Apr 20th, 2:50 PM

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Shannon R. Trimboli
Mammoth Cave International Center for Science and Learning, Ogden College of Science and Engineering, Western Kentucky University, shannon.trimboli@wku.edu

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[1] Mammoth Cave International Center for Science and Learning, Ogden College of Science and Engineering, Western Kentucky University

Introduction

Citizen science is a phrase used to describe partnerships between the public and professional scientists to conduct scientific research. Citizen science projects have existed for centuries and have been called many different names including volunteer monitoring, public participation in scientific research (PPSR), crowd-sourced science, and research by amateur naturalists. Citizen science projects can cover a wide variety of topics including microbiology, ecology, geology, hydrology, meteorology, history, and public health to name a few.

In 2012, the National Park Service identified citizen science as a way of creating and engaging the next generation of park researchers and stewards in *A Call to Action: Preparing for a Second Century of Stewardship and Engagement*. In 2015, the Citizen Science Association was founded as the first professional organization focused on the field of citizen science. In 2016, the National Science Foundation made citizen science and related forms of public participation in scientific research a funding priority. Public interest in participating in citizen science projects both inside and outside of the traditional classroom has also rapidly increased in recent years.

The Mammoth Cave International Center for Science and Learning (MCICSL), a partnership between Western Kentucky University (WKU) and Mammoth Cave National Park (MCNP), has actively built a strong citizen science program at MCNP. The goal of MCICSL's citizen science program is to integrate research and education. To achieve this goal, each project under the citizen science program teaches the participants about the resources being studied, while also providing resource managers and/or researchers with scientifically valid data they would not otherwise be able to collect.

MCICSL's citizen science program at MCNP encompasses a wide range of research projects to appeal to a wide variety of audiences and helps meet MCNP's numerous

Figure 1: High school interns with The Nature Conservancy collect data for a water discharge citizen science project at Mammoth Cave National Park.

research and monitoring needs. The scope of the citizen science program includes projects focused on both natural and cultural resources and projects that occur both in the caves and on the surface (Figures 1 - 4).

Participant engagement covers a wide spectrum. At one end of the spectrum, participants simply collect data that is sent to a professional scientist. At the other end of the spectrum, the participants are primary investigators on the research permit and participate in all aspects of the scientific process. Tables 1 and 2 summarize the MCNP-based citizen science program developed by MCICSL.

Accomplishments

MCICSL's citizen science program at MCNP has grown from a single citizen science project in 2009 to 11 park-based citizen science projects today. Since funding for the program was received in 2012, almost 900 individuals have participated in the citizen science program as of March 15, 2016. Those individuals have contributed approximately 5,700 hours of volunteer work equivalent to over $132,000 in labor.

Figure 2: Middle school students from Edmonson County Middle School have a citizen science project conducting wood frog and early-breeding salamander egg mass surveys at Mammoth Cave National Park.

The data collected and research conducted by the citizen scientists add additional value to the program because each citizen science project is designed to provide scientifically valid data that MCNP resource managers and/or partnering researchers would not otherwise be able to collect.

The majority of program participants are middle school through college students. MCICSL's citizen science program provides unique opportunities for the students to learn about the park's resources, gain in-depth research experience, and make a valuable contribution through their work. Through the citizen science program, MCNP creates deep connections between the participants and the park, fosters the next generation of resource stewards, and sponsors excellence in scholarship while increasing the park's knowledge and ability to make science-informed decisions.

By integrating education, research, and stewardship, MCICSL's citizen science program supports 12 action items identified in *A Call to Action* and is creating the next generation of park visitors, stewards, supporters, and advocates.

The citizen science program is a model for other parks wanting to start park-based citizen science projects. Each year, several parks contact MCICSL's education coordinator for expert advice and guidance on establishing citizen science projects. MCICSL's education coordinator has presented at several conferences and workshops on ways to effectively integrate citizen science into park resource management programs. The lead researchers for many of MCNP's individual citizen

science projects have also given their own presentations about their projects and the results of the citizen science-based research.

Challenges and Opportunities

The citizen science program developed by MCICSL has faced and continues to face many challenges. There are also many exciting opportunities for the program. The two most significant challenges and the two greatest opportunities are discussed below.

The largest challenge for the program is a lack of secure and reliable funding. MCICSL and the citizen science program it has developed for MCNP are grant and project funded. Funding for MCICSL to develop and implement MCNP's citizen science program came through an NPS fee project that MCNP received in FY12. New funds to continue and grow the citizen science program were requested, but were not approved. Without additional funding, the citizen science program will end in 2017 when the current funds run out.

