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Cover Page Footnote

We are thankful for the participation and support from the Izaak Walton League of America White Oak Chapter, White Oak-New Riverkeeper Alliance, and NC Cooperative Extension - Onslow County.

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Abstract

Citizen science, also known as participatory research, combines the efforts of professional researchers and community volunteers to collect data. We have established one such collaborative project in eastern North Carolina, near the 79,000-acre Hofmann Forest, called the Hofmann Open-Water Laboratory (HOWL) citizen science project. The White Oak River, New River, and Trent River all flow out of the Hofmann. The Hofmann is an ecological keystone in the region, acting as a natural filtration system for harmful runoff that occurs in the coastal plain of North Carolina. Our purposes for this study were twofold: (a) to evaluate the HOWL project by assessing the perceptions of HOWL participants and determining whether the project achieved its goals of individual development and community engagement and (b) to provide recommendations for the HOWL project as well as suggestions for other participatory research projects in their beginning phases. We interviewed 12 HOWL citizen scientists who participated in the project, and we drew two major conclusions from our research. First, we recognized that community engagement and collaboration drastically increased in rural eastern North Carolina due to the community members' participation in water monitoring and natural resource management. Second, citizen scientists achieved their personal goals and objectives by participating in the HOWL project: Participants reported that they learned new skills, gained knowledge of scientific and research procedures, developed an attachment to their community and region, and acted as environmental stewards.

Citizen science approaches, which combine the research efforts of professional scientists and community volunteers, have emerged within the past decade. A search for "citizen science" in Web of Science, a website with access to multiple academic and scientific databases, identified only 19 scientific articles published between 1950 and 1990 that included the term (Lepczyk et al., 2009). From 1990 to 2013, however, there were more than 400 papers on the subject, and in 2018 alone, a search for "citizen science" in Web of Science revealed more than 2,000 available articles. Even a search for similar phrase, such as "participatory research," retrieved approximately 300 articles published between 1990 and 2013; in 2018, Web of Science discovered more than 700 publications.

Although the term "citizen science" evolved only recently, participatory and stakeholder involvement approaches to research are quite old. For example, early practices grew out of the work of naturalist hobbyists like John Muir and Georges Cuvier (Dickinson et al., 2012). Today, any individual who engages in scientific processes—whether or not they have experience in a scientific discipline—can be a "citizen scientist" (Dickinson et al., 2012). While traditional citizen science projects involve participants, who collect and share observations and data from a wide range of geographic areas, researchers are devising new, varied types of participatory research project to meet their goals. Researchers develop most projects to meet a specific scientific outcome (Cooper et al., 2007). However, some projects have broader goals, such as increasing community networking, building community engagement, expanding participants' perceptions of stewardship, and offering environmental education.

The number of citizen science initiatives has skyrocketed in the last decade, enabling professional researchers to collect data from across the globe in less time. Data collection processes can be time consuming, and citizen scientists can collect large quantities of data more quickly and more often than researchers would be able to alone (Wildschut, 2017). Citizen science unites communities and individuals around a common interest or goal (Wondolleck & Yaffee, 2000). Not only does it bring citizen scientists together, but it also creates a bridge between professional scientists and citizen scientists. For example, people often think of the "typical scientist" as someone who wears a lab coat and works inside a laboratory all day. Although this perception may be valid in some cases, citizen scientists have the opportunity to work one-on-one with professional scientists as they ask questions and solve problems in the field. Working with a professional scientist can motivate and inspire individuals who are dedicated to the professional's field of interest. Participatory research approaches can also bring STEM instruction to communities and classrooms and provide new educational opportunities for hobbyists and other interested individuals (Shah & Martinez, 2016). Last, the data and information that citizen scientists collect can be valuable in natural resource management, decision-making, and policy formation or implementation (Newman et al., 2017).

Critics of citizen science argue that such participatory approaches can lead to issues with data credibility and completeness because citizen scientists may lack knowledge of proper data collection procedures (Gouveia et al., 2004). Citizen-collected data may be inconsistent and therefore may lack credibility. In many cases, policy- or decision-makers value the "expert knowledge" of professional researchers and their years of expertise over local or indigenous knowledge, which they may overlook or deem less reliable (Ascher et al., 2010). Also, citizen science projects may not be sustainable in the long run because of issues with funding and the retention of volunteers (Bonney et al., 2009).

When formulating the structure and design of the Hofmann Open-Water Laboratory (HOWL) project, we followed the citizen science program model developed by the Cornell Lab of Ornithology (CLO). CLO manages many citizen science projects that have attracted participants from across the United States. The lab designs its projects to answer scientific questions while informing the public about environmental and ecological systems (Bonney et al., 2009). Members of CLO constructed this model to fulfill the goals of recruitment, research, conservation, and education. In this section, we address the final step of the CLO model: how to evaluate a project's outcomes.

Shirk et al. (2012) described three types of outcomes associated with citizen science projects to assist with natural resource conservation and management:

- outcomes for research (e.g., scientific findings)
- outcomes for individual members (e.g., obtaining new knowledge)
- outcomes for socio-ecological, also known as a human-environment, system purposes (e.g., building community networks and relationships)

Participatory research projects indeed focus on data outcomes and scientific discoveries, but researchers can also evaluate a project's outcomes in terms of citizen scientists' perspectives and perceptions. Typical participant outcomes of citizen science projects include an increased understanding of scientific subjects and field research (Ballard & Belsky, 2010; Shirk et al., 2012; Trumbull et al., 2000), a deepened relationship with other community members and organizations (Bell et al., 2008; Kountoupes & Oberhauser, 2008; Overdevest et al., 2004; Shirk et al., 2012), and an enhanced sense of place and stewardship (Evans et al., 2005; Shirk et al., 2012; Wilderman et al., 2004; Wondolleck & Yaffee, 2000). The literature also supports such socio-ecological outcomes as increased community engagement and collaboration (Ballard et al., 2008; Shirk et al., 2012; Tudor & Dvornich, 2001; Wondolleck & Yaffee, 2000); increased access to natural resources management, data, and educational outreach programs (Overdevest & Mayer, 2008; Shirk et al., 2012); and an increased likelihood of future collaboration among participants on other projects, especially projects that are related to public policy- and decision-making (Overdevest et al., 2004; Shirk et al., 2012; Wilderman et al., 2004).

