THESIS

U.S. FOREST SERVICE CITIZEN SCIENCE: IMPROVING MONITORING CAPACITY, ECOLOGICAL LITERACY AND OUTREACH

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ABSTRACT

U.S. FOREST SERVICE CITIZEN SCIENCE: IMPROVING MONITORING CAPACITY, ECOLOGICAL LITERACY AND OUTREACH

The Forest Service is integrating citizen science projects and data into the management of national forests around the country. I selected three citizen science projects that involve the Forest Service collaborating with secondary school students in direct field collection of monitoring data to: understand the objectives and design of the programs, determine the impacts on participants; and identify the benefits, if any, for the agency. I conducted eight interviews with the project leads and teachers to understand their goals, design, and objectives for the program. To determine the impacts to the participants I interviewed and surveyed 25 current students before and after their participation in the project. I also interviewed five students who participated in the projects in previous years. My findings show that both students and the agency achieved their desired outcomes for beginning the citizen science projects. I found that the objectives and design of these programs have a significant influence on student outcomes and should be designed with objectives in mind. My findings suggest enhanced ecological literacy is a potential outcome of these youth based, citizen science monitoring programs. I found evidence of increased environmental stewardship, although I was unable to determine whether this persists. The projects experienced some minor challenges with the students' data reliability; however, project leads and students alike concluded that these projects, although they did produce valuable data, had greater value for the relationships built between students and the agency, their teachers, and the natural world.

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Citizen Science, Forest Service, Monitoring, Ecological Literacy, Youth Engagement

THESIS OVERVIEW

A nationwide discussion is taking place about children becoming disconnected from nature. In a recent *Science* article, researchers suggest there is a divide between science and environmental education and, in the future, this separation will prevent students from understanding and engaging with complex sustainability challenges and socio-ecological issues (Wals et al. 2014). Researchers suggest citizen science could be a critical avenue for fostering a future generation of environmental stewards by promoting increased scientific literacy and understanding of the natural world (Wals et al. 2014). Citizen science refers to any group of public volunteers that collect data for a scientific purpose (Silverton 2009; McKinley et al. 2015). Citizen science programs, often focused on community-based monitoring, are becoming more common, particularly with federal agencies (Akin et al. 2013).

Citizen science is especially useful for local, state, and federal agencies because with thoughtful design and development it can produce long-term and large amounts of monitoring data. "Monitoring" refers to any measurement taken over an extended period of time to gather baseline data and observe trends for some aspect of environmental quality (Hartanto et al. 2002; Noon 2003). Monitoring is useful for agencies like the Forest Service because it can, among many things, inform decisions and promote transparency during civic engagement; however, mandated monitoring programs within the Forest Service are often underfunded and unsupported. Research suggests that multiparty monitoring, when groups work together to collect monitoring data, offers new opportunities for the Forest Service to collect the mandated monitoring data and also enhance collaboration, create an inclusive environment for diverse groups, and address conflict. Multiparty monitoring, which can be a kind of citizen science, is gaining traction nationwide (Fernandez-Gimenez et al. 2008). Along with supporting legislation, multiparty monitoring was recently required and supported with funding by the Forest Service.

Because of the national dialogue regarding youth and the outdoors, the emphasis of federal agencies on monitoring, and the potential for citizen science to bridge science and environmental education, I was interested in citizen science projects that engage youth and also contribute data to the Forest Service. This study was designed to investigate three youth-based, citizen science monitoring projects, understand their impacts on participants, and identify the benefits to the agency. In particular, this work was organized around three general research objectives:

1. Identify the objectives of Forest Service citizen science projects with secondary school students.
2. Identify the effect on the students who participate in these projects.
3. Identify whether and how the citizen science projects are accomplishing the desired outcomes and/or other unexpected outcomes.

This research used a qualitative, mixed-methods, multiple case-study approach (Yin 2009; Creswell 2014). Because little research has been conducted on Forest Service citizen science monitoring programs with youth, my intent was to investigate multiple case studies of such programs to obtain an in-depth understanding of the design and results from such programs. I interviewed Forest Service staff, field instructors, and teachers associated with the projects. I also surveyed and interviewed students before and after participation in the project. I recorded, transcribed, and used a grounded theory approach to code interviews, during analysis this included an iterative process of developing concepts and hypotheses, coding data, memo writing, hypothesis formulation through theoretical induction and deduction, and data saturation of the developed categories. I treated individual projects as case studies to explore how design and outcomes had developed over time within cases. In addition, I looked for thematic similarities and key differences across cases.

I chose to focus this research on projects involving high school students to maintain the focus on youth engagement, while considering a population that was likely capable of quality data collection. My goal was to gain an understanding of the design, content, outcomes, and lessons learned that were transferable to other forests; therefore, I used several criteria to select projects, looking for those that had been active for more than five years, were long term (i.e., multiple weeks) in design, and involved students in direct collection of field data. From the list of possible projects I identified, I selected the three youth-based, citizen science monitoring programs that met the criteria. To the best of my knowledge, I believe I selected all of the long-term, citizen science monitoring projects occurring between the Forest Service and secondary school students in 2015. The three case studies selected were: the Alaska Natural Science Course on the Tongass National Forest, the Montana Youth Forest Monitoring Program on the Helena-Lewis and Clark National Forest, and the Delta Apprenticeship in Science and Engineering on the Grand Mesa, Uncompahgre, and Gunnison National Forests.

This research began with the aforementioned objectives; however, these have been repackaged to support two distinct peer-reviewed articles. Chapter 1 addresses the following objective: to understand content, design, and objectives of these projects and to determine if they were meeting their objectives; what was transferable to other forests or agencies; and what benefit, if any, they were having for the Forest Service. Chapter 2 focuses on a related but unique objective: to determine how and if these citizen science projects were integrating science and environmental education and if they were increasing students' ecological literacy and environmental stewardship.

This research also included a survey administered to students before and after participation in the program. The findings of this portion of the research did not produce statistically significant results; however, the instrument demonstrated measurement reliability and accuracy. The findings and survey instrument are provided in appendices A and B. In addition, the interview guides for the students (pre and post), project leads, and instructors are provided in appendix C. Finally, appendix D includes more detail on the coding methodology used for this research.

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CHAPTER 1

1. Introduction

There has been a concerted effort within the executive branch to introduce youth to the outdoors. Nationwide programs such as *Every Kid in a Park*[1] and *Let's Move Outside!*[2] encourage youth and their families to explore and experience public lands. The Forest Service has aligned its ongoing internal initiatives, such as *Discover the Forest*[3], with these nationwide efforts. In addition, the Forest Service recently released an Integrated Youth Strategy with a vision to connect youth to nature, nurture their understanding of natural resources, and provide opportunities for conservation service and employment to ensure the next generation cares for their public lands (USDA 2015). The agency's new regulations under the National Forest Management Act (NFMA), commonly referred to as "the 2012 planning rule," also emphasize the importance of involving youth during the public participation aspects of forest planning (see 36 CFR 219.4(a)(1)(ii)).

One avenue for enhancing youth engagement on public lands is through citizen science initiatives (i.e., when a group of volunteers collect data for a scientific process) (Silverton 2009; Davis et al. 2015). In September 2015, the director of the White House Office of Science and Technology Policy released a piece of proposed legislation that would allow federal agencies to use citizen science collected data to support informed decision-making (Holdren 2013, 2015). This proposed legislation reflects a growing awareness of citizen science as a vehicle to leverage resources, expand opportunities for public participation, and foster citizen engagement in the scientific process. Citizen science initiatives also can help agencies promote robust youth

[1] http://www.everykidinapark.gov
[2] http://www.letsmove.gov/lets-move-outside
[3] http://www.discovertheforest.org

engagement, build trust with partners, and meet a variety of national policy objectives (McKinley et al. 2015). Citizen science also can fulfill requirements or goals to support multiparty monitoring (i.e., when groups work together to collect monitoring data) (Davis et al. 2015). The importance of multiparty monitoring is emphasized in the 2012 planning rule (36 CFR §219.12) and in the 2009 legislation that established the Collaborative Forest Landscape Restoration Program (CFLRP) (16 USC §7303). In the face of long-standing challenges to sustain monitoring capacity and efforts, researchers suggest citizen science projects can provide long-term and valuable monitoring data, although doing so involves some challenges related to data reliability and precision (Dickinson et al. 2010; Vaske 2008).

Given the tandem goals of increasing youth engagement and meeting mandated monitoring requirements, I investigated current Forest Service citizen science monitoring programs with youth. I identified specific case studies of youth-based, citizen science projects with a monitoring component to understand the design, content, and objectives of these programs; identify whether and how the Forest Service is meeting their objectives with these programs; and distill lessons learned that could be transferrable to other units interested in initiating a citizen science monitoring program with youth. Specifically, I was interested to know whether these programs are meeting both youth engagement and monitoring objectives and how they were designed to do so.

1.1 Citizen Science

"Citizen science" refers to any group of public volunteers that collect data for a scientific purpose (Silverton 2009; McKinley et al. 2015). Citizen science has a long history. For example, the Christmas Bird Count sponsored by the National Audubon Society has invited people from across North America to observe and record bird sightings and contribute their data to a long-term, large-scale citizen science project (Silverton 2009; Tulloch et al. 2013). Citizen science projects are also occurring as collaborations between federal agencies and youth. For instance, staff at Nez Perce National Historical Park are currently engaging high school students to assist them with monitoring the status of camas root (*Camassia quamash*), a ecologically, culturally, and historically significant plant species (USDI 2009).

Citizen science can be an avenue to achieve a variety of objectives, including: promoting knowledge generation, changing volunteers' attitudes or behaviors, helping volunteers attain personal and social benefits, and increasing the effectiveness of public involvement processes in federal decision-making (Dickinson et al. 2010; Stepenuck and Green 2015). Researchers also suggest citizen science, because of the capacity to collect long-term and large-scale data, might be the only practical way to document large-scale ecological changes resulting from climate change or other factors (Dickinson et al. 2010). Researchers also suggest that citizen science could be the bridge to connect environmental and science education, increase scientific literacy, and engender environmental stewardship (Wals et al. 2014).

Aspects of data collection and analysis, including observer error and sampling bias, can be challenges for citizen science monitoring efforts (Danielsen et al. 2005; Bonney et al. 2009, 2014; Bodillis et al. 2014; Davis et al. 2015). Nonetheless, researchers have found that citizen science projects can provide long-term and valuable monitoring data, as long as attention is paid to the data collection efforts (Dickinson et al. 2010). Other potential challenges include significant time commitments from staff, lack of funding for volunteer programs, and a lack of program evaluation to determine if objectives are being met (Dickinson et al. 2010; Stepenuck and Green 2015).

1.2 An Overview of Youth Engagement Initiatives on Public Lands

In April 2010, President Obama launched the America's Great Outdoors (AGO) initiative to address Americans' perceived detachment from nature (AGO 2012). In 2015, the White House also launched the administration-wide effort *Every Kid in a Park*[4], supported by all of the land management agencies. Individual agencies, such as the Forest Service, have supported youth engagement for decades. Since the 1970s, with the launch of Woodsy Owl, the Forest Service has sought to engage children in learning about and protecting the natural environment (USDA 2007b). In 2007, the Forest Service launched *More Kids in the Woods*[5], a cost-share program with partners to improve children's health and help reconnect youth to nature (USDA 2007a, 2007b). *Natural Inquirer*[6] and *Discover the Forest*[7] are just a few additional examples of ongoing Forest Service programs and initiatives that leverage resources and enhance youth engagement. These initiatives are all part of the aforementioned 2015 Integrated Youth Strategy, which focuses on engaging youth through place-based experiences in nature, engendering environmental ethics and stewardship, enhancing youth understanding of resource management, and fostering respect for civil servants as well as providing youth opportunities to investigate potential careers in natural resource management (USDA 2015). The agency's new regulations (36 CFR 219 et seq. [2012]) in the 2012 planning rule also emphasize the importance of involving youth during the forest planning process, and one avenue for doing so is through multiparty monitoring (see 36 CFR 219.4(a)(1)(ii)).

[4] https://www.everykidinapark.gov
[5] http://www.fs.usda.gov/detail/conservationeducation/programs
[6] http://www.naturalinquirer.org
[7] http://www.discovertheforest.org

1.3 Multiparty Monitoring within the Forest Service

"Monitoring" refers to any measurement taken over an extended period of time to gather baseline data and observe trends for some aspect of environmental quality (Hartanto et al. 2002; Noon 2003). The natural resource management literature highlights the importance of monitoring as a critical aspect of forest management, especially in the context of today's management goals and challenges such as ecological restoration, climate change, and the use of adaptive management as a decision-making paradigm (Stankey et al. 2003; DeLuca et al. 2010; Schultz and Nie 2012).

