Citizen Science: A Best Practices Manual and How it Can be Applied

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- Amateur birdwatchers visit their local nature center and record observations for a one-hundred-year-old national study to monitor bird populations.
- Schoolchildren sample stream invertebrates for a long-term study of water quality in Yosemite National Park.
- Park visitors collect and identify fungi for an All Taxa Biodiversity Inventory in Great Smoky Mountains National Park.
- Coastal residents work with the North Carolina Aquarium to survey for horseshoe crabs.
- Youth at an Audubon summer camp track wood turtle movement and use the data to suggest an alternative, turtle-friendly design for a new shopping center development.

These examples are all forms of "citizen science" happening at environmental education centers, National Park research learning centers, nature centers, and other non-formal education institutions. Citizen science is a research and education tool that involves everyday people in real and meaningful forms of science, including biological inventory, long-term monitoring, and investigative research. All of these examples demonstrate ways that these institutions are using citizen science as a tool for furthering their missions of educating the public about the environment, teaching people about the process of science, and connecting people to the natural world. They also demonstrate ways that citizens are helping to generate reliable, useful data for science.

While this approach is known by many names (e.g., citizen monitoring, collaborative research), "citizen science" is a term in wide use and recognized by many individuals in both the education and science community. Citizen science can take many different forms, but typically includes several elements that make it distinct from other education and research tools.

A key component of citizen science is, of course, the citizens. The citizens may be youth or adults and come from backgrounds as varied as the citizenry itself. Often the citizens are considered volunteers. Their roles in a citizen science project can vary widely as well. Citizens may participate in just the data collection step of the scientific process or they may play larger roles by posing their own research questions, designing protocols and collecting data to answer them, and sharing their results with interested stakeholders.

Another key component is that citizen science projects are done under the direction of professional scientists. Like the citizen participants, the roles for scientists may vary greatly. Often scientists play the role of primary investigator; in other cases, the professional scientists may play more of an advisory role. This involvement ensures that the research is "real" and the connection to the greater scientific community is vital, or else the project is an education program based on science.

The goal for citizen science projects is to obtain meaningful, useful data that aim to advance scientific understanding and can be applied to real-world problems. This quality is what makes citizen science different from a canned laboratory or field activity that produces data, but that data are never reviewed or used. Exercises with known results or that generate unused data may have educational value in teaching about scientific processes, but they fall short of contributing to scientific understanding. The marriage between researcher involvement and educational goals is what makes citizen science such a powerful tool for both scientists and educators. Properly trained volunteers can:

- Assist with inventory work;
- Conduct long-term monitoring;
- Provide baseline / pilot data with which to apply for funding for professional study; and
- Provide justification for conducting a study that would not otherwise be a priority but, depending on results, could become a priority.

Regardless of the length of study, the ultimate goal of using the data is critical, whether in peer-reviewed publication or the management plan for a natural area or some other significant use.

A citizen science project also must have objectives that include education of the citizenry, whether it is education about a specific organism or study system, the scientific process, or conservation and natural resource management. A project that uses citizen volunteers to collect data, but does not include educational objectives and strategies for achieving them, is not a successful citizen science project. In this type of project, the citizens may not be aware that their activities are part of the scientific process, and thus are no more than unpaid data collectors. In other words, education without the science protocols is incomplete science. Using citizen science but leaving out the education objectives equals cheap labor. In some cases, cheap labor is the right tool for your needs—just be careful not to call it citizen science.

Case study 1: A simple one-time project

Chris Carlton, a coleopterist from Louisiana State University, is interested in a particular type of small beetle that is found living in rotting fungi. One out of a hundred or more individual beetles in a given fungi is the species he is looking for, so he has to find the right fungi and then collect a lot of beetles. In 2002, he spent four weeks at the Appalachian Highlands Science Learning Center (AHSLC) in Great Smoky Mountains National Park. After several weeks, he had failed to find the correct fungi or the beetles he was seeking.