Researchers can evaluate these participant and socio-ecological outcomes in several ways. For example, each dimension can be assessed in term of the following:

Participant outcomes:

- New knowledge (e.g., does the project contribute to better understanding of a science topic?)
- Ownership gained (e.g., do participants feel responsible for the project and its mission?)
- Change in attitude (e.g., does the project influence values regarding science?)
- Change in behavior (e.g., does the project trigger a change in personal behavior?)
- Motivation and engagement (e.g., does the project motivate participants to be involved in future or similar work?)

Socio-ecological outcomes:

- Societal impacts (e.g., does the project enhance social capital and community engagement?)

- Ecological impacts (e.g., does the project protect or manage natural resources?) impacts (Kieslinger et al., 2017).

According to Jollymore et al. (2017), few scholars have investigated the perspectives and perceptions of participants in citizen science projects to understand the projects' limitations and successes. Therefore, for our study, we gathered and assessed the experiences and perceptions of HOWL citizen scientists to evaluate the degree to which HOWL successfully met its socio-ecological and participant outcomes. We evaluated whether the HOWL project's citizen scientists achieved personal goals while participating in the project (i.e., participant outcomes) and considered the increase in community engagement and collaboration between the local participating organizations and community groups (i.e., socio-ecological outcomes). Our objectives were to assess how well HOWL:

- achieved the outcomes of increased, active community engagement and collaboration,
- constructed sustainable personal relationships and networks,
- allowed participants to accomplish personal outcomes,
- and facilitated its own future sustainability.

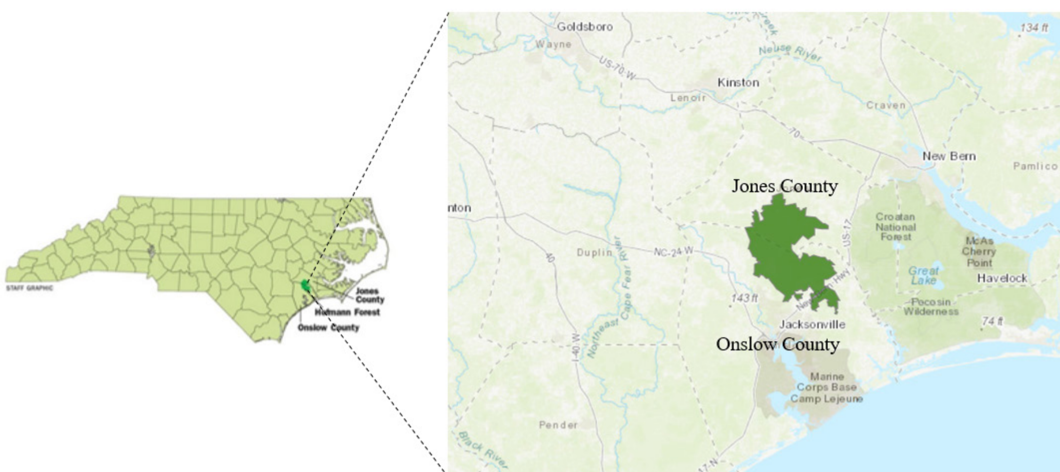
The purpose of this paper is to understand how citizen science efforts influence socio-ecological systems and participants' scientific and interpersonal objectives. This study assesses the merits of different components of a citizen science project based on the perceptions of citizen scientists. Communities can employ citizen science initiatives to meet outcomes of collaboration, community engagement, ecological sustainability, and environmental and scientific education. In this paper, we provide recommendations drawn from our assessment of the HOWL project that can be used by other communities and groups who wish to develop a citizen science project to meet similar socio-ecological and participant outcomes.

Methods

Hofmann Forest and Study Area Background

The Hofmann Forest, founded in 1934, is North Carolina State (NC State) University's 79,000-acre education and research forest (North Carolina State University, 2017). The Hofmann Forest landscape, comprised of wetlands, agriculture, and forests, is the country's largest university forest. It also contains a large variety of flora and fauna, including vulnerable and keystone species such as the Venus flytrap (Dionaea muscipula; U.S. Fish & Wildlife Service, 2018). Hofmann is situated in eastern North Carolina, falling within both Onslow and Jones Counties (Figure 1). The White Oak and New Rivers both flow out of the Hofmann, as well as the Trent River, which headwaters begin in the Hofmann. The water quality of this region is at risk of harmful pollution due to deforestation, sea level rise, substantial development, agricultural expansion, and concentrated animal feeding lots (Edwards & Driscoll, 2008; Huffman & Westerman, 1995; Nicole, 2013; U.S. Geological Survey, 2018; U. S. Government Accountability Office, 2008). Since August 2016, citizen scientists have collected crucial data on the physical, chemical, and biological properties of water in and around the Hofmann to understand the forest's ecological significance in the coastal community. The HOWL

Figure 1. Placement of Hofmann Forest in Jones and Onslow Counties in the State of North Carolina



project gives full responsibility, data access, and project development and management duties to its citizen scientists.