Multiparty monitoring involves discussion and mutual learning among a diverse group of individuals representing different and sometimes opposing groups and interests through the process of designing or implementing a monitoring program (Fernandez-Gimenez et al. 2008; Moote 2011). In this research I define multiparty monitoring to involve interested stakeholders who are not necessarily in opposition, working with the agency through some part of the monitoring process; this definition is consistent with others' conceptualization of multiparty monitoring (Davis et al. 2015). Multiparty monitoring can often involve citizen science if members of the public are collecting or evaluating data (CFLRP; Davis et al. 2015; McKinley et al. 2015). Research suggests that multiparty monitoring offers new opportunities to assess the effectiveness of management actions, produce large amounts of agency-relevant data, involve diverse stakeholders in an inclusive environment, build trust, address conflict, and inform future actions in an adaptive management framework (Fernandez-Gimenez et al. 2008; Moote 2011; Davis et al. 2015). As with citizen science initiatives, the challenges associated with multiparty monitoring include the issue of data quality and the need for agency capacity to support effective programs (Bonney et al. 2009; Moote 2011; Davis et al. 2015).

The 2012 NFMA regulations (also known as "the 2012 planning rule") emphasize the use of monitoring as part of an adaptive planning cycle (36 CFR § 219.5 (a)). The 2012 planning rule requires identification of opportunities to pursue multiparty monitoring, including opportunities to carry out multiparty monitoring with other Forest Service units; federal, state, or local government agencies; scientists; partners; members of the public; and federally recognized Indian Tribes and Alaska Native Corporations (36 CFR §219.12). In addition, the legislation that established the CFLRP, which provides funding through a competitive process to collaboratively designed ecological restoration treatments on national forest lands, specifically requires multiparty monitoring programs and provides a flexible funding stream that can be used to fund such monitoring (Schultz et al. 2012; Davis et al. 2015).

Biber (2011) argues that, while monitoring is a way to understand complex ecosystems and improve decision-making, the lack of congressional funding and positive institutional incentives have left monitoring programs at the bottom of the priority list for agencies. Monitoring is a strategic, long-term data collection process that captures the trends and changes in complex, slowly changing natural systems; however, it does not produce immediate results and deliverables. This is fundamentally mismatched with federal funding cycles and political incentives that drive decision-makers and their political overseers to focus on short-term deliverables and accomplishments as part of annual evaluations (Biber 2011). In addition, effective monitoring requires careful design, with attention to how data are collected, processed, delivered to decision-making bodies, and used to inform subsequent phases of planning and implementation (Doremus 2008). The key question is how to increase monitoring capacity in light of these persistent obstacles, and my research investigated whether citizen science with youth might be an avenue for doing so.

1.4 Summary and Research Questions

To understand how citizen science initiatives could be used to meet both youth engagement and monitoring goals, I looked for projects on federal lands that involved youth in collecting monitoring data. Given the strong emphasis on both youth engagement and monitoring in the Forest Service, I chose to focus on such initiatives that exist on national forests. There is little research on this topic, and therefore, my objectives were both to identify and describe such programs, as well as to evaluate their outcomes. My research questions were as follows:

1. What is the nature of current Forest Service citizen science monitoring programs with youth in terms of their design, content, and objectives?
2. To what extent is the Forest Service meeting their objectives with these programs?
3. What are the challenges, best practices, and lessons learned associated with these youth-based, citizen science monitoring programs?

2. Methods

This research used a qualitative, mixed-methods, multiple case-study approach (Yin 2009; Creswell 2014). Little research has been conducted on Forest Service citizen science projects with youth, and this type of research approach is appropriate for exploratory research designed to understand a phenomenon in-depth (Creswell 2014). I treated individual projects as case studies to explore how design and outcomes had developed over time within cases; in addition, I looked for thematic similarities and key differences across cases. To identify potential case studies, I used agency list-serves and personal contacts, querying for national forest programs involving high school students in citizen science monitoring. I chose to focus my research on projects involving high school students to maintain the focus on youth engagement, while considering a population that was likely capable of quality data collection. I used several criteria to select projects: those that had been active for more than five years, long term (i.e., multiple weeks) in design, and involved students in direct collection of field data. From the ten projects I identified, I selected the three youth-based citizen science monitoring programs that met my criteria. To the best of my knowledge, I believe I selected all of the long-term, citizen science monitoring projects occurring between the Forest Service and high school students in 2015. The case studies I selected were: the Alaska Natural Science Course on the Tongass National Forest; the Montana Youth Forest Monitoring Program on the Helena-Lewis and Clark National Forest; and the Delta Apprenticeship on the Grand Mesa, Uncompahgre, and Gunnison National Forests.

My goal was to interview the entire population of individuals involved with these projects at present, including Forest Service staff and field instructors directly involved with the projects and all current students. I also spoke with willing and available past students to understand their perspectives. In total, I conducted interviews with 38 individuals (Table 1). I successfully interviewed all staff and most students who were currently involved with the projects (due to class time limitations I was unable to interview four of the 12 students in Alaska). I also interviewed all of the past students who were willing to speak with us. I interviewed students both before and after participation in the project to gauge the effects of participation. During the data collection phase of this research, I was also able to observe fieldwork and classroom time for two of the three projects in the field and see most of the students' presentations to add to my understanding of the projects. I conducted 87% of interviews in-person.

Table 1: Project Participants Interviewed

	Alaska Natural Science Course	Montana Youth Forest Monitoring Program	Delta Apprenticeship (Colorado)
Adult Project Leaders	2 (Forest Service staff member and teacher)	5 (1 Forest Service staff member, 3 teachers, and 1 instructor who was a past student)	1 (Forest Service staff member)
Current Students	8	15	2
Past Students	3	0	2
Data Collection Times	January and May 2015	June and July 2015	June and July 2015

Interviews were semi-structured, using an interview guide that allows in-depth exploration of a topic according to the interviewee's interests and expertise (Charmaz 1991). I obtained consent, recorded, transcribed, and maintained confidentiality procedures approved by the Institutional Review Board for all interviews. First, I interviewed the project leads. It quickly became clear that although these three case studies were similar, the projects were designed to meet different objectives. For example, the Alaska project focused on climate change and wilderness, and, therefore, my interview questions assessed what students knew about each of these two topics at the outset and after project completion. In addition, my student interview guide for students included sets of open-ended questions on topic areas of interest, developed based on my literature review, including: past outdoor experiences, understanding of the Forest Service, scientific literacy, and questions directly related to their research objectives and procedures. For example, scientific literacy included questions related to students' understanding of ecosystems, climate change, and the scientific method (see appendix C for interview guides).

Some drawbacks to interviews with youth include noncooperation, challenging schedules, short responses (e.g., "I don't know"), and desirability bias where a student could respond with an answer that is consistent with societal norms or perceived viewpoints of the interviewer (Vaske 2008). To build rapport and have the best chance of an in-depth conversation with high school-aged students, I met in-person at least once with current student interviewees and used photo-elicitation—a technique where students take pictures throughout their project participation to provide additional insight into their experience as well as stimulate a conversation with the participant (Smith et al. 2012).

A grounded theory approach with open coding was used to analyze the data. Grounded theory (i.e., developing theory through analysis) uses a process of reviewing data and coding for themes with the goal to refine and saturate existing theme categories where new information is no longer being generated (Strauss and Corbin 1990; Gibson and Brown 2009). I coded interview content based on the primary questions asked and identified new codes as new themes emerged from the data. I analyzed the student data by comparing pre-participation to post-participation responses for individuals within case studies to track changes in specific topic areas such as Forest Service knowledge. I looked for themes that arose individually and across projects to consider whether there were emergent themes that were present among all of the projects or unique to one. After the initial or open coding, U conducted axial coding, this included using the constant comparative method to compare findings and observations to other instances where similar findings from these programs emerged and were relevant. This second level of coding is a standard technique in grounded theory that provides additional insight into overarching concepts emerging from the data (see appendix D for coding scheme). In addition, I ensured qualitative validity through member checking to confirm the accuracy and consistency of my findings with the three project leads from the programs (Creswell 2014).

3. Results

This section is organized by case study. I first describe the design, content, and objectives of the citizen science project and then look at the outcomes of these programs based on Forest Service project objectives. The final section details my findings related to the lessons learned that could be transferred to other units interested in initiating a youth-based, citizen science monitoring program.

3.1 Alaska Natural Science Course

This project began as a collaboration between Craig High School and the Craig Ranger District of the Tongass National Forest on Prince of Wales Island, Alaska. In 2009, with a focus on bringing high school students into the wilderness, the Forest Service recreation planner began working with the teacher of the Alaska Natural Science Course, an elective science credit offered fall and spring semesters. According to the interviewee, the Alaska case study's initial objectives were (1) for students to experience wilderness, and (2) to foster wilderness stewardship. Over the last several years, the project has evolved to include a third objective: (3) to collect wilderness and climate change data, which would serve as a baseline for the forest and could be used by the agency or other groups interested in the students' specific research topics. The project was designed specifically to target high school students because of safety concerns with younger students and because they hoped that high school students, with a foundation in scientific methods, would contribute relevant data to the agency. In 2015, 12 students, ages ranging from 16 to 19, were enrolled in the 2014–2015 Alaska Natural History course.

Throughout the first semester, Forest Service employees, led by the recreation planner, repeatedly visited the class to guest lecture and introduced the students to topics related to land management. During the second semester, with continued input from Forest Service staff, students focused on designing their part of an ongoing longitudinal research project in the Karta River Wilderness. Students began by conducting a literature review, reviewing the reports and data from the previous year's students, and then modifying their research project accordingly. At the end of the semester, the students traveled to the Wilderness for a one-day field trip where they collected their data. In the past, students have gone for overnight camping trips for data collection. For the remainder of the semester, students analyzed their data, wrote a research paper, and then prepared a presentation of their findings, which they shared with the Forest Service at Craig Ranger District.

Evidence of Meeting Objectives

I interviewed 10 students before their second semester of the course in January and after their field trip to the Karta River Wilderness in May to determine if the project was meeting the initial objectives. I found that the one-day field trip for students to the Karta was a first introduction to wilderness areas for some students. In pre-participation interviews, students often did not know where wilderness areas were located on the island, which has five such areas, or what differentiated them from other public lands. Many students suggested the trip to the Karta River Wilderness was the reason they had signed up for the course and what they were most looking forward to. I saw evidence in the post-participation interviews that students gained an understanding of wilderness on the island, its legislation, and the management of these designated areas. Most students stated it was the highlight of the course, and some suggested future semesters include more trips to collect data. For example, one student said:

> I guess that trip to the Karta made a pretty big impact on me. I'd never been to a wilderness area I didn't know any of the rules or anything. I learned a lot on that trip...no motorized equipment, no bikes, nothing like that. Just really a lot more isolated than I realized….

Many students also suggested a new appreciation and respect for wilderness, identified leave-no-trace techniques that they would use in future visits, and suggested how their research project could be improved to prevent degradation of wilderness areas and the unique experience it affords. I saw evidence in post-participation interviews that most students developed an appreciation for wilderness, showing evidence of meeting objective 2. For example, one student said, "[This experience] makes me respect it a lot more than I probably did. Makes me not want to do some of the things that I did before." Another student said, "[The trip] changed the way I treat it…be more careful, definitely pick up after myself, to leave no trace."

With regard to objective 3, students, for the most part, were confident in the overall study reliability and the data they collected for their research project, meaning their research design and data collection effort was repeatable by future student scientists or Forest Service employees. Students also appeared to feel empowered that their data were being distributed to the Craig Ranger District or outside partners. In the post-participation interviews, students were able to articulate their research design, methods, and findings, and often had suggestions for improving their research design for more reliable data in the future. At the urging of the Forest Service, students have begun integrating Forest Service protocols into some of the student research projects. Students focused their efforts on surveillance monitoring (i.e., monitoring trends that are unconnected to management actions) to track species, collect baseline data, and determine trends and changes in the Karta River Wilderness that could be indicators of climate change. The Forest Service used the data and the course to meet the recreation site monitoring and wilderness education elements of the Chief's 10 Year Wilderness Stewardship Challenge, which promotes accountability and transparency across the agency. Other departments from Craig Ranger District have not yet used the data that the students collected.

Summary and Lessons Learned

I saw evidence in post-participation interviews with students that the Alaska Natural Science Course was meeting its objectives. All students suggested other national forests should consider doing a project like this because it collects monitoring data for the agency, and afforded students opportunities to improve their understanding of climate change, connect with Forest Service staff, and develop a new respect for wilderness. Students also repeatedly said the Forest Service needs students to track vital trends in wilderness, and many said they would treat wilderness areas differently as a result of this project. Compared to my other cases, although students were able to identify the point of contact who visited the classroom regularly and some Forest Service history and its role on the island as a large landowner, they did not have strong impressions of the Forest Service or consider it for future employment.

The project lead suggested that the Alaska Natural Science course has been successful in getting new and diverse groups of students into the wilderness. She believed that it met the objectives; however, because the project had only been in existence for five years the project lead cannot verify the long-term goal of wilderness stewardship at this point. The project lead suggested committed staff members and partnership with a flexible teacher were key components to this program's success.

3.2 Montana Youth Forest Monitoring Program

The Youth Forest Monitoring Program (YFMP) began in 1998 with four students, representing four different high schools, who were to review the 1986 forest plan and collect some kind of data that the Helena National Forest (now the Helena-Lewis and Clark National Forest) could use. Since 1998, the program has evolved to include on-the-ground forest monitoring during an intensive summer program and a total of 160 participants. The current project lead surmised that the project involved high school students originally because they have a solid science foundation, are able to ask hard questions, and the Forest Service wanted to engage youth. According to this staff member, the initial objectives of the citizen science project were for students to: (1) feel some sense of ownership as they learn about and understand public lands; (2) explore different career fields within the Forest Service; (3) learn about monitoring; and (4) and collect usable data, although this was not one of the initial objectives of the project but, rather, one that emerged in recent years.

