tide get exposed to air when the tide drops, leading to desiccation and mortality.





Aquatic Insect Light Trap Monitoring

- Conclude & Report
  - In 2018, stakeholders of the Glen Canyon Dam Adaptive Management Program initiated an experimental flow regime from Glen Canyon Dam. The experiment is informally known as "bug flows." Bug Flows were released from May to August in 2018 and 2019. They are different from regular hydropeaking flows because they include 48 hours a week, Saturday and Sunday (when hydropower costs less) when flows are released at a low and steady discharge.
- Reflect & Rethink
  - The decision by managers to implement Bug Flows in 2018 led us to a very important follow-up question: Do stable flows increase aquatic insect abundance and diversity in Grand Canyon?


Citizen Science Based Acoustic Bat Monitoring Project
• Glen Canyon National Recreation Area

Citizen Science Based Acoustic Bat Monitoring Project

- Observe & Wonder
    - We noticed the spread of White Nose Syndrome, and wanted to know how it might affect Southwest bat species.
    - White Nose Syndrome (WNS) is a wildlife disease that affects hibernating bats and has killed millions of bats primarily in the northeast/eastern United States. Recently, WNS has been shown to be spreading westward due to the social nature of bats. Currently, there is a lack of understanding of the distribution of bat species in the Southwest, therefore if WNS makes its way to the Southwest, it will be difficult to understand how it is affecting Southwest bats. No bats have yet been found to have White-Nose Syndrome in Glen Canyon National Recreation Area as of yet, but the park does provide habitat to known susceptible species. This research is an effort to document bat species distribution and behavior to better prepare for the potential arrival of WNS in the Southwest.

Citizen Science Based Acoustic Bat Monitoring Project

- Question
  - What are the spring, summer, and fall distributions of bat species that are susceptible to white-nose syndrome in this presumed white-nose syndrome-free area within Glen Canyon National Recreation Area, and how do these change over time?
  - Are bat conservation efforts improved by involving citizen scientists in bat monitoring and education efforts?
  - Will data collections yield high quality data that can be used to influence management decisions?

Citizen Science Based Acoustic Bat Monitoring Project

- Develop Hypothesis
  - Distribution data on bat species susceptible to white-nose syndrome is greatly lacking in many areas of North America including Glen Canyon.
  - Therefore, we implemented this citizen science study to fill data gaps, engage the public in bat conservation, and inform future management decisions.
- Plan & Test
  - Citizen scientists and Glen Canyon Biological Science Technicians will use bio-acoustic hardware and software to collect and analyze acoustic recordings.
  - All acoustic recordings will be entered into the National Park Service Bats Acoustic Survey Database and North American Bat Monitoring Program Bat Population Database.
  - Data collections will contribute to a statistically robust dataset that will enable researchers to make inferences about bat species distribution and threats on a local, regional, and continent-wide scale.

