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Youth-Based Citizen Science Monitoring: Case Studies from Three National Forests

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The Forest Service is integrating citizen science programs and data into the management of national forests. We selected three Forest Service citizen science programs that involve secondary school students in field collection of ecological monitoring data and investigated the following: their design, content, and objectives; whether and how the Forest Service is meeting their objectives; and what have been the key lessons learned. We conducted semi-structured interviews with the program leads, teachers, and students. Program leads and students said programs produced reliable data and met monitoring and other Forest Service stewardship objectives. Although these programs varied significantly in design and objectives, they all offered students opportunities to explore careers with the Forest Service and to better understand public lands management. We suggest that objectives have a significant influence on student outcomes and should be designed with the collection of useful data as an objective from the outset. We also found that committed external partners and participation from multiple internal staff members support success.

Keywords: citizen science, monitoring, US Forest Service

Introduction

Over the last decade, US federal agencies have made a concerted effort 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 experience public lands. The Forest Service hosts its own initiatives, such as Discover the Forest[3] and its Integrated Youth Strategy, that are aligned with these nationwide efforts to encourage youth to experience national forests (USDA 2015). One specific avenue for enhancing youth engagement on public lands is through citizen science opportunities (Silverton 2009, Davis et al. 2015). Citizen science initiatives can promote robust youth engagement, build trust with partners, and meet other policy objectives (McKinley et al. 2015). Citizen science also can support multiparty monitoring goals and potentially provide long-term and valuable monitoring data, thereby increasing an agency's capacity (Dickinson et al. 2010, Davis et al. 2015). Given the potential to increase youth engagement and improve monitoring capacity, we investigated current Forest Service citizen science monitoring programs that engage youth to understand the design, content, and objectives of these programs, whether the Forest Service is meeting their objectives with these programs, and lessons learned that could be transferrable to other contexts or public land units.

Citizen Science

"Citizen science" refers to any group of public volunteers that collect data for a scientific purpose (Silverton 2009). Citizen science programs are diverse in their design and purpose; McKinley et al. (2015) state: "[C]itizen science, as we define it, is indistinguishable from conventional science, apart from the participation of volunteers—both can use a variety of methods and can achieve a variety of goals including basic research management, and education" (2015, p. 3). There is a long history of citizens observing and documenting changes in their environment and conducting citizen science in various forms (McKinley et al. 2015). One example is the National Audubon Society's 100-year-long Christmas Bird Count that uses citizens around the world to observe and record birds (Silverton 2009). Other examples include citizen monitoring of water quality, population density of non-indigenous fish species in the eastern Mediterranean, and precipitation (Miller-Rushing et al. 2012, Bodillis et al. 2014, McKinley et al. 2015).

Citizen science efforts can be organized to meet multiple 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). Some researchers suggest that 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). Others have noted that citizen science offers a potential path for bridging environmental and science education, increasing scientific

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literacy, and engendering environmental stewardship (Wals et al. 2014). Aspects of data collection and analysis can be challenges for citizen science monitoring efforts (Bonney et al. 2009, Bonney et al. 2014). Researchers have found that citizen science programs can provide long-term and valuable monitoring data, as long as attention is paid to data collection efforts (Dickinson et al. 2010). Other challenges include significant time commitments from staff, lack of funding for volunteer programs, and a lack of program evaluation (Dickinson et al. 2010, Stepenuck and Green 2015).

Youth Engagement and Monitoring Initiatives on Public Lands

The Forest Service has a long history of conservation education. Since the 1970s, with the debut 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,[4] a cost-share program with partners to improve children's health and help reconnect youth to nature (USDA 2007a, 2007b). Natural Inquirer[5] and Discover the Forest[6] are ongoing Forest Service initiatives to enhance youth engagement. In 2015, the White House launched Every Kid in a Park,[7] an effort supported by all of the land management agencies. These initiatives complement the Forest Service's 2015 Integrated Youth Strategy, which focuses on engaging youth through place-based experiences in nature, engendering environmental ethics and stewardship, fostering respect for civil servants, and helping youth investigate potential careers in natural resources (USDA 2015).