In the summer of 2015, 15 students, ages 14 to 17, participated in the YFMP. This program had a rigorous application process, and students received a stipend upon completion of the project. Students participated in an overnight training week, after which they were placed on five teams that focused on streams, weeds, or soils monitoring. Students conducted both effectiveness and surveillance monitoring, where they tracked changes to determine if management actions were having the desired effect and also to detect trends in areas without direct connection to management actions. Students had a four-day workweek, with most of their time spent in the field collecting streams, weeds, and soils monitoring data and an hour for data entry at the end of each day. They concluded their time in the program with a week at Helena College where they created a binder of their findings from that season and prepared a presentation that included their key findings and prescriptions for future Forest Service management actions. Students' presentations were open to the Forest Service and public, and a local news station attended and interviewed students for an evening story.

Evidence of Meeting Objectives

I interviewed all 15 current students before and after participation in the project, four field instructors, including a teacher and past YFMP student, and the Forest Service project lead.

With regard to Objective 1, in post-participation interviews, most students discussed showing friends and family the places they collected data and sharing the implications of their monitoring results. Students also shared the reasoning behind Forest Service management techniques with friends and families. For instance, one student specifically described a seasonal road and area closure that prohibited ATV use, and said he had explained the management rationale for this decision. He added, “I used to think...when I was younger, walking around, ‘Oh, there's no motorized vehicles past this point. That's pretty stupid…,’ but now that I've done this, I know how important it is to keep minimal use to certain areas of the forest.” Most students also described in detail how their experience in the YFMP had deepened their interest in spending time outdoors and their knowledge of public lands, specifically the forests around Helena. In addition, students were aware of their actions and the impacts they had on ecosystems.

When asked about future careers in post-participation interviews, students suggested an interest in mostly science degree programs such as physics, science and health education, silviculture, hydrology, entomology, and some specifically identified careers with the Forest Service. Many students of the YFMP suggested an interest in science and the outdoors in their pre-participation interviews and some suggested they applied to the YFMP to explore their options. One student said, “I was leaning towards civil engineering but after this, I think maybe environmental engineering, because then I could still get hopefully some…aspect of the environment.” Many of the students also said they would pursue Forest Service seasonal positions or field instructorships for the YFMP in the upcoming years while they worked toward college degrees. In addition, students described the value they had working alongside adults and their new comfort with data analysis, public presentations, and teamwork.

When asked about the importance of monitoring, students were unwavering in the value monitoring data afforded the Forest Service to make informed decisions in the future. Students identified their surveillance monitoring data as a baseline for land managers to use to track trends or changes due to climate change. When talking about climate change, one student said:

> In our eco presentation, we actually focused on how our stream,…used to be only one stream…and now there are two, and it is a braided stream…. We concluded that because that snow is melting sooner, it is giving more water volume to that stream and that is why now there are two channels instead of just one.

Students were able to clearly articulate the protocol they used for collecting monitoring data and suggested additional places to be monitored or places needing an increased frequency of monitoring.

Instructors felt students were given the tools, techniques, and instruction to collect reliable data in a process that was developed by the Forest Service, repeatable by scientists, and also indicative of trends present across the forest. In post-participation interviews, students felt comfortable with the quality of their data and contributing it to agency professionals for future decision-making. Students described challenges and how they worked through monitoring equipment failure (e.g., sound devices to monitor black-backed woodpecker (*Picoides arcticus)* populations), challenging weather, and long days. They suggested that if incorrect data collection occurred in the field they would detect it during the daily data input and analysis. One instructor suggested students might be providing more reliable data than professionals because students do not trust their professional judgment and measure and re-measure when collecting their data before turning it over, whereas a professional might make a judgment call or quick visual estimate without measuring, in hopes of visiting more sites in a shorter period of time. The students' data was used in a variety of ways including: in the Annual Forest Monitoring Report; to meet the Environmental Protection Agency grant compliance on local stream work; and also complied as part of the wildlife monitoring summaries for the summer field season. In addition, the students' detection of changes in longitudinal trends was raising awareness about areas of concern for the Forest Service, according to the project lead who was also confident in reliability of the data.

Summary and Lessons Learned

I saw evidence of all project objectives being met. Project instructors, leads, and students suggested other forests begin a program like the YFMP for various reasons, such as connecting the Forest Service to the community, providing educational programing for youth, monitoring a large number of sites around the forest, and generating longitudinal datasets. Field instructors, however, mentioned challenges and barriers to this project that could occur elsewhere. For instance, except funding for the time of one Forest Service staff during the field portion of the program, most of this program was not funded by the Forest Service. A partnership with a nonprofit paid for most staff time, some equipment, and student stipends. Instructors of the program suggested that awareness in the project area is growing but not all families are aware such a program exists, and it takes dedicated staff and strong partnerships for this program to continue every year. In addition, one field instructor was a local teacher who had been part of the program since its outset 20 years ago. Through his connection to the school and local students, he was able to provide additional resources, equipment, and outreach to many students.

3.3 Delta Apprenticeship in Science and Engineering

The Delta Apprenticeship in Science and Engineering, run by the Grand Mesa, Uncompahgre, and Gunnison National Forests (GMUG), invites two students every year to participate in the six-week Delta Apprenticeship Program. I interviewed both of the current students, two past students, and the Forest Service project lead. I reached out to the teacher involved in the program and sought other past students but were unable to obtain additional interviews. The project lead for the Colorado case study said the Delta Apprenticeship Program had two objectives of equal importance: (1) to expose students to what they could study in college, specifically science and engineering, and (2) to provide information to students about the variety of college degrees that could lead to careers in civil service with agencies such as the Forest Service.

In 2015, both students were 16 years of age and had heard about the program through friends or family. Participants in the Delta Apprenticeship, similar to the YFMP, went through a rigorous application process, applying for the program, providing a reference letter, and interviewing with and being selected by a teacher from their high school. For the first three weeks of the program, the two students shadowed Forest Service employees from different departments, including law enforcement, engineering, lands, and archaeology. Then the remaining three weeks the students focused on designing their research project with their Forest Service mentor and collecting their data. Examples of student projects include riparian health monitoring including grazing improvements and vegetation rehabilitation, stream temperature characteristics in the Big Dominguez Creek watershed, and suitability for native trout translocation. This year's students worked on the redesign of an irrigation ditch to improve habitat for greater sage grouse (*Centrocercus urophasianus*) and fire effects in past fuel treatment areas. Students presented their research to the Forest Service, community members, and the school board. Students also received a stipend for completion of the apprenticeship.

Evidence of Meeting Objectives

In post-participation interviews, both students demonstrated an enhanced understanding of science and engineering topics. All students became well-versed in their topic area and stated three weeks of intensive fieldwork, data collection and analysis, and mentorship supported their understanding. One past student said, “I did a project with them and ended up taking it to international science fair and winning a full tuition scholarship to come to school [college].” Another past student noted:

> At the end of our apprenticeship program we give a presentation of what our projects were to the entire Forest Service office. Which was kind of my first exposure to explaining what my project was…. I am a little bit more comfortable and…my public speaking has increased a lot. We've also taken our project and presented it to the CFLRP meetings held in Montrose…and we present our projects to the people who actually granted us the money to do the Apprenticeship program, which is pretty cool.

The past students from the program I spoke with are studying natural resources in college or were accepted and preparing to pursue a natural resources degree. I saw evidence that their participation in the project had helped guide them in this direction and generated interest in a career with the Forest Service. For instance, one past student said:

> I originally entered [college] as an environmental science major, but I realized right before term started that I think the sustainability is really something I’m more interested in, just because I like field-work, [and] I really want to preserve what we have. So for the future…working with the policy of [the] Forest Service, because on my project originally a lot of the things that I was changing were management problems in the area and just the fact of being able to do that through policy and feel the variables change and that you’re doing something…would be something I would like to do.

Students were also able to identify and describe the many departments that were housed within the Forest Service and referenced their time shadowing staff from different departments. Students highlighted the complexity of the Forest Service and its responsibilities to work collaboratively with other agencies to create solutions to natural resource issues. Students also discussed the behind-the-scenes work that the Forest Service does that local communities were unaware of such as measuring culverts, stream crossings, and bridges every year. One student suggested these efforts make a big difference but are overlooked or not known by most visitors to national forests, he said:

> A lot of youth nowadays don't really see a career in natural resources as an option just because I don't think they really hear about it. I think this internship is a really good opportunity to really show youth what it is like to be a scientist and working with natural resources and working for the government.

Another student concluded, "I liked all of it. It's really interesting to see what people do. There's all these different ways you can work with the Forest Service, but not necessarily have to even be a scientist." The project lead said it is too soon to determine if they have attracted youth to work for the Forest Service but was aware that past students are studying natural resources and are currently pursuing these fields in college.

Summary and Lessons Learned

The Delta Apprenticeship in Science and Engineering is meeting its initial objectives. In addition, it is advancing student professional development. Students' knowledge of local ecosystems increased as well. For example, one student said:

> I learned how to apply the mathematical and science skills I've learned in school…seeing how it… applies to all the work we do. I learned a lot about hydrology, how water moves…. It really taught us stuff like good places to build fish diversions. Just doing stuff like in-stream flows, cross sections of streams and stuff like that….

Students also felt they had a good understanding of the health of the GMUG ecosystem, as one student explained, "The large amount of biodiversity, which is a generally good indicator of a healthy ecosystem. The only thing I could say would not be healthy is we do not let wildfires go through. Those usually help reset ecosystems and manage them." Although data collection was not an identified objective of this project, it was part of the design of the program because of the CFLRP funding. For example, the students' projects were designed around their interests but also to provide usable data to the Forest Service with an identified use before data collection began. The Forest Service and partner organization groups used the students' data; for example, the native westslope cutthroat trout (*Oncorhynchus clarki lewisi)* population identified in 2012 is the basis for the redesign of a fuels treatment in a watershed. The students interviewed and the project lead suggested this project could and should be expanded to other programs and forests. However, the project lead noted that this is probably best done on a forest level and potentially a district level, suggesting the strength of this program was derived from its grassroots beginnings and local commitment.

4. Discussion

4.1. Reflecting on the Design and Objectives of Forest Service Citizen Science Programs

There was considerable variation in the design and content of the three cases, and this was in large part dependent on the objectives identified during the development of each program. Objectives that all programs had in common were youth engagement and introducing youth to public lands; in two cases, this included an introduction to possible career paths in land management. I saw clear evidence that projects are meeting their objectives in interviews with students based on their increased understanding of wilderness, public lands, monitoring and monitoring protocols, and the Forest Service as an agency and future employer.

My findings also indicate that stated objectives of each project directly influenced student outcomes. For example, I saw a much more complete understanding of the Forest Service as an agency in the two projects that had an established objective for this topic area and subsequently had more departmental involvement. If either enhanced understanding of the Forest Service or opportunities to explore natural resource careers are objectives, then my findings suggest that the incorporation of an interdisciplinary team during design, development, and implementation could provide a more holistic experience for students and ultimately more support for the data generated. It also was notable that two of the projects evolved to include the objective of generating usable data, which was an objective of the Delta Apprenticeship from the outset. The students in all three projects, following monitoring protocols, were all able to collect data that project leads felt were reliable and usable using methods that were repeatable. Data quality is a major concern identified in the citizen science literature (Bonney et al. 2009, 2014); however, project leads did not indicate that this was a concern and, if anything, said that the students were especially diligent in following protocols.

One limitation of this work is that my findings are not able to confirm achievement of the long-term objectives of the three case studies. For example, one objective, according to project leads for the Alaska and Montana case study, was fostering a sense of public lands stewardship. In my post-participation interviews with students I saw evidence of an increased understanding of the natural world and what they needed to do in the future to protect it, but I would need to conduct longitudinal research to understand if this sense of stewardship endured. Another long-term objective, from the Delta Apprenticeship, was to provide information to students about the variety of college degrees that could lead to careers in civil service with agencies such as the Forest Service. None of the participants interviewed from this research have yet returned to work for the Forest Service; however, past Colorado students I interviewed are pursuing degrees in natural resources, attribute this choice to their participation in the project, and said they would consider the Forest Service for employment in the future. One past student explained:

> It definitely changed my life. If I wouldn't have done that first internship I would not be here [at university] for sure. There is no way I would have made it to this school…and I think it is a really great way to get students involved with where they live.

In addition, I found that projects were having some broader impacts beyond project objectives. I saw evidence of built relationships between students and the agency, their teachers, and the natural world. Multiple students discussed sharing what they had learned with their family and community and said they had developed professional communication skills and confidence. Students also demonstrated a better understanding of science and ecosystems. Researchers have suggested this kind of ecological literacy can lead to environmentally responsible behavior (Roth 1992; Cutter-Mackenzie and Smith 2003; Carleton-Hug and Hug 2010). Further research on this topic would need to be done to understand whether and how this manifests—longitudinal data collection with past students could aid in this determination.

