An evaluation of the participant and socio-ecological outcomes of eastern North Carolina citizen science project and recommendations for similar participatory research projects

Abstract

Citizen science, also known as participatory research, combines the efforts among professional researchers and community volunteers to collect data. We have established a collaborative project in eastern North Carolina, near the 79,000-acre Hofmann Forest, comprising of 55,000 acres of planted forests and 24,00 acres of deep pocosin natural forests. The White Oak River, New River, and Trent River all flow out of the Hofmann. The Hofmann acts plays a keystone ecological role as it acts as a natural filtration system for harmful runoff that occurs in the coastal plain of North Carolina.

The purpose of this study was to (1) evaluate the Hofmann Open-Water Laboratory (HOWL) citizen science project by assessing the perceptions of the HOWL participants and concluding if the project achieved its goals of individual development and community engagement and (2) to provide recommendations for the HOWL project, but also suggestions that can be used for other participatory research projects that are in the beginning phases. We interviewed 12 HOWL citizen scientists who participated in the project. Two major conclusions were drawn from the research. First, we recognized community engagement and collaboration drastically increased in rural Eastern NC due to the community member's participation in water monitoring and natural resource management. Second, citizen scientists achieved their personal goals and objectives by participating in the HOWL project. Citizen scientists believed by participating in the project, they learned a new set of skills, gained knowledge of scientific and research procedures, developed an attachment to the community and region, and acted as an environmental steward

Further, by comparing the HOWL citizen scientist's perceptions to the current citizen science literature, additional recommendations for the HOWL project were provided with this project's evaluation. The results discussed in this paper will be used to sustain the collaborative efforts of the HOWL citizen science project for the future.

Introduction

Citizen science combines research efforts between professional scientists and community volunteers. Citizen science approaches have recently emerged within the past decade. A search for "citizen science" in Web of Science identified only 19 scientific articles published between 1950 to 1990 (Lepczyk et al., 2009). However, from 1990 to 2013 there were over 400 papers on the subject. Now, in 2018, if searched "citizen science" in Web of Science, over 2000 articles are available. Even a search for similar phrasing such as "participatory research" from 1990 to 2013 retrieved approximately 300 articles; however, in 2018, Web of Science discovered more than 700 publications.

Although the terminology of "citizen science" evolved only recently, participatory and stakeholder involvement approaches are quite old. For example, early practices arose from naturalist hobbyists like John Muir and Georges Cuvier (Dickinson et al., 2012). But today, individuals who lack experience or a background in a science discipline or practices, professional researchers, and any who engages in scientific processes can be "citizen scientist" (Dickinson et al., 2012). As citizen scientists dedicate some of their lives to a natural or environmental hobby. In some citizen science project, participants feed observations and data from a wide range of geographic areas and share with the world. Thus, as citizen science approaches increase, researchers are using and designing different types of participatory research projects to meet their goals. Most projects are specifically developed to meet a scientific outcome (Cooper et al., 2007), but some are created to also include goals of increasing community networking, building community engagement, participant's perceptions of stewardship, and environmental education.

Citizen science has sky-rocketed in the last decade to help professional researchers collect data from across the globe in less time. Data collection processes can be very time consuming, and citizen scientists can collect large quantities of data more quickly and more often (Wildschut, 2017). Citizen science brings communities and individuals together with a common interest or goal (Wondolleck & Yaffee, 2000). Not only does it bring citizen scientists together, but it also allows a bridge between professional scientists and a citizen scientist. For example, we often acknowledge the "typical scientist" as one who wears lab coat and works inside a laboratory all day. Although true for some cases, citizen scientists have the opportunity to work one-on-one and see the work of professional scientists solving and asking problems in the field. Working with a professional scientist can be motivating and inspiring for individuals who are also dedicated to the field-of-interest. In addition, participatory research approaches bring a STEM opportunity to a community, a classroom, or allow for new educational opportunity for hobbyists and other interested individuals (Shah & Martinez, 2016). Lastly, the data and information that is collected by the citizen scientists can be used in natural resource management and decision-making and policy formation or implementation (Newman et al., 2017).

Critics of the field argue that such participatory approaches lead to issues with data credibility and completeness because citizen scientists may lack knowledge and expertise of science procedures and data collection (Gouveia et al., 2004). Because the data may be inconsistent and, therefore, may lack credibility. In many cases, policy- or decision-makers value the word from professional researchers as they bring to the table years of expertise, commonly referred to as "expert knowledge" (Ascher et al., 2010). Traditionally, "local" or "indigenous" knowledge is overlooked and deemed less reliable (Ascher et al., 2010). Lastly, 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).

Evaluative Framework

When designing 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, attracting participants from across the United States. The lab designs their projects to answer scientific questions while informing the public of environmental and ecological systems (Bonney et al., 2009). The model used for the HOWL design was constructed by members of CLO to fulfill goals of recruitment, research, conservation, and education. In this section, we have addressed step nine of the CLO model, which is to evaluate the project's outcomes.