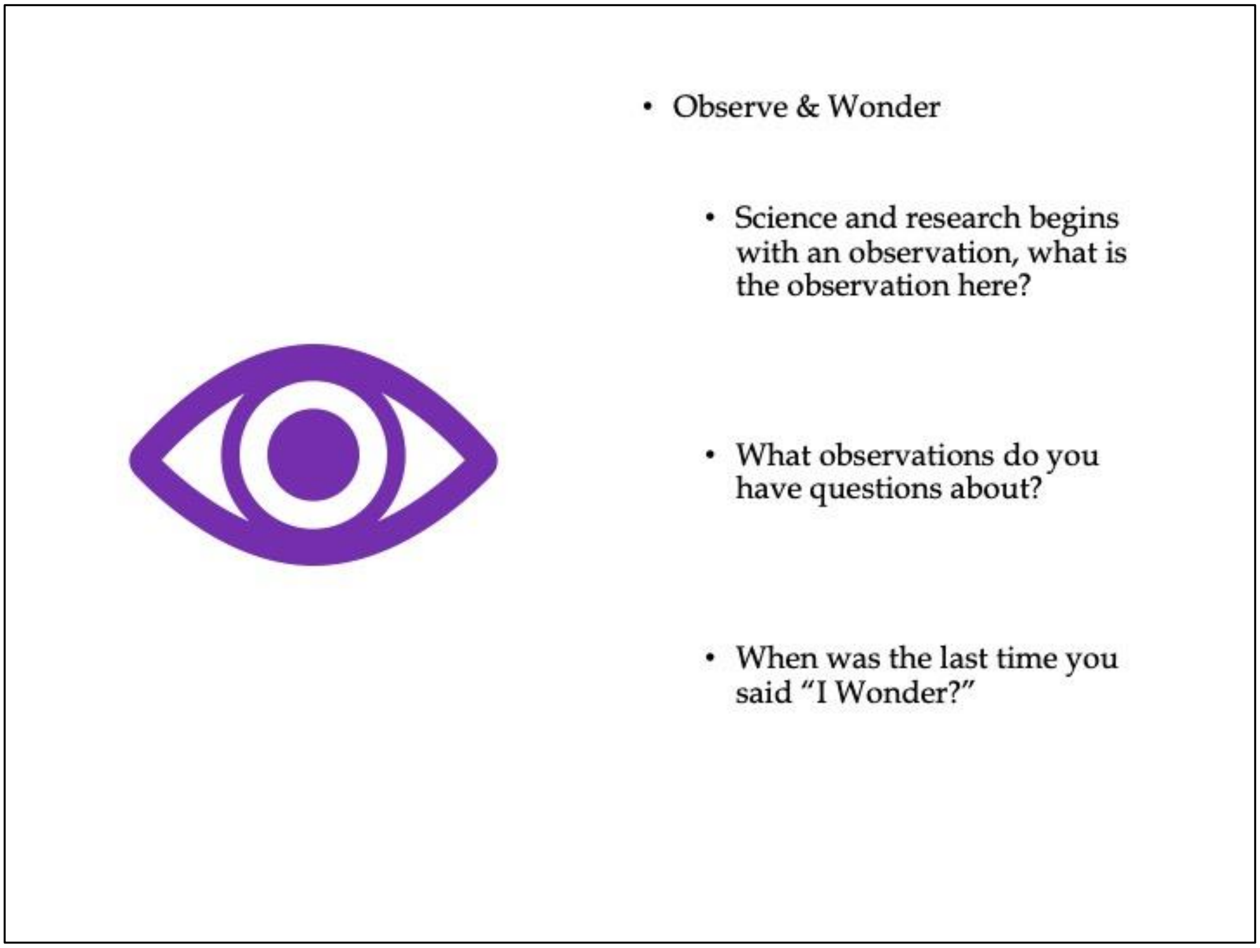
Citizen Science Based Acoustic Bat Monitoring Project

- Analyze & Interpret
  - Between 2016 and 2018, Citizen Scientists collected 47,152 acoustic call files within Glen Canyon, 21,645 of which were identified to species.
  - Sonobat software was used to confirm presence of 10 bat species susceptible to white-nose syndrome.
  - Citizen scientists recorded the first GLCA record of the greater mastiff bat.
  - Citizen scientists confirmed the presence of the following species: Allen's big-eared bat, hoary bat, and canyon bat.
  - Young and old citizen scientists are generally very interested in learning about bio-acoustic technology and learning how they can further bat conservation efforts.