Formation and Structure of HOWL

In January 2013, the NC State Endowment Fund and Natural Resources Foundation initiated a proposed sale of the Hofmann Forest (Cubbage et al., 2016). The proposal alarmed numerous individuals not only in Raleigh, North Carolina, but also across North Carolina's coastal plain, especially within Jones, Onslow, and Carteret Counties, located approximately 130 miles southeast of Raleigh. A coalition of local community members, coastal conservation groups, school groups, and other interested individuals formed to defend the forest in light of the proposed sale and continued to be involved with the forest even after NC State decided in 2015 to retain the land and halt the sale (Figure 2). Figure 2 shows a timeline of Hofmann Forest events and history.

The citizens' collaborative efforts to save the Hofmann Forest prompted additional and continued involvement among other local individuals and community groups at the Hofmann to solidify its value and importance within the coastal community. The triggering event of the proposed sale motivated the individuals and organizations to stay connected. Before the proposal, these interested groups did not collaborate or work together, and if they did, their interaction was minimal. HOWL was developed by a team of researchers from NC State and the Cooperative Extension Service, who then recruited additional community members to join in collaborative efforts. The HOWL leadership team consists of individuals from NC State University, the Izaak Walton League of America (IWLA), the NC Cooperative Extension Service, and the White Oak-New Riverkeeper Alliance (See: https://www.facebook.com/wonriverkeeper/).

The HOWL project, officially established in August 2016, is a participatory research project to analyze the ecosystem services that the Hofmann Forest provides, including its effect on the water quality of the three rivers that run through it—the Trent, New, and White Oak. HOWL's mission is to understand the Hofmann's place in the coastal ecosystem and how the local water quality affects the surrounding human and ecological community. The HOWL team has established sites to monitor chemical, physical, and biological water properties outside of the forest. The project integrates the scientific efforts of local researchers and community groups representing the NC Cooperative Extension Service, the White Oak-New Riverkeeper Alliance, the IWLA, homeschoolers, Boy Scouts and Cub Scouts, Onslow County 4-H groups, and other local interested individuals and youth. This scientific and participatory effort offers an innovative and collaborative approach that engages citizens and community groups in the process of collecting new data within the North Carolina coastal region, helps citizens better understand the world in which they live, and creates a partnership among professional researchers, organizations, and local volunteers. The citizen science approach—involving locals, professional scientists, field collection technology, and fieldwork—allows citizen scientists to understand, measure, and monitor their local community as well as improve natural resource management, protection, and decision-making for North Carolina's coast.

Researchers at NC State University, members of the Izaak Walton League, and employees of Cooperative Extension recruited in citizen scientists several ways. The most vital and persuasive recruitment strategy involved relating the project to volunteers on a personal level (Petty et al., 1981). Those who felt personally responsible for and associated with HOWL or the Hofmann Forest were most likely to participate. Therefore, recruiters used two specific strategies to connect prospective participants to the HOWL project: (a) stressing the need for clean water for individuals in and around eastern North Carolina and (b) promoting the ability for volunteers to learn and gain opportunities (such as building and maintaining community and individual relationships) that they may not have achieved otherwise. The HOWL project reached out to individuals of all ages, especially to less involved and low-income groups in the Jones, Onslow, and Carteret counties. HOWL also recruited from under resourced schools, local youth organizations, and conservation groups in Jones, Onslow, and Carteret Counties by aligning its goals with the communities' interests. Among people who lived near the Hofmann Forest, learning about how the quality of the watershed affected their communities prompted many to become involved to better understand the quality of the water in their area.

Once the recruiters acknowledged the target audience, the leadership team held a

HOWL Science Kickoff event at the White Oak Campground in Maysville, North Carolina, on October 5, 2017, to attract interest and recruit participants. The HOWL leadership team advertised the event to the campground residents, visitors, and other members of the community by posting flyers in community centers, schools, and other local meeting points in Onslow, Jones, and Carteret Counties. The flyer provided the HOWL team's contact information and general event information to engage prospective participants. At the event, the HOWL team demonstrated a preview of water quality and benthic-macroinvertebrate sampling techniques in an effort to encourage attendees to become HOWL citizen scientists. The Carteret County News-Times covered the event with an extensive write-up, which helped promote participation and recruitment.

Once recruited, the HOWL leadership team trained and educated citizen scientists on standard monitoring protocols. Protocols are formal instructions for citizen scientists to follow when collecting data (Bonney et al., 2009). They are simple and clear to understand for users who may not be familiar with conventions of the field. The protocols used for the HOWL project were adopted by the IWLA's Creek Freaks program, which provides data sheets for citizen scientists to record biological, chemical, and physical measurements, such as number and types of benthic-macroinvertebrates found and amount of Nitrates and Phosphates in the water. The HOWL groups complete the forms at each site visit. The data forms follow the project protocols and are later used in data analysis (Bonney et al., 2009).

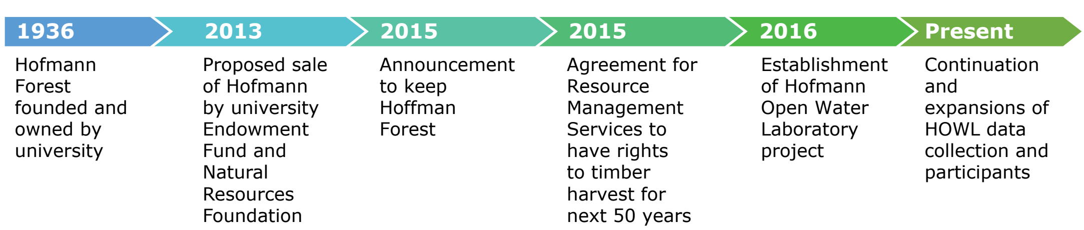
The HOWL project adopts the "training the trainer" approach used by the IWLA Creek Freaks program. Once citizen scientists complete a training session, they then train their groups to monitor and collect data adequately. The training process encourages participants to understand, learn about, and follow the scientific method. The protocols mandate step-by-step processes that require precise measurements, and participants are also required to enter the same data in multiple locations. The training protocols explain the purpose of various data entries and the importance of precise measurement. Bonney et al. (2009) discuss how training citizen scientists helps them gain confidence in their data collection skills.