Shirk et al. (2012) describe three types of outcomes associated with citizen science projects to influence 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 purposes (e.g., building community networks and relationships)

Participatory research projects indeed focus on the data outcomes and scientific discoveries, but they can also focus on citizen scientist's perspectives and perceptions to evaluate a project's outcomes. Typical participant outcomes of citizen science project include an increase in understanding of scientific subjects and/or 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/or an enhanced sense of place and/or stewardship (Evans et al., 2005; Shirk et al., 2012; Wilderman et al., 2004a; Wondolleck & Yaffee, 2000). As for socio-ecological outcomes, the literature includes outcomes such as an increase in community engagement and/or 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/or an increase in likelihood of future collaboration between participants on other projects, especially engaging in public policy and decision-making (Overdevest et al., 2004; Shirk et al., 2012; Wilderman et al., 2004a).

These participant and socio-ecological outcomes can be evaluated in several ways. The citizen scientist, or participant, dimension can be assessed by looking at new knowledge (e.g., does the project contribute to better understanding of a science topic?) and ownership gained (e.g., do participants feel responsible for the project and its mission?) or a change in attitude (e.g., does the project influence values regarding science?) and behavior (e.g., does the project trigger a personal behavior change?). Participant outcomes can also be assessed by focusing on motivation and engagement (e.g., does the project motivate participants to be involved in the project in the future or similar work?) Further, the socio-ecological dimension can be evaluated through a societal (e.g., does the project enhance social capital and community engagement?) and ecological (e.g., does the project protect or manage natural resources?) impact (Kieslinger et al., 2017).

According to Jollymore et al. (2007), few scholars have investigated the perspectives and perceptions of the participants to understand the limitations and successes of the project. Therefore, for our study, we focused HOWL's successes in terms of the socio-ecological and participant outcomes by gaining knowledge from the experiences and perceptions of the HOWL citizen scientists. 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 increase in community engagement and collaboration between the various organizations (i.e., socio-ecological outcomes). Our objectives were to assess how well HOWL:

- achieved the outcomes of increased and active community engagement and collaboration,
- constructed sustainable personal relationships and networks,
- accomplished their personal outcomes through participation in the HOWL project,
- and created the project to be sustainable for the future.

Methods

Hofmann Forest and Study Area Background

The Hofmann Forest, founded in 1936, is North Carolina 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 the Venus fly-trap (*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 that flow out of the Hofmann and the Trent river which headwaters begin in the Hofmann. This 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; Government Accountability Office, 2008; Nicole, 2013; U.S. Geological Survey, 2018). Since August 2016, citizen scientists have collected crucial water monitoring data on physical, chemical, and biological properties surrounding the Hofmann Forest to understand its ecological significance in the coastal community. The HOWL project gives full responsibility, data access, and project development and management to its citizen scientists.

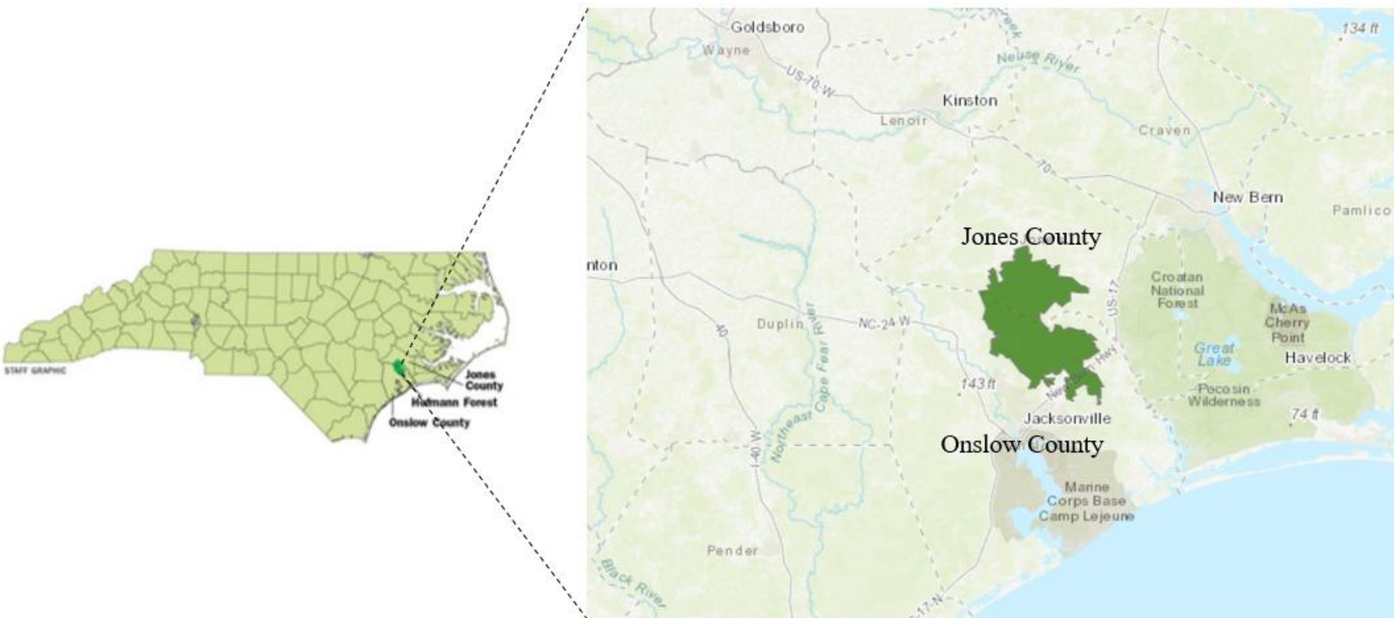

Figure 1: Placement of Hofmann Forest in Jones and Onslow Counties in the state of North Carolina.