These findings lead me to make two conclusions/recommendations for land management agencies based on my work: (1) project objectives have a significant influence on student outcomes and should be designed intentionally; and (2) projects in which students are collecting field data should strive to generate reliable data from the outset, as this became a common objective among my case studies and is achievable. In addition, I suggest that systematic evaluation and longitudinal research on the citizen science projects could be valuable to understand the long-term impacts of these projects.

4.2 Citizen Science as a Way to Meet Youth Engagement and Monitoring Objectives

Goals from the Forest Service Integrated Youth Strategy focus on engaging youth through place-based experiences in nature, engendering environmental ethics and stewardship, enhancing youth understanding of resource management, and fostering respect for civil servants as well as providing youth opportunities to investigate potential careers in natural resource management (USDA 2015). These three programs align with the Forest Service's Integrated Youth Strategy vision and meet many strategy goals. For instance, in interviews with students before participation in the project, many students suggested identifying the Forest Service as either Smokey the Bear or wildland firefighters. In post-participation interviews, students were able to clarify the different facets of the Forest Service and the important role the agency played in the protection and management of public lands. In addition, many of the goals of the Integrated Youth Strategy focus on future career opportunities in natural resources and mirroring the diversity of the U.S. population in the Forest Service workforce. I found some indication of interest in natural resource careers among the students in post-participation interviews.

In addition, a diverse group of students participated in the three projects, including students of different ages, ethnicities, and recreational interests. Students' stories of past outdoor experience and frequency and comfort level outdoors were wide ranging as well. However, most students felt they were already strongly connected to nature. Two of these programs had intense application processes that might be an obstacle to students not already interested in natural resources. Future research could be designed to identify who applied for these programs and how to reach an even more diverse group of students. Nonetheless, these programs appear to be supporting broader youth engagement goals such as the mandate to engage diverse youth as part of forest monitoring and planning.

As I noted above, project leads felt that these programs were yielding usable data. The notion of citizen scientists collecting data for a federal agency has generated a lot of concern regarding the quality and reliability of the data (Bonney et al. 2009; Bodillis et al. 2014). I found data quality to be a concern but not a barrier to these projects contributing data to the agency. Project leads provided students and instructors thorough training on Forest Service and other agency monitoring protocols to ensure reliable data collection that could be duplicated by next year's students or another scientist. In addition, the value of this data collection in meeting both monitoring and other Forest Service stewardship objectives was particularly apparent in my work. The Craig Ranger District used their project data to meet the wilderness education and recreation site monitoring elements in the Chief's 10 Year Wilderness Challenge. In Montana, the macroinvertebrate data has been used by the forest's hydrology department as an additional way of monitoring water quality on EPA partner projects. The students' data are also included in an annual forest monitoring report, wildlife monitoring summaries, and the Forest Service has also acted on student's management suggestions. At times, 20 Forest Service program managers have attended the Montana project's end-of-year presentations, and, according to the project lead, these recommendations have resulted in different management practices being applied in specific cases, or additional monitoring focused on sites of concern. In Colorado, student projects have also influenced management actions.

My findings suggest that youth-based, citizen science monitoring programs have the potential to be a vehicle to contribute to youth engagement, monitoring objectives, and help the Forest Service meet other agency objectives and requirements. For instance, these programs have the opportunity to reach communities that may not be represented in other public involvement processes, but are represented by their children in schools. These projects could have beneficial effects if initiated in more urban schools and environments, and more research should be done to determine the effects of these projects on students who do not already have an established connection to the outdoors. In addition, the longitudinal research I suggested would help me understand the long-term impacts on students resulting from participation in these programs.

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CHAPTER 2

1. Introduction

The concern that children are becoming disconnected from nature has received national attention (Louv, 2005). Executive branch initiatives such as *Every Kid in a Park*[8] are designed to encourage youth to spend more time outdoors. This issue is also a central aspect of the national conversation about educational standards. In 2001 elementary and secondary education were reshaped, eliminating environmental education. In response to public concern, the Every Child Succeeds Act (2015) reestablished environmental education as part of the curriculum, with focus on environmental literacy and service learning opportunities (Public Law 114-95, Sec. 4104. A).

In order to affect an individual's environmental behavior and foster environmental stewardship, environmental education focuses on enhancing environmental literacy (Roth 1992; Berkowitz et al. 2004; Pe'er et al. 2007). Environmental literacy involves understanding the interrelationships of the environment and knowing how to take appropriate action to maintain, restore, or improve its health (Roth 1992; McBride et al. 2013). In 1986, ecological literacy was introduced as a more developed form of environmental literacy to incorporate explicitly scientific inquiry and systems thinking into environmental literacy (Risser 1986; McBride et al. 2013).

The divide between environmental education, which focuses primarily on values and behavioral change, and science education, which promotes increased scientific literacy and understanding of the natural world, could be a detriment to the development of environmental stewardship (Wals et al. 2014). Researchers suggest science and environmental education need to merge in order to support an ecologically literate citizenry that can respond to society's complex

[8] https://www.everykidinapark.gov

environmental stewardship challenges (McBride et al. 2013; Wals et al 2014). Citizen science projects (i.e., when a group of community members conduct local environmental monitoring) could offer an avenue for combining environmental and science education (Silverton 2009; Wals et al. 2014). Citizen science also is a valuable tool for federal land management agencies to enhance monitoring capacity and promote youth engagement (Conrad and Hilchey 2011; Davis et al. 2015; McKinley et al. 2015).

Given the momentum from executive branch initiatives to reconnect youth to the outdoors and public lands and the emphasis on citizen science to foster environmental stewardship, I researched youth-based, citizen science monitoring programs within a federal land management agency. I identified specific case studies of youth citizen science projects with environmental education and scientific monitoring components to understand the design of these programs and in what ways they were integrating science and environmental education. In addition, I was interested in if these programs are advancing student ecological literacy and whether students demonstrated an increased sense of environmental stewardship.

1.1 An Overview of Environmental Education and Ecological Literacy

Environmental education has a long history in the United States and rose in prominence in the 1960s (Carson 2002; McBride et al. 2013). In 1977, the world's first intergovernmental conference on environmental education defined three goals for environmental education: (1) to foster clear awareness and concern about economic, social, political, and ecological interdependence in urban and rural areas; (2) to provide every person with opportunities to acquire the knowledge, values, attitudes, commitment, and skills needed to protect and improve the environment; and (3) to create new patterns of behavior of individuals, groups, and society as a whole toward the environment (UNESCO 1978). This declaration highlights the importance of providing opportunities to foster environmental stewardship (i.e., responsibility for environmental quality shared by all those whose actions affect the environment) (EPA 2005).

Since the late 1970s, environmental education has found its way into course work in the classroom, outdoor adventure programming, and wilderness therapy (Talbot and Kaplan 1986; Kellert 1998; D'Amato and Krasny 2011). Much of environmental education research has focused on how to change behavior and foster environmental stewardship (Bonney et al. 2009; Jordan et al. 2012). Researchers have focused on understanding what antecedes environmentally responsible behavior in order to help environmental educators find the most effective ways to foster environmental stewardship (Kollmuss and Agyman 2002). Early models suggested that increasing someone's environmental knowledge will result in environmental stewardship; however, researchers determined early on that this relationship was not linear (Kollmuss and Agyman 2002; Pe'er et al. 2007). Kollmuss and Agyman (2002) identified other influential factors that contribute to environmentally responsible behavior including: demographic factors, external factors (e.g., institutional, economic, social, and cultural factors), and internal factors (e.g., motivation, environmental knowledge, awareness, values, attitudes, emotion, locus of control, responsibilities, and priorities).

A body of research suggests increased environmental literacy could be one way to improve environmental stewardship (Cutter-Mackenzie and Smith 2003; Berkowitz et al. 2004; Pe'er et al. 2007). Environmental literacy includes the knowledge of basic ecological concepts, environmental sensitivity or appreciation, awareness of environmental issues and problems, and skills and behaviors to prevent and/or resolve those issues (Roth 1992; McBride et al. 2013). A recent enhancement of the concept of environmental literacy is that of ecological literacy, which emphasizes cognitive skills, particularly ecological systems thinking and scientific inquiry, using systematic observation, measurement, experiment, and the formulation, testing, and modification of hypotheses (McBride et al. 2013). As McBride et al. (2013) explain, "Recent ecological literacy frameworks also emphasize systems thinking, which involves identifying the various biophysical and social components in a given environmental context and distinguishing their interrelations, allowing for the construction of a 'big picture' view" (p. 13). Jordan et al. (2009) suggest that a majority of Americans are not well versed in ecology and suggest ecological literacy is necessary for understanding the natural world and human interaction with it, and thus fostering a land ethic or an environmentally informed citizenry.

1.2 Citizen Science

A recent article in *Science* suggests that there is currently a disconnect between environmental education, which is focused on values and changing behavior, and science education, which is focused on increasing knowledge and skill generation; connecting the two would likely foster environmental literacy (Wals et al. 2014). Researchers explain while science education might teach students how to monitor water quality, identify pollutants, and understand technologies that can reduce pollution, environmental education would involve an analysis of circumstances and behaviors that caused the pollution, along with the identification of ways to protect water quality (Wals et al. 2014). Wals et al. (2014) suggest citizen science projects afford a ready pathway for linking environmental education with science education.

Citizen science projects involve a group of volunteers collecting data for a scientific process. Its use has dramatically increased in recent years across disciplines (Lepcyzk et al. 2009; Silverton 2009). While citizen scientists have been collecting and interpreting data for over a century, citizen science has recently expanded from simply collecting data to integrating measurable educational objectives (Bonney et al. 2009; Wiggins and Crowston 2011; Jordan et al. 2012; Tulloch et al. 2013). Collaborative and community-based monitoring programs also are becoming more frequent (Fernandez-Gimenez et al. 2008; Akin et al. 2013). Citizen science offers a unique opportunity because it can involve many volunteers in large-scale data collection processes and can incorporate public education about environmental issues, teach participants about scientific methods and ecology, and simultaneously produce usable data (Dickinson et al. 2010). Researchers have identified a multitude of other benefits associated with citizen science projects, including improved communication and trust between government and local stakeholders; increased knowledge and changed attitudes among participants; and increased scientific literacy (Fernandez-Gimenez et al. 2008; Conrad and Hilchey 2011; Stepenuck and Green 2015). It can afford federal agencies an opportunity to meet multiple objectives, including those related to increasing monitoring capacity, achieving multiparty monitoring requirements, and engaging youth.

The Forest Service recently released an integrated strategy for youth to support and educate tomorrow's conservation stewards (USDA 2015). In addition, the agency's new planning regulations (36 CFR 219 et seq. [2012]) emphasize the importance of involving youth during the forest planning process, which involves assessment, planning, and monitoring, the latter of which is the stage during which citizen science might be relevant (see 36 CFR 219.4(a)(1)(ii)). Researchers suggest participatory youth engagement (where children and young adults are involved in decision-making processes about local and relevant issues to their lives) has the possibility to provide genuine and meaningful opportunities to empower youth and foster a sense of social responsibility and build an effective citizenry (Pearson and Voke 2003).

1.3 Summary and Research Questions

While the benefits of citizen science have been studied (Bonney et al. 2009; Jordan et al. 2012; McKinley et al. 2015), there has been limited research on the effects of citizen science and the outcomes of engaging youth. I chose to investigate citizen science with youth and focus on the Forest Service because of its multiparty monitoring and youth engagement objectives. I was interested in investigating how Forest Service citizen science projects with youth are being designed and whether such projects are promoting ecological literacy and environmental stewardship. My primary sets of research questions were the following:

1. What is the design of these projects and in what ways do these programs integrate environmental education and science education?
2. Is there evidence of increased ecological literacy and environmental stewardship in students?

2. Methods

This research used a qualitative, mixed-methods, multiple case-study approach (Yin 2009; Creswell 2014). Little research has been conducted on Forest Service citizen science projects with youth, and this type of research approach is appropriate for exploratory research designed to understand a phenomenon in-depth (Creswell 2014). I treated individual projects as case studies and looked for thematic similarities and key differences across cases. To identify potential case studies, I used agency list-serves and personal contacts, querying for national forest programs involving high school students in monitoring. I chose to focus my research on projects involving high school students to maintain the focus on youth engagement, while considering a population capable of quality data collection. I used several criteria to select projects: those active for more than five years, long term (i.e. multiple weeks) in design, and with students involved in direct field data collection using the scientific process. From the list of possible projects, I selected the three programs that met all criteria. To the best of my knowledge, I selected all of the long-term citizen science monitoring projects occurring between the Forest Service and high school students in 2015. The case studies were: the Alaska Natural Science Course on the Tongass National Forest, the Montana Youth Forest Monitoring Program on the Helena-Lewis and Clark National Forest, and the Delta Apprenticeship in Science and Engineering on the Grand Mesa, Uncompahgre, and Gunnison National Forests.