Lastly, the data collected on the forms are transferred by the leader of the site to the project's internal database as well as an iNaturalist site. Community researchers, collaborators, and citizens can view existing user-generated data via iNaturalist. Additionally, citizen scientists can upload data through smartphones or tablets via the iNaturalist app (www.inaturalist.org/projects/hofmann-citizen-science). iNaturalist is an innovative, participatory citizen science service designed to engage citizens in enhancing data, incorporating other data collected in the area, better understanding the world in which they live, and extending the reach of community and other organizational networks. The data are reviewed primarily by the data manager before they are posted for the public. Any errors or data concerns are eliminated from the data set and not provided in the enterprise system.

Qualitative Research Approach

We chose a qualitative research approach to achieve the study's objectives and gather evaluative feedback from the HOWL participants. By using the qualitative method, we hoped to answer our questions about how social experiences are created and give meaning to projects. A qualitative structure may contain a mixture of a few practical tools, such as interviews, document reviews, focus groups, and observations (Anderson, 2010). In this study, we solely assessed the HOWL participants' perceptions through semistructured interviews as a way to reveal complex experiences and ideas, which can be more compelling than quantitative information. Interviews are a useful way to gauge the reality of people's lived experiences (Peräkylä, 2005), and we chose this method because it allowed for thorough and comprehensive understanding

Figure 2. Timeline of Hofmann Forest History and Engagement (Cubbage, et al., 2016)



of each participant's experience in our particular case, which does not concern or represent the broader population. Additionally, interviews can be restructured and quickly revised as participants reveal new information (Anderson, 2010).

However, there are some limitations to face-to-face interviews. For example, the researcher's personal biases may skew or affect the impartiality of data collected through qualitative research (Anderson, 2010). The interviewer may interpret or understand the interviewee's words and opinions differently than the interviewee anticipated. It is crucial to acknowledge that the presence of an interviewer may also affect the responses given by the interviewees (Anderson, 2010).

In the semistructured interviews, we asked project participants open-ended questions. If interviewees answered "yes" or "no" or provided similar responses with little information, we encouraged the participants to expand on their answers. We designed our interview questionnaire to gather participants' perceptions of the project.

The interview script was constructed before the interview process and approved by NC State University's institutional review board (IRB). The questionnaire sought to discover the impacts of the project on the citizen scientists, how they believed the project could be sustained, and their opinions on working in a collaborative setting. We grouped the questions according to the study's research objectives.

We used thorough note-taking and audio recordings to collect comprehensive data from the participants. After each interview, we transcribed the audio recordings. In cases of uncertainty, we summarized and restated the participants' statements to clarify their meaning during the interview process. After transcription, we coded the interviews manually. We chose to review the language by hand since our sample size was small.

Approximately 80% of HOWL citizen scientists are youth from ages ranging from six years-old to 18 years-old; however, we excluded them from the interview process for this study. We attempted to contact 17 HOWL (non-youth) citizen scientists via email to participate in the interviews. Of those we contacted, 12 individuals (N = 12) responded (a 70% participation rate). We conducted interviews either over the phone and in person. All participants agreed to and signed the consent form required by the IRB before participating in the study. Three of the interviewees had participated in monitoring activities once, while nine had participated two or more times. Participants' ages ranged between 26 and 65 years old, and the group of interviewees included two men and 10 women. All organizations involved in the HOWL project were represented in the interview process.

Results and Discussion

Participant Outcomes

Nearly all participants (n = 8) communicated that they had an initial objective in mind before joining the HOWL project (Table 1), and almost all participants (n = 10) stated that they achieved a personal goal over the duration of the project. Two of the participants who stated that they did not have an initial goal when entering the project each identified an outcome that they accomplished while participating in the project. Each participant is labeled *CS*, standing for citizen scientist, and assigned a number to distinguish each of their responses (Table 1). Four achieved outcomes emerged as participants discussed their experiences with the HOWL project. HOWL citizen scientists stated that they: (a) learned new skills, (b) gained knowledge of scientific and research procedures, (c) developed an attachment to and contributed to their community, and/or (d) acted as environmental stewards.

First, some of the HOWL participants noted that they gained the new skill of educating others by completing the training sessions, and leading Scout, homeschool, and 4-H groups. Members also indicated that they learned skills of networking, event planning, and communicating while involved in the project. A few citizen scientists (n = 2) recognized that they gained teaching and instructing skills. Participants learned procedures that they could then teach to their respective groups; CS8, for instance, "wanted HOWL to be an educational program for [their] organization and wanted to get kids out to learn about water monitoring." Also, almost half of the interviewees (n = 5) collaborated with new community groups and individuals. CS3 said, "I was guided by other people. …Everyone does what they do best and brings their expertise and experiences to the trainings and field days." Likewise, CS4 said, "What helped me be a part of the project was talking to the people who have participated and collected data before me…communicating with other people who have been involved and learning from them."