One way to engage youth is through monitoring efforts, which are an important aspect of forest management, especially in the context of today's management challenges such as ecological restoration, climate change, and the implementation of adaptive management (DeLuca et al. 2010). Researchers suggest that engaging youth in participatory research such as monitoring can have beneficial outcomes, including youth development, science literacy, and community development and activism (Krasny and Doyle 2002, Schusler and Krasny 2008). Maintaining incentives and funding for monitoring has been a perennial challenge for federal agencies, but multiparty monitoring efforts can engage members of the public in building capacity and support for monitoring (Doremus 2008, Biber 2011). Multiparty monitoring involves mutual learning among a group of individuals representing different interests through the process of designing or implementing a monitoring program. It can involve citizen science if members of the public are collecting or evaluating data, can produce large amounts of relevant data, and can involve diverse stakeholders in an inclusive environment (Davis et al. 2015, Fernandez-Gimenez et al. 2008, Moote 2011). The Forest Service's planning regulations require monitoring and emphasize the potential for involving youth in the planning and monitoring processes (36 CFR 219.4(a)(1)(ii)). Collaborative Forest Landscape Restoration Program (CFLRP), created under the Federal Land Assistance and Management Enhancement Act of 2009, also requires multiparty monitoring (P.L. 111-11). Challenges associated with multiparty monitoring include data quality and the need for agency capacity to support effective programs (Bonney et al. 2009, Moote 2011).

Summary and Research Questions

To understand how citizen science initiatives could be used to meet both youth engagement and monitoring goals, we looked for programs on national forests that involved youth in collecting ecological monitoring data. We focused on the Forest Service given its emphasis on both youth engagement and monitoring. Our research questions were: 1) What are the design, content, and objectives of ongoing Forest Service citizen science monitoring programs with youth? 2) To what extent is the Forest Service meeting their objectives with these programs? And 3) What key lessons have been learned from existing programs that can improve future youth citizen science and monitoring efforts on public lands?

Methods

To conduct this investigation, we used a qualitative, mixed-methods, multiple-case-study approach (Yin 2009, Creswell 2014). Little research has been conducted on Forest Service citizen science programs with youth, making this topic appropriate for case-study research designed to understand a phenomenon in depth (Creswell 2014). We used agency list-servs and personal contacts, querying for national forest programs involving high school students in citizen science monitoring to maintain the focus on youth engagement, while focusing on an age group that was likely capable of quality data collection. We used several criteria to select programs, including those that had been active for more than five years, were multiple weeks in design, and involved students in collection of field data. We also selected programs that were ongoing, in order to have opportunities to observe the programs and interview current students. From the 10 possible programs that our contacts connected us with, we selected the three youth-based citizen science ecological monitoring programs that met our criteria. To the best

Management and Policy Implications

Youth-based citizen science projects have the potential to meet youth engagement objectives, contribute useable monitoring data to agencies, and engender interest in natural resource careers. They also can be an avenue for meeting multiparty monitoring objectives and engaging communities that are not traditionally involved in forest planning. We investigated the design, objectives, and outcomes of three youth-based citizen science programs run by the Forest Service in partnership with teachers and other community members. Each of these programs was designed with different objectives, which varied from collecting monitoring data to introducing students to wilderness or land management. Our findings indicate that these programs are successfully meeting their objectives. Students show evidence of greater awareness of the natural world and the Forest Service as an agency, with several expressing a greater understanding of land management or interest in natural resource careers. We found that all projects evolved to have systematic data collection to support monitoring. The citizen science literature indicates that it can be difficult to ensure data quality; however, all of the projects found that they were able to train students to collect reliable monitoring data. We recommend that projects set objectives intentionally because they have a significant influence on student outcomes. Commitment from Forest Service staff and an external partner, like a teacher, also are important for success. For federal land management agencies interested in increasing youth engagement and monitoring capacity, our findings indicate that citizen science programs have significant potential to meet these objectives and more.

of our knowledge, we selected all of the long-term citizen science monitoring programs occurring between the Forest Service and high school students in 2015. Based on Silverton's (2009) definition of citizen science, that is, any group of public volunteers that collect data for a scientific purpose, the three programs we selected would fall under the broad umbrella of citizen science. These included 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.