My goal was to interview the population of individuals involved with these projects at present, including Forest Service staff and field instructors directly involved with the projects, and all current students. I also spoke with willing and available past students to understand their perspectives. In total, I conducted interviews with 38 individuals (Table 2). I successfully interviewed all staff and almost all students who were currently involved with the projects (due to class time limitations I was unable to interview four of the 12 students in Alaska). I interviewed students before and after participation in the project to gauge the effects of participation. During the data collection phase of this research, I was able to observe fieldwork and classroom time for the Alaska and Montana projects. I was also able to observe students' final presentations from the Montana and Colorado case studies. These opportunities to observe the projects added to my understanding of the projects' content and design. I conducted 87% of interviews in-person.

Table 2: Project Participants Interviewed

	Alaska Natural Science Course	Montana Youth Forest Monitoring Program	Delta Apprenticeship (Colorado)
Adult Project Leaders	2 (Forest Service staff member and teacher)	5 (1 Forest Service staff member, 3 teachers, and 1 instructor who was a past student)	1 (Forest Service staff member)
Current Students	8	15	2
Past Students	3	0	2
Data Collection Times	January and May 2015	June and July 2015	June and July 2015

Interviews were semi-structured, using an interview guide that allows in-depth exploration of a topic according to an interviewee's interests and expertise (Charmaz 1991). I obtained consent, recorded, transcribed, and maintained confidentiality procedures approved by the Institutional Review Board for all interviews. First, I interviewed the project leads. It quickly became clear that the projects had different objectives and thus had different content and design. For example, the Alaska project focused on the scientific process and wilderness, and, therefore, my interview questions assessed what students knew about each of these two topics at the outset and after project completion. In addition, my student interview guide included open-ended questions on topic areas of interest, developed based on my literature review, including: past outdoor experiences, understanding of the Forest Service, scientific literacy, and research objectives and procedures. For example, scientific literacy included questions related to a student's understanding of ecosystems, climate change, and the scientific method (see Appendix C for interview guides).

Some drawbacks to interviews with youth include noncooperation, challenging schedules, short responses (e.g., "I don't know"), and desirability bias where a student could respond with an answer that is consistent with societal norms or perceived viewpoints of the interviewer (Vaske 2008). To build rapport and have the best chance of an in-depth conversation with high school-aged students, I met in person at least once with current-student interviewees and used photo-elicitation—a technique where students take pictures throughout project participation to provide additional insight into their experience as well as stimulate a conversation with the participant (Smith et al. 2012).

A grounded theory approach with open coding was used to analyze the data. Grounded theory uses a process of reviewing data and coding for themes with the goal to refine and saturate existing theme categories where new information is no longer being generated (Strauss and Corbin 1990). I coded interview content based on the primary questions asked and identified new codes as new themes emerged from the data. I analyzed the student data by comparing pre-participation to post-participation responses for individuals within case studies to track changes in specific topic areas. I looked for themes that arose individually and across projects to consider whether there were emergent themes that were present among all the projects. After the initial or open coding, I conducted axial coding. This second level of coding is a standard technique in grounded theory that provides additional insight into overarching concepts emerging from the data (see Appendix D for coding scheme).

This article focuses on two emergent themes in my data: increased ecological literacy and environmental stewardship. Ecological literacy could manifest as a student demonstrating "understanding of key ecological systems using sound ecological thinking, while also understanding the nature of ecological science and its interface with society" (Berkowitz et al. 2005, p. 230). I have interpreted this in my findings to equal two distinct components: (1) enhanced understanding of systems thinking, including human integration into systems, and (2) understanding of scientific processes. I also coded environmental stewardship as a multifaceted concept including: changes in behavior intentions such as "leave-no-trace" etiquette and interest in natural resource careers.

3. Results

This section is organized by case study. I first describe the design, content, and objectives of the projects. Then I explore how the project integrated science and environmental education, evidence of enhanced ecological literacy, and evidence of increased environmental stewardship. In addition to quotes in text, additional evidence is provided in Tables 3 and 4.

3.1. Alaska Natural Science Course

3.1.1. Design: Aspects of Science and Environmental Education

Twelve students, ages 16 to 19, enrolled in the 2014-2015 Alaska Natural Science Course, which provides science credits for high school students who often are not enrolled in physics, calculus, or other mandatory courses for college-bound students. According to interviewees, the Alaska case study's objectives, in addition to meeting the science course requirements, were for students to experience wilderness, to foster wilderness stewardship in students, and collect wilderness and climate change data. The students' data would serve as a baseline for the forest and could be used by the agency or other groups interested in the students' specific research topics. The project was designed specifically to target high school students because they hoped the research students conducted would contribute relevant data to the agency; for this reason, they wanted students who had a good foundation for learning and understood the scientific method.

Throughout the first semester, Forest Service employees, led by the recreation planner, repeatedly visited the class and introduced the students to topics related to land management, such as wilderness legislation and philosophy, fisheries, and wildlife biology. During the second semester, with continued input from Forest Service staff, students focused on designing their piece of an ongoing longitudinal research project in the Karta River Wilderness. During class time students conducted a literature review, reviewed the reports from the previous year's students, and modified their experimental design accordingly. At the end of the semester, the students traveled to the Wilderness for a one-day field trip where they collected their data. For the remainder of the semester, students analyzed their data, wrote a research paper, and then prepared a presentation of their findings for the Forest Service.

The course involved a mixture of science, through research project design and data collection and analysis, and environmental education, through class discussions of wilderness philosophy and legislation, including discussions about motorized equipment in wilderness areas and the development of a timeline of events surrounding the passage of the Wilderness Act of 1964.

3.1.2 Evidence of Improved Ecological Literacy and Environmental Stewardship

Students learned about the local environment and the interrelationships within ecosystems. They conduct a robust literature review and contribute to longitudinal research. Students also were able to offer the Forest Service their perspectives on the appropriate management actions in wilderness. Some students were able to describe the "big picture" implications of their research and often identified connections between student projects. For instance, one student said:

> Being able to do my own research and learn new things about…how dissolved oxygen links to the climate change, and how the ph of the water can link to dissolved oxygen which can lead to climate change…it was just really cool to see how everything has to do with something.

I also saw some evidence of enhanced understanding of the scientific method. The project lead said, "[Students] actually use the scientific method…to take their research to a level that they hadn't been able to do at school before, and really…become excited about wilderness as a baseline and…natural laboratory." In my interviews with students, they typically responded to questions on the scientific method by describing their research project and the process that they used for data collection (see Table 3). For instance, one student said, "We followed our methods, materials, and procedures step by step and did it all right besides the buckets floating, but…I put [that information] in my discussion, [saying] this is what needed to be done [in the future]." After participation in the Alaska Natural Science Course, students demonstrated a better understanding of how to use the scientific process in research and ultimately communicate their findings.

According to the Forest Service project lead, fostering wilderness stewardship was an objective of the Alaska Natural Science Course, although fostering environmental stewardship was not a course objective. I saw some evidence in student interviews that demonstrated potential for changes in behavior. For example, one student said, "[This course] probably changed the way I treat [the wilderness]…be more careful, definitely pick up after myself, to leave-no-trace."

3.2 Montana Youth Forest Monitoring Program

3.2.1 Design: Aspects of Science and Environmental Education

The objectives of Youth Forest Monitoring Program (YFMP) were to have students feel some ownership of public lands, explore potential careers with the Forest Service, learn about monitoring, and collect usable data. The first week Forest Service staff and seasonal technicians (many of whom are past YFMP students) introduced the students to protocols, provided field instruction, and demonstrated techniques for working with the equipment they would use throughout the six-week field season. Students collected monitoring data for streams, weeds, and soils to determine the effects of management actions and detect other relevant trends. Students had a four-day workweek, with most of their time in the field collecting monitoring data and an hour for data entry at the end of each day. Students in the YFMP spend significantly more time in the field than the Alaska Natural Science Course. Their internship concluded with a presentation on their findings with suggested future management actions to the public and the Forest Service.

The YFMP involved a mixture of science education, through data collection and analysis, and environmental education, through the lens of the Forest Service. A field instructor explained, “We're doing forest conservation management. The technical science side of what the Forest Service does in terms of monitoring and giving them a taste of the different aspects of what the Forest Service is. What it means. What conservation is.” The YFMP focused on students’ scientific inquiry and enabling students with the skills to make sense of the data they collect. The structure of the course supports opportunities for students to understand scientific processes and apply it to further understand the interrelationships within an ecosystem and also ecosystems within a landscape. Environmental education was not identified as an objective or incorporated as a major component of the structure of the YFMP; however, the project lead and instructors implied they were increasing students’ awareness on the land. An instructor said, “I would personally say that you are giving them an experience. You're not expecting all of them to go out and want to join up with the Forest Service and become a biologist. You're getting them out in the woods and making them a little bit more aware of what is out there."

3.2.2 Evidence of Improved Ecological Literacy and Environmental Stewardship

Students were able to use their understanding of the scientific process to begin thinking complexly about ecosystems. An instructor said, "They put soils and water and basic species and wildlife and all that stuff together. They start looking at it as a big ecosystem and they start seeing it how things work together." Students were able to identify the interrelationships within an ecosystems and commented on the connections between monitoring teams. For example, a student noted that the data collected by the soils team could be used to further understand water quality at a monitoring site.

They also demonstrated an increased understanding of humans' role in systems. An instructor stated, "They [students in the YFMP] understand a big picture". In post-participation interviews, students reflected on how their participation in the course had enhanced their understanding of the role humans play in managing and interacting with the environment. Students expressed an understanding for livelihoods and how public land managers must balance livelihoods and conservation. For example, a student described using his data to support his rationale that ranchers should remove cattle during short windows instead of entire seasons when westslope cutthroat trout (*Oncorhynchus clarki lewisi)* roe were most fragile. Students were aware of issues like grazing in riparian areas and were able to identify the necessary skills and behaviors to prevent and resolve those issues. For example, one student said, "I think I know some of the problems and some of the solutions... I'm not an expert, but I think I have a pretty good general idea of what's going on and maybe how to fix those…problems." Another student said, "Instead of looking at the ground and being like, 'Oh that's pretty,' I can tell you everything about it, how to make it better, what would make it worse. It's a lot of explanations for things, so that's pretty cool." In a post-participation interview, a student described a seasonal road and area closure that prohibited ATV use and then explained the management rationale for this decision. He added, "I used to think...when I was younger, walking around, 'Oh, there's no motorized vehicles past this point. That's pretty stupid…,' but now that I've done this, I know how important it is to keep minimal use to certain areas of the forest." In addition, students offered specific management actions for the Forest service to consider, such as using a backpack sprayer to deal with a rapidly increasing oxeye daisy (*Leucanthemum vulgare)* population in wilderness and temporary closures for grazing in a riparian area when westslope cutthroat trout roe (*Onchorhynchus clarkii lewisi*) are especially sensitive.

Students were able to describe the scientific method, but this was not a major component of this focused monitoring program. Students articulated the monitoring protocol, data collection, and data analysis of their season. In interviews with the instructors, they suggested students became more excited about science through the process of using it and applying what they learned in school in the field.

I saw evidence of increased environmental stewardship in this case in terms of both interest in behavioral change and stewardship careers. Students gained awareness of National Forests issues and management strategies and said they would change their behavior in the future when visiting National Forests. Multiple students were able to identify changes to their own behavior and identified this as an initial motivation for signing up for the program. For example, in a pre-participation interview, a student said, "Hopefully, I can get some more knowledge about the wildlife…, so if I see something that is wrong, I'll know what to tell people." In his post-participation interview, he stated:

> I learned a lot about soil... How important it is to minimize your trace...Camping areas, you do not want to camp in the same area over and over and over again. It's just bad for the ground. [Instead of] having different fire rings, just have one main one. I learned a lot about compaction, stuff that you should be aware of when you're doing stuff like that.

Another student simply said, "If you see one knapweed on the side of the trail, just pull it. It takes five minutes."

In addition, several students expressed interest in careers in natural resources, identifying specific positions such as YFMP instructor, fire crew, soil scientist. Another student said, "I like being around people and helping people. I like doing work outside, which is why I'm thinking…some field-work in science. I like doing things that feel important, like I'm helping the planet or other people."

3.3 Delta Apprenticeship in Science and Engineering

3.3.1 Design: Aspects of Science and Environmental Education

The Delta Apprenticeship in Science and Engineering, run by the Grand Mesa, Uncompahgre, and Gunnison National Forests, invites two students, every year, to participate in the six-week Delta Apprenticeship Program. The project lead for the Colorado case study said the Delta Apprenticeship had two objectives of equal importance: to expose students to what they could study in college, specifically science and engineering, and to provide information to students about the variety of college degrees that could lead to careers in civil service with agencies such as the Forest Service.

The two students had a typical workweek (approximately 40 hours) and spent the first three weeks of the program shadowing Forest Service employees from different departments. During the remaining three weeks of the apprenticeship, students designed their research project with their Forest Service mentor and then collected their data. The project lead identified his approach as a "guided discovery approach to mentoring," and added that the point of the program is to pay students to collect data, but also to first identify their interests and then identify a related research project. The Forest Service lead then helps the student determine the data they would need to collect and think through the design and implementation of their research. Examples of student projects include riparian health monitoring including grazing improvements and vegetation rehabilitation, suitability for native trout translocation, and the re-design of an irrigation ditch to improve habitat for Gunnison sage-grouse (*Centrocercus urophasianus*). Students presented their research to the Forest Service, community members, and the school board.