Formation and Structure of Hofmann Open-Water Laboratory (HOWL)

In January 2013, the NCSU Endowment Fund and Natural Resources Foundation initiated a proposed sale of the Hofmann Forest (Cubbage, Roise, & Sutherland, 2016). The Hofmann Forest sale proposal alarmed numerous individuals not only in Raleigh, NC, but, also, across North Carolina's coastal plain, especially within Jones, Onslow, and Carteret Counties, located approximately 130 miles southeast of Raleigh. A coalition consisting of local community members, coastal conservation groups, school groups, and other interested individuals continued to be involved with the forest even after the decision to retain the land was announced in 2015. Timeline of Hofmann Forest events and history are shown in Figure 2.

The citizen's collaborative efforts and actions to save the Hofmann Forest prompted additional, and continued, involvement at the Hofmann to solidify its value and importance within the coastal community. The triggering event of the proposed sale stirred the group to stay connected. Before the proposal, the individuals and organizations did not collaborate or work together, and if they did, it was very minimal. The project was initiated by a faculty member at NC State University and, then further supported by the local community members and groups. Hofmann Open-Water Laboratory (HOWL) was developed by a team of researchers and then recruited additional community members to join in the collaborative efforts. The HOWL leadership team was created consisting of leaders of the informal coalition, including individuals from NC State University, Izaak Walton League of America, NC Cooperative Extension Service, and White Oak-New River Keeper Alliance.

The HOWL project, officially established in August 2016, is a participatory research project to analyze the ecosystem services that Hofmann Forest provides, such as the water quality of the three rivers -- 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 set-up sites to monitor chemical, physical, and biological properties outside of the forest. The project integrates the scientific efforts of local researchers representing community groups from NC Cooperative Extension Service, White Oak-New River Keeper Alliance, Izaak Walton League of America (IWLA), homeschools, Boy Scouts and Cub Scouts, Onslow County 4-H groups, and other local interested individuals and youth. The scientific and participatory effort is designed to offer an innovative and collaborative approach to engage citizens and community groups to extend data within the North Carolina coastal region; help citizens better understand the world in which they live; and create a partnership between professional researchers and organizations with local volunteers. The citizen science approaches involving locals, professional scientists, field collection technology, and fieldwork will allow 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.

Citizen scientists were recruited several ways. The most vital persuasive strategy employed for recruitment was relating the project to volunteers on a personal level (Petty, 1981). Those who feel personally responsible for and associated with HOWL or the Hofmann Forest are those who will be most likely to participate. Therefore, two specific strategies were used to personally connect participants to the HOWL project: (1) stressing the need for clean water for individuals in and around the eastern North Carolina, as well as (2) promoting the ability for volunteers to learn and gain opportunities they would not have achieved otherwise (such as building and maintaining community and individual relationships). The HOWL project reached out to all ages and individuals, especially to less-involved and minority groups in the rural counties. HOWL, also, reached to inner-city schools, local youth organizations, and conservation groups in Jones, Onslow, and Carteret Counties by aligning our goals with the community's interests. For people who live near the Hofmann Forest, the knowledge of the quality of the watershed's impact on the nearby communities can prompt many to become involved to help understand the quality of the water in their area. Once the target audience was acknowledged, to gain interest and recruit project membership, the leadership team held a HOWL Science Kick-Off event on October 5, 2017. The event was held at the White Oak Campground in Maysville, North Carolina, and advertised to the campground residents and visitors, and other members of the community. The HOWL leadership team posted flyers in community centers, schools, and other local meeting points in Onslow, Jones, and Carteret Counties. The flyer contains the HOWL team contact information and general event information to engage prospective participants. The event gave a preview of water quality and benthic macro-invertebrate sampling to engage attendees to become HOWL citizen scientists and continue to participate in the project. There was also an extensive write-up of the event in the Carteret County News-Times, which helped promote citizen scientist participation and recruitment.

Another recruitment mechanism is the HOWL website. The website (hofmanncitizenscience.com) acts as an engagement strategy for HOWL citizen scientists and potential participants. The site will motivate and encourage citizen scientists by recognizing their achievements, and participation. The will provide updates and images from fieldwork days or outreach events. It offers potential members to sign-up to become involved, as well as learn the first steps of participating in HOWL. When creating the web design, it is important to recognize the diverse audience whom may come across the page. Many individuals may approach the page with little to no scientific background, or experience with water monitoring sampling. The designers have adapted the website's language and content with simple and clear wording for those who may not be familiar with the scientific or natural resource field. Volunteer recruitment and retention centers around usability, accessibility, and attractiveness of the website.

In addition to the website, a HOWL Twitter handle, @HOWLScience, has been established to connect, and advertise, to potential citizen scientists. Social media networks integrate HOWL citizen science findings with other participatory research projects collecting similar information across the nation and globe. The social media outlet solicits innovative ideas, increases participant participation, and enhances problem-solving and critical thinking (Chun & Reyes, 2012; Khan, 2013; & Khan et al., 2014). The HOWL Twitter page promotes interactions between groups and users through sharing information, opinions, and interests (Khan et al., 2014).