Second, participants noted that they learned about scientific processes and research protocols. Many individuals recognized that they had never participated in fieldwork or research before participating in HOWL. Additionally, CS2 stated that they learned a lot about benthic macroinvertebrates and the importance of testing for them when monitoring water quality. Some of the participants (n = 4) perceived learning about scientific methods, such as data collection and fieldwork procedures, as their achieved outcomes from HOWL. For example, CS2 said, "I improved my familiarity and how to identify macroinvertebrates. I have never done that before this project." CS4 had not been involved with any sort of data collecting before the project, saying:

> Before the kickoff, I have never been involved with any kind of fieldwork before. …I wanted to see how water quality data is collecting. This one-day kickoff wasn't enough. It made me want to participate more and know more.

Third, some HOWL citizen scientists felt that they were helping their communities. According to Pandya (2012), individuals in rural areas are not typically involved in citizen science projects because of barriers such as a lack of transportation, access to the environment, or scientific education. Because some of the monitoring events were located near rural communities, many local citizens were able to join in the efforts. HOWL participants felt altruistic and happy about educating local children and their families. CS6 believed HOWL provided an opportunity for scientific and community engagement, saying:

> For me, it was a sense of community and raising awareness about the waters and streams for families to be involved. It was so nice to see people in rural development involved. This area, especially the town of Maysville, is one of the poorest cities in the county. Kids don't get the opportunity to learn about science and do this. A free event like this to engage them and their family is a great opportunity.

In addition, a handful of participants (n = 4) felt the project itself, and the opportunities it gave to the public, were unique to the region. For example, CS5 indicated, "There are not a lot of STEM projects like this in the community for children to be involved in." Likewise, CS6 conveyed that teachers in the area are always looking for presenters for "STEM activities" like this one. Additionally, CS6 mentioned, "Kids growing up want to be scientists and want to be involved outside and look at bugs." HOWL gives them this opportunity.

Fourth, citizen scientists felt as if they made a difference not only in a social capacity but also in an ecological one. Several interview participants believed they contributed to environmental stewardship by managing the White Oak, New, and Trent Rivers and by educating residents who live nearby to protect their waters. For example, CS5 stated, "My goal is to fix the White Oak River—or allow it to fix itself—and I really think we are helping do that."

Socio-Ecological Outcomes

The organizations involved in the HOWL project include the NC Cooperative Extension Service, NC State University, White Oak-New Riverkeeper Alliance, the IWLA, homeschoolers, Boy Scouts and Cub Scouts, and Onslow County 4-H groups. We were interested in discovering what these community groups were doing before the HOWL project and if the HOWL project was the reason these organizations began to collaborate with one another. Many interview participants indicated that they collaborated with the other community groups and partners for the first time when participating in HOWL.

Nearly half of the participants (n = 5) indicated that they had never worked with any of the other organizations or members before the HOWL project. The other participants (n = 7) stated that they had worked with at least one of the organizations before, but the collaboration was minimal. This latter group of interviewees acknowledged that the collaborative efforts were only with the IWLA. CS5 stated, "We had worked together but not very well nor effectively." Also, all participants (n = 12) indicated that they believed the HOWL project would not continue if any of the partners were to drop out of the collaboration. For instance, CS3 said, "Collaboration is vital for it to really grow into a successful program." A couple of participants (n = 2) revealed that it was crucial for the IWLA to continue to be involved in the project. CS10 answered, "IWLA plays a big part and role. …They are the main pusher in the program." However, CS6 expressed the importance of NC State's involvement in the project, stating, "My credentials don't mean much, but it looks good to have NC State University involved."

These responses are consistent with Wondolleck and Yaffee (2000), who argued that people come together when they share an interest

Table 1. Citizen Scientist Involvement Information and Perceived Outcomes Achieved by Each Participant Through Their Participation in HOWL

Citizen scientist	Organization represented	No. of times participated (before interviews)	Completed a training session?	Had an initial personal objective?	Achieved a new skill or goal?	Perceived outcome achieved
CS1	NC Cooperative Extension	1	No	No	No	N/A
CS2	NC Cooperative Extension	5+	Yes	Yes	Yes	Learned macroinvertebrates identification
CS3	IWLA	5+	Yes	Yes	Yes	Collaborated with other organizations
CS4	NC State University	2	No	Yes	Yes	Learned scientific procedures
CS5	Boy Scouts	5+	Yes	Yes	Yes	Collaborated with other organizations Helped the White Oak River
CS6	IWLA	1	No	Yes	Yes	Gained "sense of community" via collaboration Raised awareness in community
CS7	IWLA	1	No	No	Yes	Had fun
CS8	White Oak- New Riverkeeper	5+	Yes	Yes	Yes	Educated children and adults
CS9	NC State University	3	Yes	No	Yes	Collaborated with other organizations Learned scientific procedures
CS10	Home school; Boy Scouts	3	Yes	Yes	Yes	Educated children Learned scientific procedures
CS11	Boy Scouts	2	Yes	N/A	N/A	N/A
CS12	NC State University	5+	Yes	Yes	Yes	Collaborated with other organizations Raised awareness in the community

or mission. They also come together when they share a connection or attachment to a specific place or location. Likewise, individuals join to collaborate when they share a mutual goal or vision and can work toward it. All of the HOWL community groups and organizations share the common interest of environmental education and stewardship in their area. The HOWL citizen scientists were brought together by their mutual relationship and attachment to their unique coastal community, consisting of the Hofmann Forest and White Oak, New, and Trent Rivers.