We treated individual programs as case studies to explore how design and outcomes had developed over time within cases; in addition, we looked for thematic similarities and differences across cases. Our goal was to interview the population of individuals involved with these programs at present, including Forest Service staff and field instructors directly involved with the program, and all current students. We also spoke with willing and available past students to understand their perspectives. Teachers and Forest Service personnel reached out to past students first to gauge interest in participating in the research, and then we emailed or spoke with them directly. We contacted six students whose names were provided and interviewed five of the six past students who were willing and able to speak with us. In total, we conducted interviews with 38 individuals (Table 1). The lead author successfully interviewed all staff and most students who were currently involved with the programs. The lead author interviewed current students both before and after participation in the program to gauge the effects of participation. The lead author also observed fieldwork and class time for two of the three programs in the field and saw most of the students' presentations. The lead author conducted 87% of interviews in person. Students interviewed over the phone were: the past students from the Delta Apprenticeship, the pre-participation interviews for the two current students in Colorado, and one student who was absent during the post-participation interviews of the Alaska program. We conducted phone interviews because of the location of interviewees at the time of the interview, and we do not suspect this had any effect on the results of the research.

Interviews were semi-structured (Charmaz 1991). We obtained consent, recorded, transcribed, and maintained confidentiality using procedures approved by our Institutional Review Board for all interviews. We interviewed program leads first to understand program objectives and challenges. Our student interview guide included sets of open-ended questions on: past outdoor experiences, understanding of the Forest Service, scientific literacy, any monitoring and research they were conducting, and other questions specific to each program's objectives. For example, scientific literacy included questions related to students' understanding of ecosystems, climate change, and the scientific method. 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, we met in person at least once with current student interviewees and used photo-elicitation—a technique where students take pictures throughout their program participation to provide additional insight into their experience, and these pictures are used to stimulate conversation with the participant during the interview (Smith et al. 2012).

We coded interviews using a predetermined set of codes based on our research and interview questions. We also identified new codes as new themes emerged from the data. We also compared pre-participation to post-participation responses for individuals. We looked for themes that arose for participants and also compared themes across programs to consider whether there were emergent themes that were present among all of the programs or unique to one. The codes were developed by the lead author and reviewed by the second author. The results presented in this paper focus on program objectives, outcomes, and lessons learned, and we plan to discuss additional findings around environmental literacy, an emergent theme in our research, in a separate publication.

Results

We discuss our three cases below. For each we begin by outlining program objectives, based on our interviews, then discuss evidence that objectives were achieved, and finish by covering other findings and lessons learned through our research.

Alaska Natural Science Course

This program began as a collaboration between Craig High School and the Craig Ranger District of the Tongass National Forest. In 2009, the Forest Service recreation planner began working with the

Table 1. Program participants interviewed.

	Alaska Natural Science Course	Montana Youth Forest Monitoring Program	Delta Apprenticeship (Colorado)
Adult program leads	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); unable to arrange an interview with schoolteachers
Current students (#interviewed/#enrolled)	8/12 (4 could not be interviewed due to class time limitations)	15/15	2/2
Past students*	3	0	2
Data collection times	January and May 2015	June and July 2015	June and July 2015

*For the Alaska Natural Science case study, the past students were still students at the school where we conducted interviews. We were unable to contact any past students from the Youth Forest Monitoring Program (YFMP); however, multiple students and an instructor had been involved in the course before. The past students for the Delta Apprenticeship program were students for whom the Forest Service still had up-to-date contact information for.

teacher of the Alaska Natural Science Course, an elective science credit offered in fall and spring semesters. The objectives of the course were to foster wilderness stewardship and engage students in a wilderness and climate change data collection effort (Table 2).

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. We 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. One student said:

> I guess that trip to the Karta [River Wilderness] 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….