Once recruited, citizen scientists were trained and educated on standard monitoring protocols. Protocols are a formal design for citizen scientists to follow to collect data (Bonney et al., 2009). They are simple and clear to understand for users who may not be familiar with the field. The protocols used for the HOWL project were adopted by the Izaak Walton League of America (IWLA) Creek Freak's program. The Creek Freaks program has created data sheets for citizen scientists to record biological, chemical, and physical measurements. The HOWL groups will complete the forms at each site visit. The data forms follow the project protocols and used in data analyzation (Bonney et al., 2009).

Training procedures are adapted from the IWLA Creek Freaks program. The HOWL project adopts the "training the trainer" approach. Once a member is trained, they then train their group to adequately monitor and collect data. The training process helps reach the goals of getting participants to understand, learn about, and follow the scientific method. Not only do the protocols mandate step-by-step processes that require precise measurements, but participants are also be 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 providing citizen scientists with training allows for confidence gain in their data-collection skills.

The monitoring protocol videos (as previously discussed) were created for trainers, and newly-trained members to review and practice the water sampling procedures. Participants should refer to the videos before entering the site to familiarize themselves with the steps and materials.

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

Figure 2: Timeline of Hofmann Forest history and engagement
(Cubbage, Roise, & Sutherland, 2016.; Hartman, 2016; North Carolina State University, 2017; Resource Management Service, LLC, 2015).

Qualitative Research Approach

We chose a qualitative research approach to achieve the study's objectives and gather evaluative feedback from the HOWL participants. This qualitative method focuses on questions about how social experiences are created and give meaning to projects. A qualitative structure may contain a mixture of a few empirical tools (Anderson, 2010), such as interviews, document-review, focus groups, and observations. However, in this study, we solely assessed the HOWL participant perceptions through semi-structured interviews as a way to reveal complex experiences and ideas, which can be more compelling than quantitative information. We chose this method because it allowed for thorough and comprehensive human experience understanding of a certain case, which does not concern or represent the broader population. Additionally, interviews can also be re-structured and easily revised as new information is gathered by the participants (Anderson, 2010). However, there are limitations to face-to-face interviews to understand. For example, qualitative research may sometimes be manipulated by researcher's personal biases (Anderson, 2010). The interviewee's words and opinions can be interpreted and understood by the interviewer differently than anticipated. Another issue of interviews (that are not conducted by an external reviewer) important to recognize is how the presence of the interviewer may impact the responses given by the interviewees (Anderson, 2010).

The data were collected through semi-structured interviews with HOWL participants. Interviews are a beneficial method to gauge the reality of experiences of people who took part in them (Peräkylä, 2005). Through this approach, project participants were asked open-ended questions. If interviewees answered with a "yes" or "no" or similar responses given little information, I encouraged the participants to expand on their answers. An interview questionnaire was designed to gather participant's perceptions of the project.

The interview script was constructed before the interview process and approved by North Carolina State University IRB. The questionnaire was developed 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. The questions covered topics of project sustainability, collaboration with other partners and HOWL members, and individual goals and perceptions. The questions were grouped according to the research objectives for the study.

To provide comprehensive data from the participants, thorough note-taking and audio recordings were utilized. After each interview, we used the audio recordings to transcribe the responses of the participant. In cases of uncertainty, we summarized and reciprocated the participant's statements to clarify their meaning. However, the limitation of accurate responses due to the presence of the interviewer is often unavoidable in qualitative approaches (Anderson, 2010). After transcription, we coded the interviews manually. We chose to review the language by-hand since our sample size was small.

Attempts were made to contact 17 HOWL participants. To keep in mind, approximately 80% of HOWL citizen scientists are youth. However, we excluded them from the interview process for this study. Therefore, the 17 HOWL participants included all citizen scientists from the HOWL project. The 17 HOWL participants were invited to participate in the interviews via email. Twelve individuals (*N*=12) who were contacted responded (70% participation rate). The other 5 individuals out of the initial 17 HOWL participants never responded to the initial recruitment email, and none of the individuals have attended a monitoring event since then. Interviews were conducted over the phone and in-person. All participants agreed and signed the consent form required by the IRB before participating in the study. Three of the interviewees had participated in monitoring activities only once, while 9 had participated 2 or more times. The ages ranged between 26 and 65 years old; 2 males and 10 females. All organizations involved in the HOWL project were represented in the interview process.

Results and Discussion

Participant Outcomes

Nearly all participants communicated they had an initial goal before joining the HOWL project. All participants stated they achieved a personal goal after participating in the project. The remaining participant, whom stated they did not have an initial goal when entering the project, also identified an outcome they gained after, which also fit into the following themes. Four achieved outcomes emerged as participants discussed their experiences with the HOWL project. HOWL citizen scientists have: (1) learned a new set of skills, (2) gained knowledge of scientific and research procedures, (3) developed attachment and contributed the community, and (4) acted as an environmental steward.