The second largest challenge for the MCNP-based citizen science program is also its greatest and most exciting opportunity. Interest in the citizen science program has increased significantly over recent years. That interest continues to grow among teachers wanting to involve their students in the citizen science projects and among researchers / resource managers wanting to develop citizen science projects to support their work. The interest in and demand for these programs indicates significant opportunities for growing and expanding the citizen science program.

Unfortunately, current demand far exceeds MCICSL's capacity to meet that demand. In addition to developing and implementing the citizen science program at MCNP, MCICSL is also responsible for leading most of the

Figure 3: Honors students at Northern Kentucky University are inventorying, photo-documenting, and assessing the condition of Civilian Conservation Corps (CCC) artifacts used in trail building at Mammoth Cave National Park as part of a cultural resources-based citizen science project.

classes participating in the citizen science projects. MCICSL's staff consists of two people – a research director and an education coordinator. The education coordinator is the primary person responsible for developing, implementing, and leading the citizen science program. Both the education coordinator and the research director have other duties in addition to those associated with the citizen science program.

Only the passion of MCICSL staff and their partners has allowed the citizen science program to grow to its current capacity, but passion and dedication can only take a program so far. Currently, both researchers wishing to create new citizen science projects and classes wishing to participate in the citizen science projects are being turned away due to a lack of capacity.

Teachers and researchers / resource managers are not the only ones interested in the citizen science program. In addition to simply growing and expanding the current citizen science program focused on participation by middle school through college students, an opportunity exists to grow the citizen science program in a new direction that incorporates a new audience.

Members of the public have also expressed interest in participating in citizen science projects at MCNP either as individuals or as families. This public interest indicates an additional new opportunity for growth if solutions are found to the current funding and capacity issues facing the program.

Conclusions

Over the past five years, MCICSL has developed a strong, multi-disciplinary citizen science program for MCNP. The program provides a rare hands-on, interactive, experience that integrates research and education. Participants learn about the park's natural and cultural resources while gaining experience conducting research and making a valuable contribution to MCNP's research and resource management needs.

Researchers and resource managers benefit from the program by gaining access to data that they would not otherwise have the resources to collect. By integrating educational, research, and stewardship opportunities while reaching out to diverse audiences, the MCICSL-developed citizen science program strongly supports four of the NPS Centennial Goals and supports a dozen action items listed in *A Call to Action*.

Researchers and resource managers are actively seeking out MCICSL staff to inquire about opportunities to incorporate citizen science into their work. Teachers and professors continue to contact MCICSL staff about opportunities to participate in current citizen science programs or to develop citizen science projects in which their students are the primary investigators. Members of the public have also inquired about opportunities to participate in citizen science projects as individuals or as families indicating a new opportunity and direction for growing the program.

Although the program has been successful, it faces two significant challenges that have the potential to severely affect the program's future. Those challenges are a lack of funding and a lack of staffing to meet program demand. If solutions to those two challenges are found, then the program has significant opportunity to grow and expand while continuing to support MCNP's research, resource management, education, and interpretation goals.

Figure 4: Middle school students collect dragonfly larvae for a multi-park citizen science project studying mercury levels in dragonfly larvae.

Table 1: Citizen science projects where citizen scientists are the lead researchers and permit holders.

Project	Citizen scientists	Primary research goal	Importance	Year started	Status
Monitoring the reverse flow patterns of the River Styx	T.K. Stone Middle School, 7th grade students	Gather baseline data on the frequency and duration of the River Styx's reverse flow events and the temperature ranges of the River Styx, Echo River, and Green River.	Reverse flow events change the water temperature in the River Styx and bring additional nutrients into the cave, which can impact the animals living in River Styx. Changes in water temperature, especially during the winter, can also create condensation or fog in the cave. The condensation and fog can affect the formation of geological features and increase fungal growth on archeological or cultural artifacts.	2009	Wrapping-up
Wood frog and salamander egg mass surveys	Edmonson County Middle School, 7th and 8th students	Compare the park's current wood frog and early breeding salamander populations to the populations reported in a similar study from the 1990s.	Amphibians are highly susceptible to climate change and other local environmental changes. Since the 1990s project concluded, climate change has continued, traffic near the surveyed ponds has increased, and management strategies such as the use of brine on the roads during winter storms have changed. All of these factors could have an impact on the populations of wood frogs and early breeding salamanders.	2012	On-going
New Discovery Cultural Resource Inventory and Condition Assessment	Northern Kentucky University's Honors Program	Map, photo-document, and assess the condition of CCC artifacts in New Discovery.	The artifacts left in New Discovery by the CCC provide unique insights into the CCC and cave trail development at MCNP. While the stable cave environment provides a level of protection and preservation for the artifacts, some deterioration is occurring, especially in wetter areas of the cave. Documenting and assessing condition of the artifacts will provide the park with a better understanding of the current condition of the resources.	2014	On-going
Monitoring underwater natural and cultural resources	Mercy Academy, high school students	Expand existing knowledge about the natural and cultural resources in the park's underground rivers by using a remotely operated submersible to increase accessibility.	Cave diving is difficult, dangerous, and requires a highly specialized skill set. Because of this, much is unknown about the natural and cultural resources found in MCNP's underground rivers. This study will provide park resource managers with a better understanding of the natural and cultural resources found in the park's underground rivers.	2015	On-going