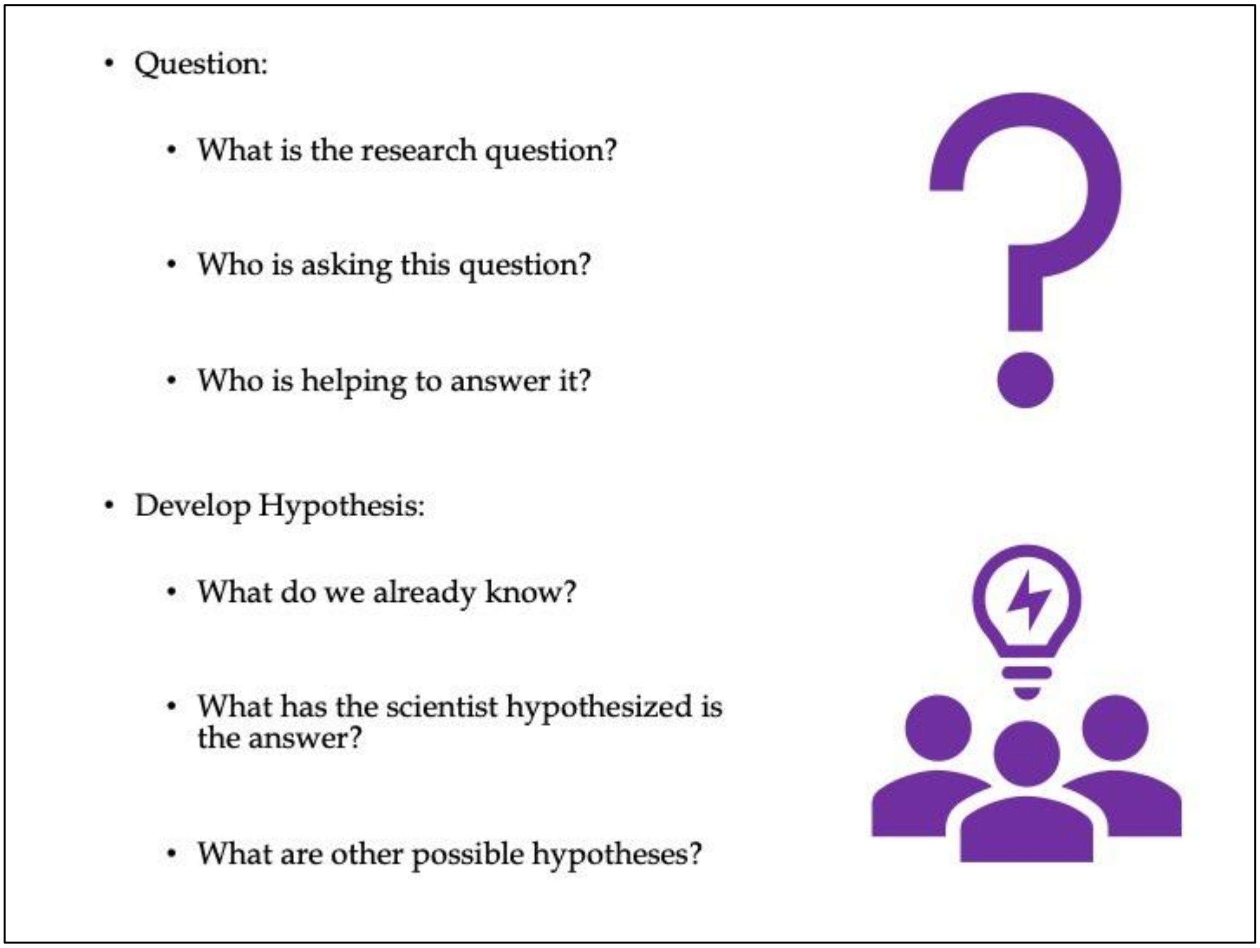
Citizen Science Based Acoustic Bat Monitoring Project

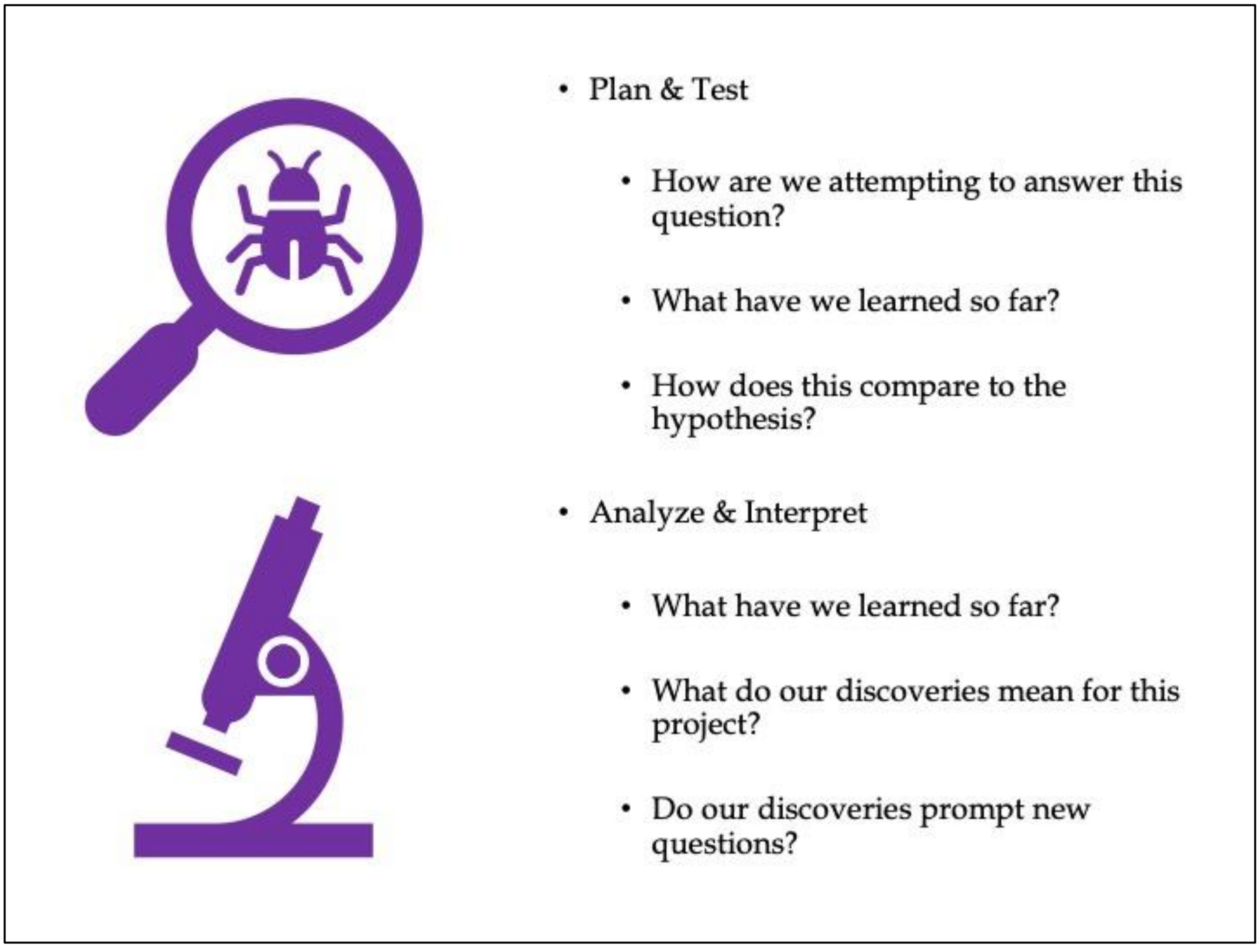
- Conclude & Report
  - We hope to develop an efficient and effective citizen science-based bat monitoring and education program that can easily duplicated by federal and non-federal entities to promote bat conservation efforts.
- Reflect & Rethink
  - How will white-nose syndrome influence species richness along the San Juan and Colorado Rivers?
  - Will significant differences in species distribution result between these two major tributaries?