First, some of the HOWL participants noted they gained the new skill of educating others. After participating in the project, completing the training sessions, and leading Scout, homeschool, and 4-H groups, participants learned how to instruct others. Members also indicated they learned skills of networking, event planning, and communicating while involved in the project. A few citizen scientists (*n*=2) recognized they gained teaching and instructing skills. Participants learned the procedures that they could then educate their prospective groups, such as one participant who "wanted HOWL to be an educational program to my organization and wanted to get kids out to learn about water monitoring." In addition, almost half of the interviewees (*n*=5) collaborated with new community groups and individuals. One citizen scientist said, "I was guided by other people… everyone does what they do best and bring their expertise and experiences to the trainings and field days." Likewise, another participant, 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 learned about scientific processes and research protocols. Many individuals recognized they had never participated in fieldwork or research prior to participating in HOWL. Additionally, one participant noted they learned a lot about benthic macro-invertebrates and their importance of testing when monitoring water quality. Some of the participants (*n*=4) perceived learning scientific procedures, data collection, and fieldwork as their achieved outcomes from HOWL. For example, one participant, said, "I improved my familiarity and how to identify macro-invertebrates. I have never done that before this project." Another citizen scientist had never been involved with any sort of data collecting before, saying, "before the kick-off I have never been involved with any kind of fieldwork before… I wanted to see how water quality data is collecting… This one-day kick-off wasn't enough. It made me want to participate more and know more."

Third, HOWL citizen scientists felt they were helping the community. According to Pandya (2012), individuals in rural areas are not typically involved in citizen science projects because of barriers such as lack of transportation, access to the environment, or scientific education. Because some of the monitoring events were located in many areas near rural communities, many of the local citizens were able to join in the efforts. HOWL participants felt altruistic and happy about reaching out and educating local children and their families. One citizen scientist believed HOWL provides the opportunity of 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 a 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. So, it was nice to see kids who probably hear about it in school get involved. During the kick-off event, I thought, 'wow! This is a great, free activity for them to see science happening in their own backyard.' These kids don't know about the White Oak or New Rivers or exactly what's out there, and 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, one citizen scientist indicated "there are not a lot of STEM projects like this in the community for children to be involved in." Likewise, one participant conveyed that teachers in the area are always looking for presenters for "STEM activities" like this one. Additionally, this participant mentioned, "kids growing up want to be scientists and want to be involved outside and look at bugs." HOWL gives them this opportunity.

Fourth, not only did citizen scientists feel as if they made a difference in social capacity building, 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 educating members who live nearby to protect its waters. For example, one participant stated, "my goal is a life-long goal… 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 NC Cooperative Extension Service, NC State University, White Oak-New River Keeper Alliance, Izaak Walton League of America (IWLA), homeschools, Boy Scouts and Cub Scouts, and Onslow County 4-H groups. We were interested to discover what these community groups were doing before the HOWL project and if the HOWL project was the reason the organization began to collaborate. Many interview participants indicated they collaborated with the other community groups and partners for the first time when participating in HOWL.

Almost half of the participants (*n*=5) indicated their organization never worked with any of the other organizations participating in the HOWL project. The other participants (*n*=7) recalled their organization had worked with at least one of the other organizations before HOWL, but the collaboration was very minimal and ineffective. A few participants recognized the importance IWLA plays in the collaboration. IWLA worked with almost all the organizations at least once. A representative from IWLA agreed they had worked with the other organizations before HOWL but believed the collaborative efforts were not efficient nor effective. Further, all participants strongly believed the collaboration would continue, especially if funding was available to employ a principal coordinator to mobilize the project.

For example, nearly half of participants (*n*=5) indicated they had never worked with any of the other organizations or members before the HOWL project. 58% of participants (*n*=7) stated they had worked with at least one of the organizations, but the collaboration was minimal. The participants that stated that there was "minimal involvement with the other groups" acknowledged that the collaborative efforts were only with the Izaak Walton League (IWLA). One participant stated, "we had worked together but not very well, nor effectively." In addition, all participants (*n*=12) indicated they believed the HOWL project would not continue if any of the partners were to drop out of the collaboration. For instance, a participant 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. One respondent answered, "IWLA plays a big part and role… they are the main pusher in the program." However, another individual expressed the importance of the University'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) that people come together when there is a shared interest or mission. They also come together when there is a shared connection or attachment to a specific place or location. In addition, individuals join to collaborate when they share a mutual goal or vision, and they work towards it. For HOWL community groups and organizations, they all 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 the unique coastal community, consisting of the Hofmann Forest and White Oak, New, and Trent rivers.

Wondolleck and Yaffee (2000), also, discuss not only do partners come together when there is a common goal or interest but when there is a shared fear or threat. Consistent with this, HOWL community members were mobilized after the NCSU Endowment Fund and Natural Resources Foundation initiated a proposed sale of the Hofmann Forest in January 2013 (Cubbage, Roise, & Sutherland, 2016). The Hofmann Forest sale 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 to monitor the White Oak, New, and Trent river, which all flow out of the Hofmann Forest. Participants also fear threats to the rivers from the increase of deforestation, construction, substantial development, agriculture, and nearby concentrated animal feeding operations.