The apprenticeship had a strong focus on science, natural resources, and engineering as evidenced in students descriptions of their research and findings. Environmental education was not identified as an objective, and I did not see evidence that it was a major component of the apprenticeship; however, students attributed their enhanced appreciation of nature to the field-work and research components of the apprenticeship.

3.3.2 Evidence of Improved Ecological Literacy and Environmental Stewardship

I saw evidence of improved ecological literacy in post-participation interviews with current and past students. Students identified many different species and described the ecosystems around them as complex and interconnected. For instance, one past student said, "I really learned a lot about the geography of the area." A current student described what she learned about the composition of forests, suggesting, "Learning that there's such a finer detail with forests...It's not just one type of tree, grass, bird, deer or something like that. There's a lot more to it than what you can see…" In addition, students in the Delta Apprenticeship described the Forest Service as a complex agency that is managing the land for multiple uses. Students were able to translate their research and their findings into solutions for the Forest Service but were also provided opportunities to learn about the 'big picture' of managing land for multiple-uses. For example, one student identified an "ineffective permittee management" as a contributing factor to deteriorating riparian health; however, her project was not successful in changing the system because of the agency's multiple use mandate. The project lead also suggested students were able to understand the complexities of land management, which I saw evidence of in my post-participation interviews with current and past students. As one student stated:

> Knowing the people who are in the agency and…everything that they stand for is just to protect but also effectively use the resources. Because growing [up] in a rural area, a lot of people want to use the resources and so for me it is really cool to see the Forest Service work hand-in-hand with those [people] and conserve and protect but also efficiently use those resources that a lot of the people depend on.

In my post-participation interviews, students stated they used the scientific method to design and implement their research and enjoyed being able to apply what they learned in school to a meaningful summer apprenticeship. For example, one student said: "applying what we have learned in math and science to the real world and the job...just really getting out there and just doing a lot of hiking and scientific work."

I saw evidence of increased environmental stewardship in this case in terms of new or increased interest in careers in natural resources. A past student who is currently studying environmental science, with a focus on sustainability and the built environment, credited the Delta Apprenticeship for her scholarship and college degree path. A current student said, "It was a great experience. It has really made me excited to pursue careers in natural resources."

4. Discussion

4.1 Current design of Forest Service citizen science programs

I was interested in investigating how Forest Service citizen science monitoring projects with youth are being designed, to what end, and whether such projects are promoting ecological literacy and environmental stewardship. The three projects selected for this research had different content, design, and objectives and did not explicitly identify the integration of science and environmental education; however, I saw evidence of this in their design. The Alaska Natural Science Course, being mainly coursework, had the strongest environmental education component with the classroom discussions of wilderness philosophy; this could be reflective of the wilderness stewardship objective identified by the project lead. This project also had a major science component; as a high school science course, students worked through the scientific method and conducted a longitudinal climate change research project. The YFMP incorporated both science and environmental education into the project design. It focused primarily on the data collection, and the students used scientific inquiry to understand what they were seeing at their monitoring sites and also to analyze and present their findings to the Forest Service. I saw some evidence of environmental education components during the project, with a focus on public lands conservation, and these manifested as informal conversations between students and mentors. I did not see evidence of environmental education incorporated into the Delta Apprenticeship in Science and Engineering; however, the Apprenticeship did not identify environmental education components (i.e., value or behavior change) or environmental stewardship as program objectives, as was the case of the Alaska and Montana programs. The Delta Apprenticeship study had a major focus on scientific inquiry as students conducted an in-depth science or engineering project, similar to the Alaska case study, and presented their findings and suggestions to the Forest Service upon completion. Some notable differences in project structure were the amount of time students spent doing fieldwork and the content of the course. The students in the YFMP and the Delta Apprenticeship spend significantly more time doing fieldwork. The students in the Alaska Natural Science Course and the Delta Apprenticeship design and conduct research projects, whereas the YMFP students execute monitoring, but do not design research.

The three projects selected for this research were similar in that they worked with high school students over a long period of time to collect and present monitoring data to the Forest Service. Individually, they each met their objectives, and their objectives had a strong influence on the impact to the students. Present across all cases was the important connection of the students' science to the real world. For example, students conducted science that would contribute data to the Forest Service and this sense of ownership over the data and their work was evident in interviews with students, project leads, instructors, and teachers. These findings suggest that these programs are incorporating both science and environmental education to some degree and are likely to be creating ecological literacy among participants.

4.2 Reflections on student outcomes: ecological literacy and environmental stewardship

As I noted above, ecological literacy encompasses ecological thinking and scientific inquiry skills and is important to create an environmentally informed citizenry (Jordan et al. 2009; McBride et al. 2013). Citizen science can promote ecological literacy by providing opportunities for participants to use scientific inquiry and systems thinking to connect data collection to management action and engage with environmental issues.

I saw evidence of increased ecological literacy among students in the three programs of this research, although the evidence of ecological literacy in systems thinking and scientific understanding varied among the projects. As I noted earlier, systems thinking involves identifying the various biophysical and social components in a given environmental context and distinguishing their interrelations, allowing for construction of a “big picture” view. I saw evidence of gains in this area among the case studies. In interviews with students, they identified connections between student projects. For instance, students in the Alaska project observed connections between research projects. Students in the YFMP noticed similarities between site characteristics and also made notable connections between monitoring teams. The students in the Delta Apprenticeship expressed their systems observations through interpretation of their data and what might have influenced their results. Students in the Delta Apprenticeship did not identify connections between student projects, but there were also only two students working with different departments. The opportunity for groups of students to connect and discuss their different research and monitoring efforts could contribute to stronger systems thinking.

Students from the YFMP showed the greatest understanding of systems thinking; this could be because of the daily fieldwork, data collection and analysis components of the project, and the communication across the multiple teams of students working on different aspects of environmental monitoring. Students in the Alaska and Colorado case studies were experts on their individual research topics, whereas the students in the YFMP were able to discuss larger relationships within an ecosystem. The difference in systems thinking in the YFMP was not necessarily more advanced but more holistic, and this also varied among students. For instance, some students were able to draw conclusions from their field observations and the longitudinal data set to inform their data analysis and also provide insight on the health of the ecosystem in their final presentations. The different manifestations of ecological thinking could be representative of the design and initial objectives of the program.

Students were also able to go beyond the interactions between biophysical components within an ecosystem and draw connections to cultural interactions and implications for land management. Students in the Alaska case study noticed the Karta River Wilderness showed signs of human occupation and offered their opinions on use of motorized equipment in Wilderness areas. In all three case studies, students used their data to present their findings to the Forest Service and suggested potential management strategies for the future. Students were able to demonstrate compassion towards many different user groups. The direct field experience of these programs on Forest Service lands could allow students to observe the management of multiple uses, connect biophysical and social components, and construct a 'big picture' view.

All three case studies emphasized scientific inquiry to provide students opportunities to question, explore, understand and interpret their data. For instance, students in the Alaska and Colorado case studies demonstrated an increased understanding of the scientific method and used their research project to articulate the process and their findings. The students in Montana were able to articulate the monitoring protocol they followed for their respective teams, felt confident that the Forest Service could use their data, and felt that other scientists could repeat their methodology. However, while students in the YFMP had a strong understanding of monitoring protocol, there was less evidence among these students that they understood the application of the scientific process. This could be indicative of the project design and objectives which did not include design of a research project. Across projects, it is my view that the data analysis component of these projects provides students a meaningful opportunity to contribute their skills, perspectives and management solutions to the Forest Service.

Environmental stewardship also manifested in different ways among students, including changes in behavior and interest in natural resource careers. For example, students in the Alaska course expressed leave-no-trace ethics and identified appropriate behaviors in Wilderness; wilderness stewardship was an objective of the Alaska course. Students in the YFMP also mentioned leave-no-trace and personal behavior changes but focused mostly on appropriate visitor behavior to national forests. For instance, students were able to identify environmental issues and problems impacting an area and then offer specific management strategies; they supported these suggestions with data and thoughtful explanations for managers to consider. Both objectives from the Delta Apprenticeship were focused on introducing students to careers in natural resources, and I saw evidence of an increased interest in careers in natural resources among Colorado students. I saw new interest in careers in natural resources among students in the Montana project as well, which also identified future career opportunities as an objective. Students from all three projects also expressed a new respect for nature, Wilderness, National Forests, and also for the Forest Service as an agency.

The objectives of these projects had a strong influence on the impacts to students. I saw evidence of stewardship manifest in different ways and to different degrees. I believe this could be reflective of the project objectives and design. For example, environmental stewardship manifested in the Alaska and Montana project mostly as changes to behavior; both projects identified stewardship of wilderness and public lands as an objective. By contrast, in Colorado stewardship manifested more in terms of management suggestions and career interest, both of which were students learning objectives and outcomes built into project design. Differences in levels of environmental stewardship also likely related to the different levels of ecological literacy.

I conclude a few key factors of these programs could yield the greatest ecological literacy, these include: design of research projects that can be applied in the field, ample time for fieldwork, and multiple student projects across resources. The field-based scientific work was present in all three programs. Students and instructors alike suggested the fieldwork component of these programs was a highlight and I believe this time helped contribute to students' enhanced systems thinking and provided opportunities to see the role of humans in ecosystems first hand. Finally, collaboration between student groups encouraged teamwork and provided students the space to collaborate and discuss the implications of their work. These three components had a strong influence on students and could lead to environmental stewardship; however, further research is needed.

One limitation of this work is that my findings are not able to confirm achievement of the long-term objectives such as wilderness or environmental stewardship. The YFMP currently distributes a survey to past students every two years. A similar effort, with surveys or interviews, could be conducted on the other two programs to evaluate the long-term effects of these programs.

5. Conclusion

My findings suggest enhanced ecological literacy and environmental stewardship are potential outcomes of youth based, citizen science monitoring programs. The direct connection of students' data and research findings to land managers provided a meaningful opportunity for students to engage with environmental issues, natural resource professionals, and controversial land management topics. Students were confident and proud of their data, and this reinforced their ideas that they could affect the lands they studied and cared for.

These youth-based, citizen science monitoring programs could be an untapped resource to increase agency monitoring capacity, engage and empower youth, and foster a sense of environmental stewardship by providing meaningful opportunities for youth to contribute to public land management. Project design has a strong influence on the achievement of objectives thus project leads should carefully develop and design the objectives and project. If environmental stewardship is a goal, then this should be built into project objectives along with strong methods for developing ecological literacy. My findings suggest if ecological literacy is a goal, project leads and other citizen science practitioners should consider integrating science and environmental education components and support time for students to develop and design research, conduct fieldwork, and interact with other students doing work across resources areas.

Future researchers should consider the long-term effects of these programs to determine if enhanced ecological literacy contributes to long-term environmental stewardship. These programs are potential outreach tools for the Forest Service as well, and future researchers could evaluate whether students pursue careers in natural resources. I also suggest that researchers partner with federal agencies to help design projects with information from the literature and study how outcomes vary based on project design.

Table 3: Evidence of Improved Ecological Literacy

Social and Ecological Systems Thinking
Instructor Perspectives: The idea is to get kids invigorated about careers with science and engineering with the hope that if we can invigorate them in that way [that] they'll see 'I can use the tools I was learning in such-and-such an education to work in land management to work in civil service.' *(CO Project Lead)* I think some of our crews have been able to go further with thinking out of the box. I think being able to look at trend lines and hypothesize why things are happening the way they do; that takes a different level of thinking. You teach them to go from being bean counters, to just write down the data, to looking at it and then trying to figure out what's going on. *(MT Field Instructor)* From the start of the season to the end of the season I'd say they gained more of an awareness of what the forest means, you know what it means to them. What we do with it, why it matters. *(MT Instructor)* The first year the two students…spent nearly three weeks up on the Uncompahgre Plateau, looking at riparian habitat and getting some sort of pre-treatment data… Unfortunately, we were never able to get the cows [removed from] the riparian area. So, they learned about the realities of land management as well as how to collect [and] present data. *(CO Instructor)*
Student Perspectives: More of an understanding about everything, like how everything connects to each other. *(AK Student)* I learned a lot of ecology…it has really influenced how I look at the world in general and especially when I'm out in nature. It's not just like, "Oh, pretty forest." It's a connection and [I] look at a forest and say, "Okay, what's going on here at a deeper level?" That's really helped me to appreciate…how complex things are and how great of a responsibility it is to be a person in the Forest Service and to work with all these millions of acres of land because it's not simple. *(MT Field Instructor & Past Student)* Once you know about one thing in a forest,…through research and…digging you can find out about everything….I didn't realize how intertwined nature was, and how if one thing is affected [then] it is a domino effect. I definitely think that was my biggest takeaway from this program. *(MT Student)* The [Cunningham] Ditch takes water off of Mill Creek and it sends it down to the Miller Ranch and the Parks and Wildlife bought the Miller Ranch. It is this big lot and it is full of sagebrush and…they have the endangered Gunnison sage-grouse. It is prime habitat. They use the ditch water and it just leaks water throughout that whole sage grass and it creates unique habitat for the Gunnison sage-grouse. It wasn't supplying enough water because the whole upper ditch was leaking. That's what I worked on, I was proposing a solution to move more water down stream, so they can deliver it for the sage-grouse. *(CO Student)*