We also saw evidence in post-participation interviews of increased wilderness stewardship. Many students suggested a new appreciation and respect for wilderness and suggested how their research program could be improved to prevent degradation of wilderness areas. 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." Most students were confident in the overall study reliability and the data they collected for their research project. At the urging of the Forest Service, students, with their teacher's guidance, have begun integrating Forest Service protocols into some of the research projects. Students focused their efforts on surveillance monitoring to track species, collect baseline data, and determine trends and changes in the wilderness that could be indicators of climate

Table 2. Case study design and objectives.

	Alaska Natural Science Course	Montana Youth Forest Monitoring Program	Delta Apprenticeship in Science and Engineering
Student participants	12 students, ages ranged from 16 to 19 years old	15 students, ages ranged from 14 to 17 years old	2 students, both 16 years old
Initial objectives	(1) For students to experience wilderness and foster wilderness stewardship; (2) to collect wilderness and climate change data	(1) Students to feel some sense of ownership as they learn about and understand public lands; and for students to; (2) explore different career fields within the Forest Service; (3) learn about monitoring; and (4) collect usable data	(1) To expose students to what they could study in college, specifically science and engineering; (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; and (3) collect monitoring data to support the CFLRP multiparty monitoring requirements
Program design	High school elective science credit offered for two semesters; Forest Service employees repeatedly visit the classroom; students develop part of ongoing longitudinal research project in Karta River Wilderness; students analyze data, write a research paper, and present findings to the Forest Service. Students spend a majority of their time in this program in the classroom before and after their one-day trip to the Karta River Wilderness during the spring semester. Not all students take both semesters of the course. Data collected by students are reviewed by the teacher and Forest Service personnel.	Students apply for a seven-week summer internship program and receive a stipend upon completion. Program begins with intensive overnight training week. Students had a four-day workweek and spent most of their time in the field. Students typically conclude each day with an hour of data entry in an office. Program concluded with students analyzing data, comparing it to students from previous years data and presenting their findings at Helena College to the Forest Service and public. Data collected by students are reviewed by the team and field crew leader and entered daily. In addition, students the following year compare data to monitor and also check for irregularities in data. YFMP was identified as a top priority for the Helena-Lewis and Clark National Forest outreach and education programs.	Students apply for program and receive a stipend upon completion. Students then shadow different Forest Service employees for the first three weeks of the six-week program. Students spend the remaining three weeks collecting data and ultimately present data to Forest Service, community members, and the school board. Students' first three weeks vary depending on who they are shadowing, but they spend a majority of this time in the field. Students spend the remaining three weeks collecting research in the field and conducting data analysis with their Forest Service mentor. Data collected by the students are reviewed by the Forest Service program lead, the teacher (who is also paid through the apprenticeship and helps students with the presentation and implications of their research), and at times an additional Forest Service mentor who might have an expertise in the students' project.
Student project examples	Skunk cabbage phenology, stream surveys, smolt population counts, evidence of large mammal habitation, and newt population densities and the prevalence of chytrid fungus.	Students are placed on streams, weeds, or soils monitoring teams conducting both effectiveness and surveillance monitoring as well as wilderness monitoring.	Riparian health monitoring including grazing improvements and vegetation rehabilitation; stream temperature characteristics in the Big Dominguez Creek watershed; suitability for native trout translocation; redesign of an irrigation ditch to improve habitat for Gunnison sage grouse (*Centrocercus minimus*); and fire effects in past fuel treatment areas.
Partnerships / Support	Craig High School, Southeast Alaska Conservation Council, Sitka Conservation Society, and University of Indiana	Montana Discovery Foundation, Helena College of Technology, Lewis and Clark County, Forest Service Region 1 YFMP received grants from the National Forest Foundation Matching Awards, 21st Century of Service Initiative.	Delta School District, and the Norwood School District Collaborative Forest Landscape Restoration Project

change. 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. Students explained that their data were being distributed to the Craig Ranger District and outside partners. 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, an agency-wide initiative.

Students perceived value in the project, asserting that other national forests should consider a similar project because of the valuable ecological monitoring data that can be collected for the agency; we also found that the program afforded students opportunities that they valued to improve their understanding of climate change and develop a new respect for wilderness. 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 the steward of a large block of land, they did not have strong impressions of the Forest Service or consider it for future employment. According to the Forest Service point of contact, the course introduced new and diverse groups of students to the wilderness. Our data indicated that committed staff members and partnership with a flexible teacher were key to this program's success.