HOWL participants have a shared mission to maintain the Hofmann Forest, as well as, manage and help facilitate the White Oak, New, and Trent rivers through management and monitoring. This shared vision, referred to as a “superordinate goal,” is the overarching vision individuals work towards and the goal that resides above the current problem or issue. The superordinate goal imagines a solution to the shared fear and cannot be done without collaboration from all parties (Wondolleck & Yaffee, 2000).

Further, interview participants recognized additional partners who are apt to join the collaborative efforts. For instance, interview participants acknowledged local conservation groups and non-profits, municipalities, colleges and universities, teachers and schools, and Camp Lejeune Marine Base to recruit to join HOWL. 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 natural resource stewardship.

As previously mentioned, community partners have a shared fear or threat of annihilation of the Hofmann Forest and the Trent, New, and White Oak Rivers which mobilize them to become involved. Additionally, as several interviewees mentioned, 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 provide to the collaboration is crucial for the project (i.e., analyzing their constraints and opportunities). Lastly, when recruiting to additional community groups, HOWL citizen scientists must agree on a common vision they work towards (i.e., agree on an action plan).

Recommendations for HOWL

In addition to project creation and structure design, the HOWL participants discussed other aspects of the project that could be implemented and enhanced for future continuity. Interview participants shared their perspectives of what components worked well in the HOWL project and should be continued in the future. HOWL participants indicated 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 for assistance and guidance among the many participants involved. Interviewees also acknowledge they liked the protocols established by the IWLA. They believed they were clear and easy-to-understand, especially for individuals without a science background.

Also, HOWL participants recognized six other strong aspects of the project: (1) the kick-off community outreach and recruitment event, (2) collaborative efforts between local organizations and partners, (3) hands-on and interactive components, (4) HOWL website as a recruitment and engagement tool, and (5) the training sessions (Table 1).

Table 1: Frequency count of strong aspects of HOWL mentioned by interviewees	
Strong aspects of the project recognized by HOWL interviewees	**Number of participants who mentioned strength**
HOWL Kick-Off event	4
Collaboration	3
Hands-on and interactive	5
Website	1
Trainings	2

Interview participants contributed feedback and suggestions to improve HOWL project's components. Some of the participant's recommendations fell within the steps described in CLO. We also took into consideration additional improvements that participants had expressed in the interviews. These categories did not fall within one of the 9 steps discussed in the CLO model. We, then, combined the recommended improvements into a total of seven categories: (1) establishing a leadership team, (2) recruiting participants, (3) training participants, and (4) analyzing, reporting, and sharing the data and results, (5) valuing and including all participants, (6) meeting regularly and communicating often, and (7) obtaining funding (Figure 3).

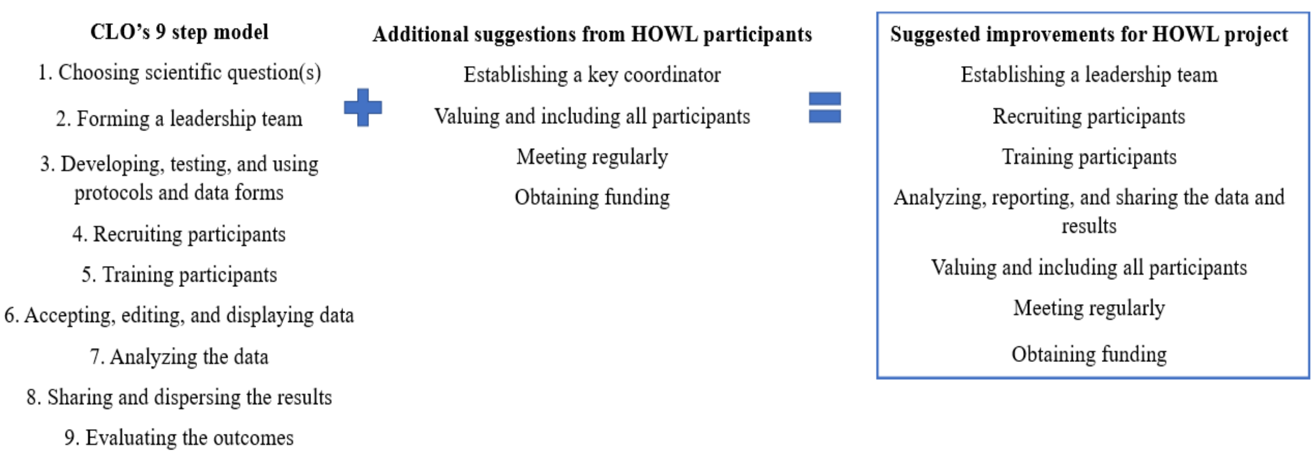

Figure 3: CLO model recommendations and the suggestions by HOWL participants taken into consideration to formulate final recommendations for HOWL.

Establishing a leadership team

A few participants conveyed a need for key representatives from each organization to lead the project, similar to the approach discussed in step 2 of the CLO model, forming a leadership team. Some interview participants believed there needed to be one overall coordinator to supervise the project and manage the organization's representatives. This information overlaps with the evidence provided by Bonney et al. (2009): a successful citizen science project consists of a team consisting of members with various backgrounds. Additionally, Wondolleck and Yaffee (2000) support the need for "an advisory committee" or leadership team. They suggest forming an advisory committee, consisting of different interests and backgrounds, to discuss, evaluate, and make recommendations about desired decisions.