Wondolleck and Yaffee (2000) further discuss how partners come together not only when there is a shared goal or interest but also when there is a shared fear or threat. Consistent with this, HOWL community members were mobilized after the NC State University Endowment Fund and Natural Resources Foundation proposed selling the Hofmann Forest in January 2013 (Cubbage et al., 2016). The proposal worried many individuals in the coastal area, especially in Jones, Onslow, and Carteret Counties. HOWL citizen scientists felt the urge to act and become involved somehow in the community and with the forest. Thus, the HOWL project evolved. HOWL participants became active in monitoring the White Oak, New, and Trent Rivers, which all flow out of the Hofmann Forest. Participants also fear threats to the rivers posed by increased deforestation, construction, substantial development, agriculture, and nearby concentrated animal feeding operations. CS5 stated:

> We are always going to have the Hofmann Forest close to us. The forest and what we can do to save the White Oak River is what brings us together. Its headwaters in the Hofmann are some of the most pristine waters. The river and its health are the common denominators that bring us together.

Using citizen science efforts, participants feel as if they have been able to come together to enhance their ecological habitat and environment.

HOWL participants have a shared mission to maintain the Hofmann Forest as well as manage and monitor the White Oak, New, and Trent Rivers. This shared vision, referred to as a "superordinate goal," is the overarching vision that individuals work toward and the goal that resides above any current problem or issue. The superordinate goal imagines a solution to the shared fear of environmental degradation and cannot be achieved without collaboration from all parties (Wondolleck & Yaffee, 2000).

Furthermore, interview participants recognized additional partners who would be apt candidates to join the collaborative efforts. For instance, interview participants suggested a number of organizations that could be recruited to join HOWL, including local conservation groups and nonprofits, municipalities, colleges and universities, teachers and schools, and Marine Corps Base Camp Lejeune. Consistent with Wondolleck and Yaffee (2000), HOWL citizen scientists believe the potential collaborators have a shared interest in the project, such as environmental education, water quality health, and/or natural resource stewardship.

As previously mentioned, community partners have a shared fear of destruction of the Hofmann Forest and the Trent, New, and White Oak Rivers, which mobilizes them to become involved. Additionally, as several interviewees noted, HOWL needs both financial and technical resources. Reaching out to community groups who have power in terms of funding as well as diverse knowledge or skills they can bring to the collaboration is crucial for the project (i.e., analyzing the prospective collaborator's constraints and opportunities). Lastly, when recruiting among new community groups, HOWL citizen scientists must agree on a common vision or an overall mission they work toward (i.e., agree on an action plan).

Recommendations for HOWL and other Participatory Research Projects

In addition to discussing the creation and structure of HOWL, participants considered other aspects of the project that could be implemented or enhanced to help the project succeed in the future. Interview participants shared their perspectives on which components of the project worked well and should continue into the future. HOWL participants indicated that they liked the project's hands-on, organized, and interactive characteristics. Additionally, many of the participants liked how multiple trainers were at each event to lead the various sections, which allowed the trainers to spread themselves widely to assist the many participants involved. Interviewees also liked the protocols established by the IWLA and believed they were clear and easy to understand, especially for individuals without a science background.

HOWL participants recognized five other strong aspects of the project: (a) the kickoff community outreach and recruitment event, (b) collaborative efforts between local organizations and partners, (c) the hands-on and interactive components, (d) the HOWL website as a recruitment and engagement tool, and (e) the training sessions (Table 2).

Interview participants also contributed feedback and suggestions to improve the HOWL project. Some of the participants' recommendations fell within the steps described in the CLO model. We also considered additional improvements that participants suggested in the interviews, which did not fall within one of the nine steps discussed in the CLO model. We then combined their recommended improvements into a total of seven categories: (a) establishing a leadership team; (b) recruiting participants; (c) training participants; (d) analyzing, reporting, and sharing the data and results; (e) valuing and including all participants; (f) meeting regularly and communicating often; and (g) obtaining funding.

Establishing a Leadership Team or Advisory Committee

A few participants conveyed a need for key representatives from each organization to form a leadership team to guide the project, similar to the approach discussed in step two of the CLO model. Some interview participants believed there needed to be one overall coordinator to supervise the project and manage each organization's representatives. This information overlaps with the evidence provided by Bonney et al. (2009): A successful citizen science project requires a team consisting of members with various backgrounds. Additionally, Wondolleck and Yaffee (2000) supported the need for "an advisory committee" or leadership team composed of individuals with different interests and backgrounds to discuss, evaluate, and make recommendations about desired decisions.

As many of the HOWL participants suggested, it is essential to have a coordinator who can organize, recruit, and plan sampling days; however, as scholars have discussed, additional key leaders are needed for the project to flourish. For example, an educator should be available to provide information about water-monitoring protocols and procedures; a data statistician or analyst should acquire, analyze, and visualize the data that the citizen scientists collect; a webmaster may be needed to actively recruit and update the project's social media and websites; and an evaluator is necessary to ensure the project has measurable outcomes and to assess the project for sustainability (Bonney et al., 2009). Thus, HOWL should try to recruit additional citizen scientists to fulfill these roles or fill the positions with current citizen scientists who possess these technical and leadership skills.