Table 2: Citizen science projects where the primary role of citizen scientists is to collect data. In all cases, most of the citizen scientists are middle school through college classes working with MCICSL.

Project	Primary research goal	Importance	Year started	Status
Cave water discharge	Collect additional data for USGS / Tennessee State University partner on how fast the water is flowing at various locations in the cave at different times of the year.	Parking lot runoff, roadway runoff, sewer spills, and other water quality issues can result in contaminants entering the cave's aquatic ecosystems. How quickly those contaminants arrive at specific locations in the cave can vary due to precipitation patterns and weather events. A USGS / Tennessee State University researcher is developing a mathematical model for predicting how quickly contaminants could enter certain areas of the cave.	2012	On-going
Monitoring mercury levels in dragonfly larva	Collect dragonfly larvae for mercury analysis by University of Maine and USGS Forest and Rangeland Ecosystem Science Center researchers.	When consumed, mercury accumulates in the body and can cause nerve damage. Organisms higher up in the food chain have increased risks of reaching toxic mercury levels due to the mercury they accumulate from the other organisms they consume. Researchers at the University of Maine and USGS Forest and Rangeland Ecosystem Science Center are studying mercury levels found in dragonfly larvae at 53 National Parks.	2012	Wrapping up
Cave aquatic invertebrate monitoring	Gather baseline data on the population and diversity of aquatic invertebrates in the streams and pools associated with the water discharge project.	Many of the perched streams and pools associated with the cave water discharge project contain cave adapted aquatic invertebrates. Having baseline population information about those organisms could be useful if contaminants were to enter the system at those locations. The pools and streams in this study are not being surveyed as part of the Cumberland Piedmont Network's cave aquatic organism inventory and monitoring project.	2013	On-going
Mapping and documenting historic cemeteries at MCNP	Map and document condition of historic cemeteries.	MCNP has numerous historic cemeteries scattered throughout the woods. A study in the 1990s mapped and documented many of those cemeteries. Since then, the woods have continued to grow and the stones have continued to weather. By going back to map and document the cemeteries, this study provides a current assessment of the cultural resource. The project has also identified several headstones and inscriptions not documented on the MCNP Cemetery Database.	2013	Field-testing

Table 2: Continued

Project	Primary research goal	Importance	Year started	Status
Photo-monitoring of structures and locations in the cave	Create a visual reference of historic structures and locations in the cave that can be compared to older photographs to document changes over time.	MCNP resource managers often need to know when a structure such as a wall or staircase was installed or when something else changed at a historic location in the cave. These changes are not as well documented as one might anticipate. Finding historic photographs of a site and then taking periodic pictures from the same basic angle provides a quick, visual reference indicating the period of time during which any changes occurred.	2013	Field-testing; may not continue development
Project Budburst	Collect data on plant phenology at MCNP.	Climate change is causing some plants to bloom or leaf out earlier; however, the change is not uniform throughout the plant kingdom or across the globe. Project Budburst is an online, national citizen science project studying how climate change is affecting the phenology of plants. Data collected at MCNP can be used to study climate change at local and national scales.	2014	On-going
Mapping of CCC camp remains	Document and map the remains of MCNP's CCC camps.	The major CCC camp infrastructures were dismantled and removed when MCNP was established. However, artifacts still remain at most of the camps. These artifacts are subject to weathering and anthropogenic factors. Documenting and mapping existing artifacts will provide the park with a better understanding of the current condition of these resources.	2015	Field-testing