As indicated by many of the HOWL participants, it is essential to have a coordinator who can organize, recruit, and plan sampling days; however as discussed by scholars, 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 acquire additional citizen scientists to fulfill these roles or fill the positions with current citizen scientists who contain these technical and leadership skills.

Recruiting participants

Several interview participants suggested the project needed to recruit to a more extensive range of people and more diverse audiences, especially when recruiting leaders and trainers. Interviewees recommended using different methods of recruiting than what had been currently used, such as additional social media networks, as well as gave their opinion of what groups that should recruit to. For example, a few participants (*n*=3) noted that the project should recruit community college and research university professors and students. One participant noted:

> "I would like to see some involvement from the local community colleges who 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 lot of good things are happening at these little 2-year schools. Maybe we can get some of the students involved who are thinking about transferring to 4-year schools, too."

Some interviewees (*n*=2) perceived day and summer camps or other after-school programs as a good avenue for children to become involved. For instance, one individual said, "we haven't tried publicizing to after-school programs in the area… I think there could be more day and recreation camps involved, also." A couple of respondents (*n*=2) expressed the need to reach out to the marine base, Camp Lejeune, in Jacksonville, NC, stating:

> "We should be talking to the base down here. The scientists on the bases are interested in the same tests that we are taking. I think they would be happy to be involved… Especially get the schools on the base and have kids check the rivers. We can get the professionals from the field to show the kids. Also, they have a lot of resources and power – they are the economic driver in eastern North Carolina."

According to West and Pateman (2016), when recruiting collaborators, it is important to understand what motivates them to participate. If citizen scientists feel like their motivations are met, they will continue to be involved (Peachey et al., 2014; West & Pateman, 2016). West and Pateman (2016, p.3) suggest recruiting and advertising to "diverse groups, through diverse means," as well as ensuring a "diverse range of people are represented" in advertising approaches. Thus, as indicated by the interviewees, HOWL should utilize the power of the internet as recruitment strategies to reach a wide range of individuals on various media outlets, especially when recruiting to high school or younger populations. When reaching more diverse populations, going in-person to inner-city and rural schools to recruit to students, as well as speak with teacher of how their lesson plans can be incorporated with the HOWL project goals.

Further, Bonney et al. (2009) discuss the advantage of recruiting to teachers. Citizen science can help teachers develop and adapt the project's curriculum to their classroom. Also, teachers have the flexibility to work the subjects into their lessons, as well as 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 trainings 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 conveyed 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's site, Hadnot Creek in Swansboro, NC. Some participants criticized that the training dates are not consistent or well-advertised. Creating more scheduled training sessions will, also, help prevent potential biases or errors in the data (Bonney et al., 2009). The more training and repetition of the procedures participants are exposed to; the fewer data errors will occur.

Analyzing, reporting, and sharing the 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 (website: www.inaturalist.org/projects/hofmann-citizen-science); however, the results should be further analyzed, enhanced, and visualized. This can be done by hiring if funds are available or establishing a volunteer to act as a data analysis leader to review and interpret the results. In addition, the results should be published to display the results to the public and demonstrate how citizen science contributes to the science fields (Bonney et al., 2009).

According to Wang (2015), citizen science data should document descriptive metadata for participants to recall the results of the data collected, and how to interpret and use the information. He suggests CitSci.org as a mechanism to document citizen science data. CitSci.org is a free platform (www.citsci.org) "to support the entire data lifecycle" (Wang, 2015, p.2). CitSci.org allows for participants to enter sampling techniques (e.g., how temperature was measured), location (e.g., latitude and longitude), time and date, and the parameter values (Wang, 2015). On the "back-end" side of the platform, a coordinator or webmaster can tailor the attributes and fields to fit the project's scheme. Additional features include visual mapping, summary statistics, and easily downloaded datasheets (Wang, 2015). Also, the site enables project coordinators and leadership team members to document many components of the project other than the data results, such as training and protocol materials and information.

A visualization and sharing network, such as CitSci.org, is necessary for researchers, citizen scientists, and other interested individuals to access the data. HOWL currently uses iNaturalist as a data sharing and storage unit; however, CitSci.org can be a comprehensive tool to store, analyze, and share data, as well as manage a citizen science project as a whole. HOWL should adopt a data-sharing platform that can facilitate metadata collection and produce documentation. In doing so, potential issues regarding trust, bias, or errors that can be related to citizen science data collection and analysis can be limited. With an increase in data transparency and openness, as well as technical components that are simple-to-use, citizen science data can be better received and incorporated by the broader scientific community (Wang, 2015).

Valuing and including all participants

A few interview participants voiced their experiences with the lack of inclusion or self-value while participating in the project. A couple of participants expressed that they would have liked a specific role in the project where they could have prospered. One participant never returned after participating once in a 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 a trainer but felt like "it was a secret and did not feel welcomed". However, fortunately, these participants continued to be involved in the project. Also, some participants indicated they wanted to feel like their work was contributing to something greater or making a difference. According to Bell et al. (2008, p.3451), HOWL leaders and trainers should communicate to participants that their work and data is "useful and vital". Showing that citizen scientists' data, work, and time are valued, ensures participant self-value, which in turn creates a long-lasting and greater participation (Bell et al., 2008). Accordingly, HOWL definitely should try to be as inclusive, open, and encouraging as possible.