Recruiting Participants

Several interview participants suggested that the project needed to recruit from among more diverse audiences, primarily when enlisting leaders and trainers. Interviewees recommended using new and different methods of recruiting, such as additional social media networks. Participants also suggested targeting new audiences for HOWL recruitment efforts. For example, a few

Table 2. Frequency Count of Strong Aspects of HOWL Mentioned by Interviewees

Strong aspects	No. of participants who mentioned the strengths	Specific examples from interviews
HOWL kickoff event	4	CS3 said, "We had a great kickoff and had more people than we had even hoped for. I was very satisfied with everything."
Collaboration	3	CS9 stated, "I really like the collaboration with the university, home school, Scouts, and other community groups. It is a great group to work with, and I think that it can be expanded on and can continue to grow."
Hands-on and interactive quality	5	CS11 noted, "The hands-on was the most enjoyable," and likes "digging in the mud, using the microscope, and having kids or participants operating the equipment themselves."
Website	1	C12 stated, "The website was a great element to recruit and engage participants."
Trainings	2	CS9 believed "having the training was good," as did CS12, who stated, "The trainings were a great component."

participants (*n* = 3) noted that the project should recruit community college and research-university professors and students. CS6 noted:

> I would like to see some involvement from the local community colleges which might be interested. When you think about this area, there are not many large universities. In Onslow and Carteret Counties, there are community colleges, and a lot of good things are happening at these little two-year schools. Maybe we can get some of the students involved who are thinking about transferring to four-year schools, too.

According to West and Pateman (2016), when recruiting collaborators, it is essential to understand what motivates them to participate. If citizen scientists feel like a project meets their motivations, they will continue to be involved (Peachey et al., 2014; West & Pateman, 2016). West and Pateman have suggested recruiting and advertising to "diverse groups, through diverse means," as well as ensuring that a "diverse range of people are represented" in advertising approaches (p. 3). Thus, as indicated by the interviewees, HOWL should use the power of the internet as a recruitment strategy to reach a wide range of individuals through various media outlets, primarily when recruiting among high school or younger populations. To reach more diverse populations, strategies might include going in person to under resourced and rural schools to recruit students and speak with teachers about how their lesson plans can be incorporated with the HOWL project objectives.

Further, Bonney et al. (2009) discussed the advantages of recruiting teachers. Citizen science can help teachers incorporate the existing curriculum into their classroom. Teachers also have the flexibility to work the subjects into their lessons as well as the ability to reach many diverse children. This evidence is consistent with the suggestions from the interview participants.

Training Participants

The majority of the participants (n = 6) enjoyed the training sessions, which they believed were informative, organized, and interactive. However, some participants (n = 3) suggested a need for regularly organized and publicly announced sessions throughout the year. A few participants (n = 2) conveyed that they wanted to become a trainer, but they were confused about who was in charge of the trainings and how to schedule a session. Consistent with Bonney et al. (2009), the training sessions for trainers are held at a partner site, Hadnot Creek, in Swansboro, North Carolina. Some participants complained that the training dates were not consistent or well-advertised. Scheduling a greater number of training sessions would also help prevent potential biases or errors in the data (Bonney et al., 2009). The more training participants receive and the more opportunities they have to repeat procedures, the fewer data errors will occur.

Analyzing, Reporting, and Sharing Data and Results

A couple of interviewees (*n* = 2) acknowledged the need to analyze the water quality data as well as report and share the information with the coastal community and the national IWLA chapter. The water quality data, including physical, chemical, and biological properties, are currently displayed through iNaturalist (www.inaturalist.org/projects/hofmann-citizen-science). The results, however, should be further analyzed, enhanced, and visualized. HOWL could bring on someone with expertise in statistics to help with data analysis and visualization. The results should also be published so that they can be more widely shared display and demonstrate how citizen science contributes to the environmental discipline (Bonney et al., 2009).

According to Wang (2015), citizen science data should document descriptive metadata so that participants can recall how the data was collected and how they should interpret and use the information. Wang suggests CitSci.org as a mechanism to document citizen science data. CitSci.org is a free platform "to support the entire data lifecycle" (p. 2). It allows participants to enter sampling techniques (e.g., how the temperature was measured), location (e.g., latitude and longitude), time and date, and any parameter values (Wang, 2015). On the back end of the platform, a coordinator or webmaster can tailor the attributes and fields to fit the project's needs. Additional features include visual mapping, summary statistics, and easily downloadable data sheets (Wang, 2015). The site also enables project coordinators and leaders to document components of the project other than the data results, such as training and protocol materials and information. These features can mitigate potential issues regarding trust, bias, or errors related to citizen science data collection and analysis. With increased data transparency and openness, as well as technical components that are simple to use, CitSci.org allows the broader scientific community to more easily receive and incorporate citizen science data (Wang, 2015).

Valuing and Including All Participants

A few interviewees noted that they did not always feel included or like valued members of the team while participating in the project. A couple of participants expressed that they would have liked to take on a specific role where they could have prospered. One participant never returned after participating in one monitoring day because they did not feel like they fit in with the group. As previously discussed, there were a few participants who wanted to become trainers but felt like "it was a secret, and [they] did not feel welcomed." Fortunately, these participants continued to be involved in the project. Some participants also indicated that they wanted to feel like their work was contributing to something greater or making a difference. According to Bell et al. (2008), HOWL leaders and trainers should communicate to participants that their work and data is "useful and vital" (p. 3451). Showing that citizen scientists' data, work, and time are valued ensures participant self-esteem, which in turn translates into long-lasting and greater participation (Bell et al., 2008). Accordingly, HOWL should try to be as inclusive, open, and encouraging as possible.

Meeting Regularly and Communicating Often

Many interview participants indicated that it was crucial for HOWL to schedule meetings throughout the year. One interviewee recommended meeting quarterly to update on the project's goals and mission as well as plan for yearly recruitment, collaborating, training, and funding needs. Further, most participants said it was necessary for project leaders to communicate often. Otherwise, as CS1 stated, they "feel left out or out of the loop."

According to Wondolleck and Yaffee (2000), communication with organization leaders should occur early and be ongoing. Communicating often establishes relationships and builds trust among partners, which in turn increases volunteer involvement and retention. Involving all members in communication and decision-making processes is more likely to result in meaningful, useful, and enduring group governance.