Discussion Questions



• Observe & Wonder
• Science and research begins with an observation, what is the observation here?
• What observations do you have questions about?
• When was the last time you said "I Wonder?"


• Question:
• What is the research question?
• Who is asking this question?
• Who is helping to answer it?
• Develop Hypothesis:
• What do we already know?
• What has the scientist hypothesized is the answer?
• What are other possible hypotheses?



Plan & Test
How are we attempting to answer this question?
What have we learned so far?
How does this compare to the hypothesis?
Analyze & Interpret
What have we learned so far?
What do our discoveries mean for this project?
Do our discoveries prompt new questions?

- Conclude & Report
    - Who might be able to learn from this information?
    - How can we share and teach what we have learned?
    - What management can this information inform?

- Reflect & Rethink
    - Are questions left unanswered?
    - Did what we learned prompt new questions?
    - Can we revisit the hypothesis, plan, test, or analysis to learn more?

Keep Asking….

- What are ways in which you can learn about current science topics?
- How can similar projects implement management changes?
- What does it mean to be an environmental steward?
- If science is one form of stewardship, what are others?
- What are some of your passions that you could use to be a steward for places that you care about?

Appendix O

Post Season Science Questions

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info@gcyouth.org www.gcyouth.org

Hello again _____,

Thank you again for collaborating with Grand Canyon Youth! In 2020, we had (number of youth) join us on (number of expeditions), and most of them collected data for Citizen Science! We hope this collaboration assisted in your research goals for this season.

As a follow-up, we would like to get an update on the status of your project! We have a few short questions that we would like to ask about your project, on the second page of this document. These answers will be shared with everyone involved with Grand Canyon Youth including field staff, Trip Coordinators, youth, and donors in both a newsletter as well as our online Story Map of Citizen Science at Grand Canyon Youth. As these projects help contribute to our mission to inspire curiosity, it is important to us that we recognize the research taking place after the expedition is over.

Additionally, when your research is published, we would like to know! When available and if the publication platform allows, we can link to your publication from our Story Map to share the research with our Grand Canyon Youth community.

Contributing to science is important to us, and projects like yours help Grand Canyon Youth offer the unique experience to youth that we strive for. Thank you!

- These answers can be even shorter than the questionnaire we sent out prior to the season; we just want a brief update to share with our community!
    - The entire document can be 250-500 words, roughly
- Once again, please define any scientific terms used!

Project Name:	
Research Entity:	
Your Name (and anyone else's names involved in the project you wish to include):	
How much data were you able to collect this year with the help of Citizen Scientists? (300 samples, ¾ of the data needed for the project, etc., this quantification can be simple or general)	
What is one thing that surprised you about the data that was collected, and/or one new thing you learned from the project this year?	
Lastly, were any new questions prompted by the data collected or the information learned this year?	

Appendix P

Practicum Hours Record

Semester:	Total hours:
Spring 2019	156
Summer 2019	133
Fall 2019	120
Spring 2020	270