Meeting Regularly and Communicating Often

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

According to Wondolleck and Yaffee (2000), communication with organization leaders should occur early and on-going. 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 results in more meaningful, useful, and enduring decision-making and processes.

Funding

Almost all participants noted the need for project funding. All citizen scientists and trainers are volunteers, and all database storage networks are used via 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) believe 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. (2009, p.983) note that citizen science projects are "cost-effective over the long term," as they produce high quantities and quality of data. Thus, HOWL should seek additional funding through grants or potential collaborators to sustain the project for the future.

Opportunities for Future Collaboration at Hofmann Forest

In July 2016, the NCSU Endowment Fund and Natural Resources Foundation sold a 50-year contract for the rights to harvest the timber and to manage the Hofmann Forest to Resource

Management Service LLC (RMS), a private timber investment management organization (TIMO) (Hartman, 2016). RMS is required to operate the forest to meet sustainable forest management certification requirements (Hartman, 2016) under the Sustainable Forestry Initiative (SFI). According to the SFI's Forest Management Standards and Rules, forest managers are obligated "to broaden the practice of *sustainable* forestry through public outreach, education, and involvement." In addition, SFI's Forest Management Standards and Rules provide "educational opportunities promoting *sustainable* forestry" examples for forest managers, "such as (a) field tours, seminars, and workshops, (b) educational trips, (c) self-guided forest management trails, (d) publication of articles, educational pamphlets or newsletters, and (e) support for state, (Sustainable Forestry Initiative, 2015, p. 9)."

Hofmann Forest would be a huge and iconic draw for the local community through recreation and educational opportunities, which could also further connect HOWL with the University, and forge links with RMS. Currently, all of HOWL's monitoring sites are located outside and surrounding Hofmann Forest. It would be an emblematic opportunity to have participatory research and educational involvement on the forest for both, HOWL and RMS. Citizen scientists could monitor the unique headwaters of the White Oak, and Trent rivers, which begin in Hofmann, as well as manage camera traps to monitor local and vulnerable wildlife. These citizen science data and observations could be used in RMS' annual SFI reporting standards and to demonstrate cooperation with "state, provincial, and local forestry organizations and soil and water conservation districts (Sustainable Forestry Initiative, 2015, p. 9)." Additionally, RMS could have "open houses", field visits, or barbecues on the forest occasionally, as well as forest and environmental education tours for the local community. This opportunity would also benefit the organization's social mission, which they state on their website to be, "we make the lands we manage available as outdoor classrooms for students at all levels and for landowner education programs… forests can benefit society and the public because of their unique natural characteristics (Resource Management Services LLC, 2015)."

Future Work

For future evaluation and research on the HOWL project and its participants, the use of additional qualitative methods, such as a survey questionnaire and focus groups, is recommended. This triangulation approach allows for new perceptions and information to be gathered. For example, a pre-survey or questionnaire before HOWL citizen scientists participate in the project to gather information on the participant's initial objectives or goals, as well as what motivates them to participate (West & Pateman, 2016) could be useful. A simple pre-survey or "quiz" could also provide insight into how much a participant knows about scientific processes and content before participating in HOWL. Then, a follow-up should be given to evaluate participant's knowledge of scientific procedures and subjects after participating in the project (Bonney et al., 2009). Collecting this information early-on can help HOWL coordinators and/or 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 goals, specific community engagement and achievements (i.e., socio-ecological outcomes) can be evaluated. In the short-term, future HOWL research should review the number of participants and collaborators 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 or policy formation or implementation.

Future 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 as 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 important for us, as both the creators of HOWL and the project's evaluators, to understand the bias that were potentially brought to the research results and analysis. Face-to-face interviews can cause the interview participants to hold back their honest opinions and perceptions. Since 2016, we have worked closely and developed a sincere relationship with the citizen scientists involved in HOWL. While holding the position of both the 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 personal biases, or even ways we wanted to interpret or understand the participant's perceptions. As our preceding list of possible improvements suggests, we think we have been even-handed in collecting and summarizing our data. To address this potential limitation of personal bias or errors in participant's responses, we would welcome a project evaluation in the future by an external interviewer who is unassociated with HOWL.

Conclusions

This study used the Cornell Lab of Ornithology (CLO) model to design and implement Hofmann Open-Water Laboratory (HOWL) in eastern North Carolina and to evaluate the project's participant and socio-ecological outcomes. After assessing the HOWL citizen scientists' feedback, two major conclusions were drawn: (1) participant's individual goals are achieved when involved in HOWL citizen science, and (2) new community engagement and collaboration of water monitoring increased in rural eastern North Carolina through HOWL citizen science.

In addition to these implications, the study gathered further knowledge of the good practices to be continued and the aspects of the project that should be improved upon for the future using the citizen scientist's feedback from their experiences with HOWL. These suggestions can be considered for other citizen science projects in their beginning stages, like HOWL, to assist with growth in participants and potential expansion to other regions. Further, it is strongly recommended that the greater citizen science research community further examine the perceptions of citizen science participants and how such participatory research initiatives can be a mechanism for community engagement, collaboration, and environmental education.

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