Just really how to apply the mathematical and science skills I've learned in school. Just really seeing how it just applies to all the work we do. I learned a lot about hydrology, how water moves and obviously it moves downhill. It really taught us stuff like good places to build fish diversions. Just doing stuff like in stream flows, cross sections of streams and stuff like that. *(CO Student)*
Scientific Inquiry Skills
Instructor Perspectives: I do have more people now that have been to the Karta [River Wilderness] who likely wouldn't have had an opportunity to go and more people that have this knowledge that they can do scientific research. They're out there doing it and created their own methodologies…did a literature review… all these things. They put it together themselves. *(AK Instructor)*
Student Perspectives: We were looking at water quality to see if it would link into climate change in the Karta River Wilderness. We looked at ph, salinity, dissolved oxygen, temperature…and we took two samples of macro invertebrates. *(AK Student)* I learned how to use…swabbing equipment, I was able to communicate with the scientist down south…that was kind of cool…go through the process of sending samples off and getting results back…. Probably just that and being able to go through the process…writing a research paper and being able to figure all that out. *(AK Student)* I would say that if we're going to do this in the future, then we need to adapt and change some things. Our project was rather inconclusive this year…we need to find a better way of determining whether or not there's chytrid fungus there [Karta River Wilderness]. *(AK Student)* [The scientific method] starts off with asking a question, doing background research, developing a hypothesis, and then getting your procedures straightened out, performing the experiments, and then collecting data while doing that. Afterwards, taking that data and processing it into a response that corresponds to your hypothesis. Then figuring out where to go from there after the hypothesis have been proved or disproved. *(CO Student)*

Table 4: Evidence of Increased Environmental Stewardship

Behavioral intentions
[Participation in this course] makes me respect it a lot more than I probably did…makes me not want to do some of the things that I did before…. If you do go out camping and stuff, you pick all your stuff up and make it look nice so that other people go back and go camping in that area. *(AK Student)* That small things can directly impact the environment in big ways, such as weeds…there's this little spurt, it looks like nasty stuff coming out of the hillside going straight into the creek there. It's better to deal with those little things now then wait for them to become problems. *(MT Student)*
Careers in Natural Resources
So it kind of gives you an idea of like, whoa, could I do this for the rest of my life? Or something that I want to invest in? I liked that part of it. *(AK Student)* I was leaning towards civil engineering but after this, I think maybe environmental engineering, because then I could still get hopefully some of this aspect of the environment. *(MT Student)* Yeah, definitely. I think a lot of people who have done this go into careers in natural resource or summer jobs with the Forest Service, so I think it definitely changes a lot of people's lives and then I know after then you can go out and be inspired to go into nature because it's just so cool. *(MT Student)* Yeah. I'd like to be part of the fire crew, possibly, for the Forest Service while I'm in college, depending on where I decide to go to school. Or, be, like, a tech. But, for sure, yeah, this has definitely given me a taste of it. *(MT Student)* I think the sustainability is really something [I'm] more interested in just because I like field work, but I really want to preserve what we have…and the program that I am in…I get a combination of science and policy so for the future I really think I want to move back to…western United States… Just working with the policy of the Forest Service because on my project originally a lot of the things that I was changing were management problems in the area…just the fact of being able to do that through policy and feel the variables change and that your doing something…would be something I would like to do. *(CO Student)* I have learned that I can actually have an impact on these places…when you are younger you are like, 'oh man, I probably can't do anything about this,' but after doing this I am seeing people who are actively trying to engage themselves to make these places a better place and to keep them going longer and conserving them…. What was really cool to me was that I could get connected in a way that I could protect and conserve the land and nature that I love so much, and that I have grown up around. *(CO Student)*

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APPENDIX A: SURVEY FINDINGS

Survey Findings

To obtain an in-depth understanding of the effects on students from participating in these projects, surveys were given to students before and after their participation. The short surveys included questions from Dr. Daniel Silvas' dissertation and also questions from a survey administered by the project lead of the Youth Forest Monitoring Program. Survey topic areas included: favorite outdoor recreation activities (e.g., camping, fishing, and hiking); comfort levels of specific activities (e.g., working and sleeping outdoors); emotional connections to nature; attitudes toward nature; willingness to protect nature; and skill development (e.g., levels of experience with Microsoft programs, GPS units, clinometers). See appendix B for the survey. For most of the questions, students were asked to circle a number from 1 to 5 to represent their answer, these variables were then recoded to -2 to +2 to ease the interpretation of the results.

The analysis focused on comparing student responses before and after participation in the program; students' codenames were used to protect anonymity and to match their pre-participation survey with their post-participation survey. With one exception, all students completed both the pre and post surveys ($n = 26$). In addition, one student who I was unable to interview in the Alaska project because of a time restriction was able to take the survey and it was included for analysis. Surveys were administered during the spring and summer of 2015. Paired samples t-tests were used for analysis.

Although many of the paired t-tests did not yield statistically significant results, there are some notable conclusions that can be drawn from these results. First, students in pre and post-participation interviews felt they were strongly connected to nature. For instance, there was evidence of positive attitudes toward nature and an emotional connection to nature (see Table 7 and 8). Second, the students surveyed live in areas that are surrounded by national forest lands and were generally aware of their public land access. Most students were regularly recreating outside before participating in these projects.

Overall, the results suggested several implications for future research. First, the students in this sample were already connected to nature. The Forest Service should consider reaching out to students in urban areas who might be less connected to nature. Second, the survey demonstrated measurement reliability and accuracy, program evaluation is a weakness of many environmental education and citizen science programs, and this survey should be replicated in future work. Third, the survey detected some of the emergent themes from the qualitative research such as professional development. In post-participation interviews, many students suggested they were more comfortable with public presentations and working with adults and project leads also noted this as one of their observed benefits to students. This was one of the few variables that was statistically significant ($p < .05$).

In the future, researchers should consider using a larger population and also different and more diverse student groups. One potential example is the Philadelphia Field Station, part of the Forest Service's Urban Natural Resource Stewardship unit, because it has citizen science, participatory research, and youth engagement programs that have similar goals to the programs in this research and the survey would be well suited to measure their outcomes. Finally, because two of these programs identified environmental stewardship as an objective further research with this survey could be done to continue to evaluate the long-term effectiveness of participating in one of these programs.

Table 5: Comfort Level with Specific Activities

	Means			
What is your comfort level with the following activities?	Pre	Post	*t-value*	*P-value*
Working outdoors	1.6154	1.7692	-2.132	.043
Sleeping outdoors	1.38	1.538	-1.280	.212
Public presentations	.1154	.5769	-2.483	.020
Working on a team	.807	1.00	-1.224	.232

Table 6: Skill Development Variables

Rate your level of experience:	Means			
I have (no experience - a lot of experience)…	Pre	Post	*t-value*	*P-value*
Microsoft Word	1.20	1.44	-2.00	.06
Microsoft Excel	.48	.76	-1.90	.070
Microsoft PowerPoint	.96	1.12	-1.16	.26
Compass	.72	1.00	-1.50	.15
GPS Unit	.68	1.28	-4.24	<.001
Clinometer	-.68	.28	-3.23	<.001
Digital Camera	1.56	1.84	-1.90	.07

Table 7: Emotional Connection to Nature Variables

Statement	Means			
When in nature, I feel…	Pre	Post	*t-value*	*P-value*
Afraid/Peaceful	1.71	1.71	.000	1.00
Anxious/Calm	1.56	1.64	-.53	.60
Bored/Thrilled	1.04	1.12	-.63	.54
Uneasy/Comfortable	1.44	1.48	-.21	.83
Worried/Carefree	1.12	1.04	.46	.65
Hate/Love	1.24	1.16	.53	.60
Miserable/Joyful	1.36	1.44	-.57	.57
Sad/Happy	1.56	1.56	.00	1.00
Unloved/Affection	.88	1.08	-1.42	.17
Unimpressed/Fascinated	1.32	1.40	-.49	.63
Uninterested/Awestruck	1.36	1.24	.90	.38
Stressed/Relaxed	1.56	1.72	-1.28	.21
Unhappy/Lighthearted	1.32	1.08	1.81	.08
Scared/Fearless	1.04	1.24	-1.41	.17
Tense/Restful	1.24	1.28	-.272	.79

Table 8: Attitudes Toward Nature Variables

	Means			
Do you agree or disagree with the following?	Pre	Post	*t-value*	*P-value*
I feel a deep love for nature.	1.16	1.32	-1.69	.10
I feel emotionally close to nature.	1.00	1.12	-.90	.38
I do not love nature.	1.68	1.64	.30	.77
I feel emotionally distant from nature.	1.56	1.48	.70	.49
I am attracted to nature.	1.32	1.44	-1.37	.19
I care about nature.	1.68	1.68	.00	1.00
I am interested in nature.	1.64	1.56	.81	.43
I feel a strong emotional bond with nature.	.96	1.04	-.53	.60
I like being in nature.	1.88	1.77	1.36	.19
Being in nature is fun.	1.73	1.65	.70	.49
Being in nature is boring	1.62	1.35	1.49	.15
Protecting nature is important to me.	1.65	1.62	.57	.57
Nature can take care of itself.	-.27	-.08	-.84	.41
I like spending time in nature.	1.69	1.54	1.69	.10
Nature needs our help.	.81	.85	-.21	.83

Table 9: Willingness to Protect Nature Variables

	Means			
I am willing to…	Pre	Post	*t-value*	*P-value*
Participate in forest planning processes.	1.12	1.12	.00	1.00
Take action to protect nature.	1.42	1.23	1.31	.20
Not to harm animals or plants while in nature.	1.35	1.35	.00	1.00
Ride my bike instead of having someone drive me.	.96	.88	.44	.66
Volunteer to help protect nature.	1.15	1.27	-.83	.42
Recycle my cans and bottles.	1.27	1.42	-1.07	.29
Pick up litter that is not mine.	1.50	1.42	.81	.43
Compost food waste.	.92	.96	-.24	.81

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APPENDIX B: SURVEY

Survey

1. What are your favorite outdoor recreation activities?

Check all that apply.

- Camping
- Backpacking/Hiking
- Wildlife Viewing
- Mountain Biking
- Fishing
- Hunting
- Canoeing/Rafting/Kayaking
- Boating
- Off highway Vehicle Use
- Other: Please specify

____
____
____
____

2. What is your comfort level for the following activities?

	Very Uncomfortable		**Comfortable**		**Very Comfortable**
Working outdoors	1	2	3	4	5
Sleeping outdoors	1	2	3	4	5
Public presentations	1	2	3	4	5
Working on a team project	1	2	3	4	5

3. Please circle one number for each row that best describes how you feel in nature. For example, for row one if you feel somewhat sad while being in nature you would circle 2.
Circle one number for each statement.

I feel…	***Very***	***Somewhat***	***Neither***	***Somewhat***	***Very***	
Sad	1	2	3	4	5	Happy
Miserable	1	2	3	4	5	Joyful
Afraid	1	2	3	4	5	Peaceful
Anxious	1	2	3	4	5	Calm
Stressed	1	2	3	4	5	Relaxed
Uneasy	1	2	3	4	5	Comfortable
Bored	1	2	3	4	5	Thrilled
Unimpressed	1	2	3	4	5	Fascinated
Hate	1	2	3	4	5	Love
Unloved	1	2	3	4	5	Affection
Unhappy	1	2	3	4	5	Lighthearted
Scared	1	2	3	4	5	Fearless
Worried	1	2	3	4	5	Carefree
Tense	1	2	3	4	5	Restful
Uninterested	1	2	3	4	5	Awestruck

4. Below are statements that represent different ways some students feel towards nature. We're interested in knowing how you feel about nature. *Circle one number for each statement.*

Do you disagree or agree with the following?	***Strongly Disagree***	***Slightly Disagree***	***Neither***	***Slightly Agree***	***Strongly Agree***
I feel a deep love for nature.	1	2	3	4	5
I feel emotionally close to nature.	1	2	3	4	5
I do not love nature.	1	2	3	4	5
I feel emotionally distant from nature.	1	2	3	4	5
I am attracted to nature.	1	2	3	4	5
I care about nature.	1	2	3	4	5
I am interested in nature.	1	2	3	4	5
I feel a strong emotional bond with nature.	1	2	3	4	5

5. Below are statements that represent different ways some students think about nature. We're interested in knowing how you think about nature. *Circle one number for each statement.*

Do you disagree or agree with the following?	***Strongly Disagree***	***Slightly Disagree***	***Neither***	***Slightly Agree***	***Strongly Agree***
I like being in nature.	1	2	3	4	5
Being in nature is fun.	1	2	3	4	5
Protecting nature is important to me.	1	2	3	4	5
Being in nature is boring.	1	2	3	4	5
Nature can take care of itself.	1	2	3	4	5
I like spending time in nature.	1	2	3	4	5
Nature needs our help.	1	2	3	4	5

6. Below are statements that represent different ways some students are willing to help nature. We're interested in knowing your willingness to do the following. *Circle one number for each statement.*

I am willing to...	***Strongly Unwilling***	***Slightly Unwilling***	***Neither***	***Slightly Willing***	***Strongly Willing***
Participate in forest planning processes	1	2	3	4	5
Take action to protect nature.	1	2	3	4	5
Not to harm animals or plants while in nature.	1	2	3	4	5
Ride my bike instead of having someone drive me	1	2	3	4	5
Volunteer to help protect nature.	1	2	3	4	5
Recycle my cans and bottles.	1	2	3	4	5
Pick up litter that is not mine.	1	2	3	4	5
Compost food waste.	1	2	3	4	5

7. Rate your level of experience with the following:

I have…	**No Experience**		**Some Experience**		**A lot of Experience**
Microsoft Word	1	2	3	4	5
Microsoft Excel	1	2	3	4	5
Microsoft PowerPoint	1	2	3	4	5
Compass	1	2	3	4	5
GPS Unit	1	2	3	4	5
Clinometer	1	2	3	4	5
Digital Camera	1	2	3	4	5

We would like to know a little more about you.