Montana Youth Forest Monitoring Program (YFMP)

The YFMP began in 1998 and includes on-the-ground forest monitoring during an intensive summer program that has involved a total of 160 participants. The original objectives of this program were for students to learn about public lands, explore potential careers by working alongside Forest Service employees, and learn about monitoring; over time, collecting usable ecological monitoring data became a formal objective as well (Table 2). In post-participation interviews, most students discussed the places they collected data, the implications of their monitoring results, and the rationale behind Forest Service management actions; they often mentioned discussing these things with friends and family. For instance, one student specifically described a seasonal road closure and said, "I used to think... '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 nearby public lands. In addition, students showed greater awareness of their actions and the impacts they had on ecosystems (Table 3).

When asked about future careers in post-participation interviews, students suggested an interest primarily in science degree programs, such as physics, silviculture, hydrology, and entomology; some specifically identified careers with the Forest Service. Many students expressed an interest in science and the outdoors in their pre-participation interviews, and some suggested they would apply 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."

Table 3. Data from student interviews.

	Alaska Natural Science Course	Montana Youth Forest Monitoring Program	Delta Apprenticeship in Science and Engineering
Evidence of meeting objectives	[The trip] changed the way I treat it…be more careful, definitely pick up after myself, to leave no trace. [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. 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. 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.	If you see one knapweed on the side of the trail, just pull it. It takes five minutes. 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. I like being around people and helping people. I like doing work outside, which is why I'm thinking…some fieldwork in science. I like doing things that feel important, like I'm helping the planet or other people. 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. 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. 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.	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. 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… [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. It was a great experience. It has really made me excited to pursue careers in natural resources. It definitely changed my life. If I wouldn't have done that first internship I would not be here [at university] for sure.

Several also said they would pursue Forest Service seasonal positions or field instructorships for the YFMP. In addition, students described the value they found in working alongside adults and their new comfort with data analysis, public presentations, and teamwork.

When asked about the importance of monitoring, all students spoke positively about the value that ecological monitoring data affords the Forest Service to make informed management decisions. They were able to articulate the protocol they used for collecting monitoring data and suggested additional places for monitoring or places needing an increased frequency of monitoring. In post-participation interviews, students felt comfortable with the quality of their data and with contributing it to agency professionals for future decision-making. Students said that if poor data were collected, they would have detected it during the daily data input and analysis. Instructors felt students were given the tools, techniques, and instruction to collect reliable data in a process that was developed by the Forest Service, indicative of trends present across the forest, and could be replicated by scientists. One instructor suggested students might be providing more reliable data than professionals because students do not trust their professional judgment and are more careful in their data collection. The students' data were 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 as part of the wildlife monitoring summaries for the summer field season. In addition, the students' detection of changes in longitudinal trends raised awareness about areas of concern for the Forest Service, according to the program lead, who was also confident in reliability of the data.

All interviewees felt the program had value in 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 mentioned challenges and barriers to this program that could occur elsewhere. For instance, except for funding the time of one Forest Service staff during the field portion of the program, a partnership with a nonprofit paid for most staff time, some equipment, and student stipends. Instructors said 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.

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 a six-week program. The program began in 2011 and has involved a total of 10 participants; one year they accepted four students instead of the usual two. Two objectives for the Delta Apprenticeship were to expose students to science and engineering topics of study that they could pursue and to engender interest in careers in civil service with agencies such as the Forest Service (Table 2). In addition, funding for the program came from the CFLRP project on this forest, and another program objective was to collect monitoring data to meet the CFLRP multiparty monitoring objectives. Despite the small number of participants, this program could be considered citizen science because it involves members of the public in the collection of long-term data.