Funding

Almost all participants noted the need for project funding. All citizen scientists and trainers are volunteers, and all data is stored and managed on free websites such as iNaturalist. Some funding has been acquired for monitoring equipment and the HOWL website. Interview participants suggest applying for grants to fund a part-time coordinator. Bonney et al. (2009) believed a successful citizen science project requires the staff members to direct and manage project development, support and recruit participants, and analyze and curate data. Further, Bonney et al. noted that citizen science projects are "cost-effective over the long term," as they produce high quantities and quality of data (p. 983). Thus, HOWL should seek additional funding through grants or potential collaborators to sustain the project for the future.

Future Work

For future evaluation and research on the HOWL project and its participants, we recommend the use of additional qualitative methods, such as a survey questionnaire or focus groups. This triangulation approach would allow new perceptions and information to be gathered. For example, a pre-survey or questionnaire administered before HOWL citizen scientists participate in the project could be a useful way to gather information on their initial objectives or goals as well as their motivations for participating (West & Pateman, 2016). A simple quiz could also provide insight into how much a participant knows about scientific processes and content before participating in HOWL. A follow-up assessment could then be administered to evaluate the participant's knowledge of scientific procedures and subjects after participating in the project (Bonney et al., 2009). Collecting this information early on could help HOWL coordinators and trainers assist citizen scientists in meeting their individual goals and tracking their progress. The hope is that being involved in goal-setting processes can increase volunteer retention as well as help in environmental learning.

In addition to evaluating how well participants have met their personal goals, researchers can evaluate specific community engagement and achievements (i.e., socio-ecological outcomes). In the short term, future HOWL research should review the number of participants and collaborators that have been involved over the project's lifespan (Bonney et al., 2009). In the long term, future HOWL research should review the number of cases where citizen science data was used in local decision-making, policy formation, or implementation.

In the even longer term, HOWL research should focus on the discoveries made by citizen scientists and assess the scientific questions initially formed (step 1 of the CLO model). Since HOWL was established in September 2016, it is still considered a developing pilot project. Thus, as the project continues to collect water quality and quantity data and observations, we hope to evaluate the project's scientific outcomes in the future.

Study Limitations

It was essential for us, as both the creators of HOWL and the project's evaluators, to understand the bias that we potentially brought to the research results and analysis. Face-to-face interviews can cause interviewees to hold back their honest opinions and perceptions. Since 2016, we have worked closely with and developed sincere relationships with the citizen scientists involved in HOWL. Although we hold the positions of both creators and evaluators, our presence could have affected the responses given by the interviewees (Anderson, 2010). The interviews were a significant way to gather the experiences and stories from the participants; however, we acknowledge that such qualitative approaches could also be manipulated by our personal biases or even ways we wanted to interpret or understand the participants' perceptions. As our preceding list of possible improvements suggests, we think we have been evenhanded in collecting and summarizing our data. To address this potential limitation of personal bias or errors in participants' responses, we would welcome a project evaluation in the future by an external interviewer who is unassociated with HOWL.

Conclusions

This research seeks to discover how citizen science efforts can positively influence socio-ecological systems and participants' scientific and interpersonal objectives. This study recognizes that a citizen science program is only as successful as its citizen scientists perceive it to be. Citizen science initiatives can be used to meet outcomes of collaboration, community engagement, ecological sustainability, and environmental and scientific education. In this paper, we provide recommendations for the HOWL project that can be used by other communities and groups who wish to develop citizen science projects to meet similar socio-ecological and participant outcomes.

In the past, few citizen science researchers have studied the perspectives of citizen scientists to understand the limitations and successes of a project (Jollymore et al., 2017). Our recent research helps fill this gap by interviewing HOWL citizen scientists to understand how HOWL, and similar projects, can enhance participants' personal goals and increase collaborative community efforts overall. We evaluated whether the HOWL project's citizen scientists achieved their personal goals while participating in the project (i.e., participant outcomes) as well as the degree to which community engagement and collaboration increased among the various organizations involved in HOWL (i.e., socio-ecological outcomes). Our research used the Cornell Lab of Ornithology (CLO) model to design and implement the Hofmann Open-Water Laboratory (HOWL) project in eastern North Carolina and to evaluate the project's participant and socio-ecological outcomes.

Our objectives were to assess how well HOWL achieved the outcomes of increased, active community engagement and collaboration; constructed sustainable personal relationships and networks; allowed participants to accomplish their personal outcomes; and facilitated its own future sustainability. After assessing the HOWL citizen scientists' feedback and perceptions, we drew two significant conclusions: (a) participants achieved their individual goals when involved in HOWL citizen science and (b) new community engagement and collaboration of water monitoring increased in rural eastern North Carolina through HOWL citizen science. Four outcomes emerged as the participants discussed their experiences with the HOWL project. The interviewees stated that they (a) learned new skills, (b) gained knowledge of scientific and research procedures, (c) developed an attachment to and contributed to their community, and (d) acted as environmental stewards.

In addition to these implications, the study gathered citizen scientists' impressions of practices that HOWL should continue and aspects of the project that should be improved upon in the future. Other citizen science projects in their beginning stages, like HOWL, can consider these suggestions as they grow their base of participants and consider potential expansion to other regions. Further, we strongly recommend that the greater citizen science research community further examine its perceptions of citizen scientists and how participatory research initiatives can facilitate community engagement, collaboration, and environmental education. This paper could be used as a reference for citizen science practitioners, educators, managers, and other researchers who wish to plan citizen science efforts to meet outcomes of participant development and engagement in science and in their community.

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