8. Are you?
   - o Male
   - o Female

9. How old are you? ______

10. Are you of Hispanic, Latino, or Spanish origin?
    - o No, not of Hispanic, Latino, or Spanish Origin
    - o Yes, Mexican, Mexican Am., Chicano
    - o Yes, Puerto Rican
    - o Yes, Cuban
    - o Yes, another Hispanic, Latino, or Spanish Origin
    - o Other origin: ____________

11. What is your race?

- o White
- o Black, African Am., or Negro
- o American Indian or Alaska Native *Please write name of enrolled or principal tribe:* _____________
- o Native Hawaiian
- o Some other race: __________________
- o Guamanian or Chamorro
- o Asian Indian
- o Filipino
- o Korean
- o Other Asian: ________________
- o Samoan
- o Chinese
- o Japanese
- o Vietnamese
- o Other Pacific Islander: ________________

APPENDIX C: INTERVIEW GUIDES

Participant Interview Guide Pre-Participation

School and Environmental Topics

1. Do you have a favorite class or two in school? Can you tell me why you like them?
2. Why did you decide to sign up for (Alaska Natural Science/GMUG Apprenticeship)?
3. What can you tell me about the scientific method?
4. Do you have any possible careers in mind that interest you?
5. What do you hope to take away from your time enrolled in this program?

Outdoor Experience

1. Do you spend time with any of your family members outside? What kinds of things do you do?
2. Can you tell me about your last trip outdoors?
3. Do you ever explore on your own? Can you tell me about one of those trips?
4. Do you like spending time outdoors?
5. Can you describe one of your most memorable outdoor events?
6. How much time would you say you spend outdoors?
    a. With your family?
    b. By yourself?

Ecological Literacy

1. What is an ecosystem?
2. What do you know about the forest ecosystems around where you live?
3. Can you name some plants or animals there? How do you know these species?
4. What do you imagine when you think of "nature"?
5. Do you talk to friends or family about nature? (prompt them about wilderness, climate change, or the Forest Service) as the question develops.

Forest Service Knowledge

1. What do you know about the Forest Service? (make sure to find out if they've interacted with them before)
2. Do you know anything about National Forests? Have you ever visited one?
3. Do you know anything about Wilderness? Have you ever visited one?
4. How do you picture National Forests and Wilderness? Do they seem different in your mind?

Closing

Is there anything else you want to tell me? Do you have any questions for me?

Participant Interview Guide Post-Participation

School and Environmental Topics

1. Are you glad you signed up for (Alaska Natural Science/GMUG Apprenticeship/YFMP)?
2. What was your favorite part of this project? What was your least favorite?
3. Did you learn more about science and the scientific method?
4. Have you career or school interests changed as a result of participating in this project?

Photo Questions

1. Can you tell me about the first photo you chose to represent your experience?
2. Why did you select this photo? Do you remember what you thought or felt during the time when you took this photo?
3. Can you tell me about the second photo you chose to represent your experience?
4. Why did you select this photo? Do you remember what you thought or felt during the time when you took this photo?

Emotional and Cognitive Responses

1. How did you feel when you were out in the forest? Did your feelings change at different times?
2. What do you picture now when you think of “nature”? Do you think this changed over the course of the project?
3. Do you like spending time outdoors? Do you think this changed over the course of the project?

Forest Service Knowledge

1. What do you know now about the Forest Service? What is your impression of them?
2. What do you know now about national forests? Is this different from what you thought before the project?
3. What do you know now about wilderness? Has your idea of wilderness changed since you participated in this project?

Ecological Literacy

1. What is an ecosystem?
2. What do you know about the forest ecosystems around where you live?
3. Can you name some plants or animals there? How do you know these species?
4. Do you talk to friends or family about nature? (prompt them about wilderness, climate change, or the Forest Service) as the question develops.

Closing

1. What are one or two of the most important things you took away from this project?
   Is there anything else you want to tell me? Do you have any questions for me?

Forest Service Personnel Interview Guide

Citizen Science Project Description

1. Can you describe the citizen science project you are involved with in detail?
    a. What does the project consist of? (e.g. fieldwork, scientific method and readings, shadowing)
    b. What students are involved and how are they selected?
    c. What's your role?
2. What resources (time, staff, other money) does the FS commit to this project?
3. What were the initial objectives for this project?
    a. How did you plan to accomplish these objectives?
    b. Have the objectives changed over time? Have your activities changed over time?
4. Why did you decide to accomplish this project with high school students?
5. Were participants informed of the goals and objectives of the citizen science project?

Project Impacts

1. Do you feel the project accomplished the intended goals and objectives? Why or why not? What were important factors to success or important challenges?
2. Did the project lead to other benefits that were not part of the initial project objectives?
3. What impacts to students do you notice over the course of the project?
4. What would you say are the primary benefits of this project for the agency? For students?

Data Reliability

1. Is the accuracy and reliability of student data collection important to you and/or the Forest Service?
2. If so, how do you work to ensure reliability? Have you found their data useful?
3. If not, why not?

Future

1. What do you think the future of this project will be?
2. Do you think this kind of project is something other National Forests should do? Why?

Closing

1. Is there anything else you would like to tell me about or do you have any questions for me?

Instructor Interview Guide

1. How would you describe science education? Environmental education? How important are these in your curriculum?
2. How would you describe the average students connection to nature?
3. Can you describe the communities that attend your school?
    a. what type of student signs up for this course?
4. Can you describe how they use or interact with the national forest?

Citizen Science

1. Can you describe the citizen science project?
    a. Cover nature of project, their role, and their role in starting it or their current role?
    b. Make sure they discuss: fieldwork, methods and research, readings, shadowing, class time and course work.
2. What were the initial objectives for this project? (Prompt with trust building, community education, added monitoring capacity?
    a. How is the project designed to accomplish those goals?
    b. Was the process collaborative? Did you design with the USFS to accomplish specific goals? What was your experience like working with the USFS?
    c. Discuss range of projects and if these relate?
3. Have the objectives or project design changed over time?
    a. Why this age group?
4. Are there benefits to the project that were not part of the initial objectives?
5. Were participants informed of the goals and objectives of the citizen science project?
6. Do you feel the project accomplished the intended goals and objectives?
    a. Why or why not?
    b. Generally what do you think the benefits are to students and the agency?
    c. If there were any unintended can you talk about those?
7. What do you think the students took away from this course?

8. What did you take away from this course?

Data Reliability

1. How big of a concern was the accuracy and reliability of the data students collected?
    a. If not, ask why?
    b. If so, how do you insure the accuracy and does the USFS use the data collected?

Future

1. Do you think citizen science projects are important for the USFS?
2. What do you think the future of this project is? (Will it continue? How do you see it hanging over time?)
3. What are some benefits of the project you identified for the agency and the students?
4. Do you feel students have a better understanding of the focus area of the project? Did you notice any other changes in students over the course of the project?
5. Do you see a future for this project with the Forest Service or other agencies? Or for similar citizen science projects?

6. Were there any other benefits or challenges to the project you would like to tell me about?

Closing

1. Is there anything else you would like to tell me about or do you have any questions for me?

APPENDIX D: DETAILS ON CODING METHODOLOGY

Coding Methodology: Expanded Details

All recorded interviews were transcribed and analyzed using a modified grounded theory process of open coding (Straus and Corbin 1990; Creswell 2014). First, I coded interview content based on the primary research topics (initial codes) from interview guides and identified new codes as new themes emerged from the data (Table 10). I analyzed the student data by comparing pre-participation to post-participation responses for individuals within case studies to track changes in specific topic areas, such as knowledge of the Forest Service or about ecosystems. I interviewed project leads, teachers, and field instructors on their objectives for the projects (Table 11) and used this information to further refine my second round of open coding. For the second round of initial or open coding, I used the objectives identified by project leads as initial codes as I analyzed interview content from students; I also identified new codes as new themes emerged from the data (Table 12). I looked for themes that arose individually and across projects, in order to consider whether there were emergent themes that were present among all of the projects or unique to one.

After the initial or open coding, I conducted axial coding (italicized in the tables below). This second level of coding provides additional insight into overarching concepts emerging from the data. I have included my explanation for codes in the rationale column in the tables below. There were two objectives to this research. The first objective was to understand content, design and objectives of these projects and to determine if they were meeting their objectives, what was transferable to other forests or agencies, and what benefit, if any, they were having for the Forest Service (research and findings presented in chapter 1). The second objective was to determine how and if these citizen science projects were integrating science and environmental education and if they were increasing student's ecological literacy and environmental stewardship (research and findings presented in chapter 2).

Table 10: Primary research topics (initial codes) from interview guides used to code interviews with students

Initial codes	Codes — Pre	Codes — Post	Rationale
School and Environmental Topics	Classes	Classes	Objective 1 and 2: Build rapport with students and identify current interests, outdoor experiences, and comfort level outdoors
	Motivation for participation	Motivation for participation	
	Time outdoors	Time outdoors	
	Memorable moments	Memorable moments	
		Professional development	
Outdoor Experiences	Success	Success	
	Thrill	Thrill	
	Friends	Friends	
	Family	Family	
		Project Participation Moments	
		New interests	
Ecological Literacy	Nature	Nature	Objective 2: Provide opportunities before and after participation to identify any changes in ecological literacy among students
	Ecosystem	Ecosystem	
		Critical thinking (ecological literacy)	
	Local Environment	Local Environment	
	Climate Change	Climate Change	
		Issues/Problems	
		Solutions	
		Critical thinking (ecological literacy)	
Forest Service Knowledge	Image/Reputation	Image/Reputation	Objective 1: Understand students Forest Service knowledge before and after to gauge if these programs could be effective outreach initiatives
	Respect	Respect	
	Understanding	Understanding	
	Land designation	Land designation	
		Mission/Duty/Protection	
		Professional development	

Table 11: Variables derived from primary research topics from interview guide developed for project leads and instructors teachers

Variables	Codes	Rationale
Project description	Project design	Objective 1: Understand project content, design and objectives
	Resources required	
	Goals and objectives	
	Environmental education	
	Science education	
	Authentic science	
	Field component	
	Data	
Project impacts	Goals and objectives	Objective 1 and 2: Determine if projects were meeting their objectives and if and what impacts to students and the agency were evident
	Benefits to students	
	Benefits to agency	
Data reliability	Accuracy/reliability	Data reliability is a concern in the citizen science literature, these codes were used to determine reliability of data, current and future use, and if data collection was a potential for these projects. Future research should consider interviewing departmental staff to determine use of data.
	Protocol	
	Use of data	
Future	Future of this specific project	Objective 1: Understand lessons learned and determine if these projects were transferable to other Forests
	Use on other forests	
	Other potential niches	

Table 12: Initial codes derived from objectives identified by project leads and instructors then used to code interviews with students

Initial codes	Codes — Pre	Codes — Post	Rationale
Forest Service	Image/Reputation (Smokey the Bear)	More than Smokey the Bear	Objective 1: Determine if these programs were increasing Forest Service knowledge and improving perceptions and could be a potential outreach tool for the agency
		Mission/Duty/Protection	
	Forest Rangers	Interdivisional	
	N/A – "I don't know"		
		Future career opportunity	Objective 1 and 2: Determine if projects were meeting their objectives and if there was evidence of environmental stewardship
		Scientists	
Wilderness/Public lands	Legislation	Legislation	Objective 1 and 2: Determine if projects were meeting their objective and if there was evidence of environmental stewardship
		Legislation in action	
	Untrammeled	Not Untouched	
		Stewardship	
Scientific Literacy	Scientific method	Scientific method	Objective 1 and 2: Evaluate scientific literacy and how programs were incorporating the scientific method or process into the program
		Application	
		Critical thinking (ecological literacy)	
		Professional development	
Monitoring	N/A (Most students didn't know what monitoring was pre-participation)	Monitoring capacity	Objective 1 and 2: Determine if these projects increased agency monitoring capacity and if there was evidence of enhanced ecological literacy
		Value/Importance	
		Authentic science	
Future Career/Disciplines	Advanced Degree	Advanced degree	Objective 1 and 2: Determine students career interests and if they changed before and after participation, and if there was evidence of environmental stewardship
	Forest Service	Forest Service career	
		Forest Service seasonal	
	Specific field/position	Specific field/position	
	Unsure	Unsure	
		Science	
Data Collection	N/A	Research project	Objective 1: Determine if projects were collecting reliable data
		Research process	
		Authentic science	

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