In post-participation interviews, students demonstrated an enhanced understanding of science and engineering topics and were well versed in their topic area based on their three weeks of fieldwork. 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]." The past students from the program we spoke with are studying natural resources in college or were accepted and preparing to pursue a natural resources degree. We saw evidence that their participation in the program had helped guide them in this direction (Table 3). We also saw evidence specifically of interest in a career with the Forest Service. Students were also able to identify and describe the many departments that were housed within the Forest Service based on their time shadowing staff. Students also discussed the behind-the-scenes work that the Forest Service does that local communities were unaware of, and one student suggested that these efforts make a big difference but are overlooked by most visitors to national forests. A current student added in their post-participation interview:

> 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.

The program 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.

In addition to program objectives, we saw evidence of student professional development, specifically in terms of increased confidence talking to and in front of professionals, and improved knowledge of local ecosystems. Students also felt they had a good understanding of the health of the GMUG forest ecosystems. Although data collection was not an identified objective of this program, it was a foundational aspect of the design of the program because of the CFLRP funding for collecting monitoring data. The Forest Service and partner organization groups used the students' data to inform the design of fuel treatments and avoid impacts to sensitive species. The students and the program lead suggested this program could and should be expanded to other programs and forests. However, the program 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.

Discussion

The three cases varied in their design, content, and objectives. Our findings indicate that programs were meeting their objectives, among which were increasing understanding of wilderness, teaching monitoring, generating usable monitoring data, and increasing familiarity with land management or the agency as a potential employer. Program objectives influenced outcomes. For instance, we saw a more complete understanding of the Forest Service as an agency in the YFMP and the Delta Apprenticeship. These two programs identified understanding the Forest Service and possible career options with the agency as an objective and included more opportunities than the Alaska Natural Science course to learn about future opportunities with the Forest Service. The YFMP and the Delta Apprenticeship also involved more than one Forest Service staff member and exposed students to multiple agency departments. For the Alaska Course, which did not identify this as an objective, we did not find that students gained a more complete understanding of the Forest Service as an agency. We also found that generating usable monitoring data became an objective for all three programs, although this was not the case at the outset. The YFMP and the Alaska Natural Science course evolved to include the objective of generating usable data, which was an objective of the Delta Apprenticeship from the beginning. While data quality is a concern identified in the citizen science literature (Bonney et al. 2009, Bonney et al. 2014), in these cases program leads did not indicate that this was a concern and said that the students were especially diligent in following protocols.

Programs also were having broader impacts beyond program objectives. We saw evidence among students of professional development and a greater understanding of science and ecosystems, and also improved relationships between students and the agency. Some researchers have suggested this kind of ecological understanding, particularly when coupled with education about the value of the natural world and its stewardship, which was also a component of all of these programs, can support environmentally responsible behavior (Roth 1992, Cutter-Mackenzie and Smith 2003, Wals et al. 2014). In addition, based on student comments, students were sharing their new knowledge and interest with family and friends. It is therefore possible that these programs may improve students' sense of environmental stewardship and may 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 are topics for future research.

These programs also are helping the agency meet broader strategic goals, such as those in the Forest Service's Integrated Youth Strategy, which emphasizes engaging youth through place-based experiences in nature, engendering environmental stewardship, and providing all youth opportunities to investigate potential careers in natural resource management (USDA 2015). In post-participation interviews, students had a better understanding of the agency and were able to clarify the different facets of the Forest Service and the important role the agency played in the management of public lands. Many students expressed greater interest in natural resource careers. The programs also had value in meeting both monitoring and other Forest Service stewardship objectives. The Tongass National Forest used their program data to meet 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 programs. The students' data also are typically included in an annual forest monitoring report, and the Forest Service has also acted on students' management suggestions, according to interviewees. At times, up to 20 Forest Service program managers have attended the Montana program's end-of-year presentations, and according to the program lead, these recommendations have resulted in different management practices being applied in specific cases, or additional monitoring focused on sites of concern. In Colorado, interviewees said student programs have also influenced management actions. For examples, the native Cutthroat trout (*Oncorhynchus clarkii*) population identified by a student in 2012 is the basis for the redesign of a fuels treatment in the same watershed. Another Colorado student's work resulted in the redesign of a ditch to improve habitat for Gunnison sage-grouse (*Centrocercus minimus)*.

A number of factors might influence the sustainability and transferability of these types of programs to other units. The three programs involved in this research had committed external partners that were key to the success of the programs. The year after this research was conducted, the teacher and Forest Service employee involved in the Alaska Natural Science Course moved off Prince of Wales Island, and it is unclear if this program will endure. Although we do not have data to indicate what makes these programs sustainable, committed partners are likely important, based on their key roles in each of the programs we investigated. In addition, documenting the programs' objectives and goals, design, content, and logistics could support the sustainability of these programs so that others can pick them up in the case of a change of personnel.

As these were small and localized youth citizen science case studies, our findings are not generalizable and may not be transferable to other types of citizen science programs. In addition, these programs were not initiated or developed with a group of citizens, but rather they were driven by the Forest Service, although in the case of the Delta Apprenticeships, CFLRP stakeholders collaborate with the Forest Service to identify monitoring priorities. Therefore, while these programs involved citizen volunteers to collect data, they also were training programs and, as such, were a unique type of citizen science. These students had multiple incentives to participate, including career preparation and stipends and class credit in some cases. Engaging non-students in similar programs would likely be more challenging without these attendant incentives. In addition, while these programs led to the collection of valuable monitoring data, these programs do not clearly represent multiparty monitoring, which generally involves bringing together individual stakeholders with different interests in forest management together through the monitoring process in a collective learning process. As these students are recruited primarily based on their interest in the training opportunity provided, they do not clearly represent stakeholders with diverse interests in forest management. To the extent that these students collect data that is of interest to a broader group of stakeholders involved in identifying monitoring priorities, as our interviewees indicated was the case for the Delta Apprenticeship, these programs are contributing to multiparty monitoring processes. Finally, while one interviewer provides consistency, it also adds a risk of missing aspects of the program that multiple interviewers and data analyzers might reveal.

For units interested in combining youth engagement with scientific training and data collection, the lessons from these programs could be valuable across multiple contexts. Based on our findings, we offer several recommendations for land management agencies developing similar programs. We recommend that staff design programs with clear goals and objectives at the outset, as these are likely to influence outcomes and make it easier to measure success. We also suggest that for programs in which students are collecting field data, staff design these to generate usable and reliable data from the outset, as this became a common objective among our case studies and is achievable. We suspect several factors supported student career exploration and an improved understanding of the Forest Service as an agency; these included: identifying future Forest Service career opportunities as an objective; designing the program to support exploration of the Forest Service as an agency through some kind of interaction with different staff areas; and also gaining a commitment from Forest Service staff from various departments to engage with students. The involvement of many Forest Service staff may also explain why multiple departments were utilizing the data collected in the Colorado and Montana case studies. Finally, securing commitment and participation from external partners, like a teacher or local nonprofit organization, appears important for success.

Future longitudinal research in this arena would be valuable for understanding whether students who participate in these types of programs end up in natural resource careers, and if so, if this is based on the interest they developed through these experiences. Research could also investigate whether student participants develop an enduring sense of environmental stewardship. It also would be valuable to investigate what types of students, both based on demographics and previous interest in science or the outdoors, applied for these programs and how to reach a more diverse group of students. In addition, these programs occurred in rural areas surrounded by National Forest; more urban areas may present different challenges and opportunities. However, youth-based citizen science monitoring programs could have beneficial effects if initiated in urban schools and environments, and research could be done to determine the effects of these programs on students who do not already have an established connection to the outdoors.

Endnote

1. http://www.everykidinapark.gov; last accessed Jan. 14, 2018.
2. https://letsmove.obamawhitehouse.archives.gov/lets-move-outside; last accessed Jan. 14, 2018.
3. http://www.discovertheforest.org; last accessed Jan. 14, 2018.
4. http://www.fs.usda.gov/detail/conservationeduca-tion/programs; last accessed Jan. 14, 2018.
5. http://www.naturalin-quirer.org; last accessed Jan. 14, 2018.
6. http://www.discovertheforest.org; last accessed Jan. 14, 2018.
7. https://www.everykidinapark.gov; last accessed Jan. 14, 2018.

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