Does this situation have the potential to be a good project for using citizen scientists? You could involve the public, especially those with knowledge of fungi, to find the correct mushroom species. There is oversight and direction from a professional scientist who will ensure scientific meaning. The results contribute to the park's All Taxa Biodiversity Inventory, so there is a need for this data. A bigger question to ask is, Can there be an educational component or is this just a good case of recruiting for cheap labor? Other considerations are that the project is short-term, does not require significant funding or sustainability planning, and the fungi sought are non-toxic species so there would not be a significant safety concern.

Paul Super, the science coordinator at the AHSLC, contacted a local mushroom club and coordinated with one of their field trips to collect the mushroom species in question. Carlton met with the club before their outing to provide them with some information about the beetles, his research, and larger issue of biodiversity. The mushroom club, since they knew the area, was able to quickly locate the fungi species sought and brought them to Carlton in pillowcases. Next, Carlton knew he would have to search through this mass of rotting, stinking mushrooms, collecting hundreds of beetles for the type he studies. To assist in this part of the project, Susan Sachs, education coordinator at the AHSLC, knew she had the perfect group: 8th grade summer campers. Carlton gave the students a program introducing them to beetle biology and biodiversity—the education component—then put them around a pan and emptied out the smelly, rotting fungi. Hundreds of beetles were collected in minutes, including the species sought by Carlton, which turned out to be new to science.

Case study 2: Fungimap

Great Smoky Mountains National Park is in the middle of an All Taxa Biodiversity Inventory and seeks georeferenced data on fungi and their fruiting periods. The Smokies are also the destination for many a mushroom fancier, and there is at least one social group devoted to identifying (and eating) mushrooms from the area. These mushroom hunters were helpful for Carlton, but could they provide useful data for the All Taxa Biodiversity Inventory? A model was found on the internet: a project called Fungimap out of Australia.

Working with regional university mushroom experts, staff at the AHSLC developed protocols, a list of target species, a pictorial guide, and data sheets that are posted on the web at www.nps.gov/grsm/pksite/fungimap.htm. Presentations were made to mushroom clubs, with training on the project provided by local mycologists. The data sheets proved easy to use and a wealth of data was provided, with good identifications for many species. One problem that occurred early on is that mushroom hunters do not seem to like to map their findings, either with GPS units or on topographic maps. Only checklist information was produced. To rectify this problem, on some occasions volunteers who specialized in taking coordinates for finds went out with club members, learning about mushrooms while providing the georeferenced data. This example is low-cost, and all materials can be downloaded from the web; it is providing useful data for park staff to use in GIS mapping and needs little oversight from staff. Its weakest link is the educational component, which is only offered if someone attends one of the trainings. Many people participate only by downloading datasheets and guides off of the internet; in such instances, the park is getting cheap, but valuable, labor. Development of more web-based educational material and updates on the progress of the fungal inventory would help elevate this project to the level of citizen science.

Case study 3: Ozone biomonitoring gardens

Research by scientists from Appalachian State University, Auburn University, and elsewhere have identified a number of plant species native to the Smokies that show visible signs of damage by ground-level ozone exposure. Howard Neufeld and Art Chappelka envisioned establishing gardens of several of these species that could be used to monitor ozone exposure under different conditions (elevation, proximity to roads, etc.) and over different seasons. Early on in their studies, the researchers asked staff at the AHSLC if there was any way the staff could monitor the plants so that the researchers would have a better picture of the progression throughout the growing season. The research team would only be in the park during a two-week period in late July, but wanted to know when symptoms first developed, how quickly they progressed, and how quickly the plants grew. This sounded like a great citizen science opportunity for staff at the research learning center.

First, this would be a long-term monitoring project, so considerable attention needs to be made to ensuring sustainability and developing clear protocols since personnel might change. Staff worked closely with the researchers to develop easy-to-use protocols and training materials. After looking at the complexity of the protocols, it was decided by Sachs that high school students studying earth science and advanced placement biology would be a perfect target audience, since the state curriculum standards have them studying air pollution impacts. To develop a well-rounded curriculum education program, a grant was obtained from the National Park Service's Parks as Classrooms program. Teachers and the park staff, with oversight from the researchers, developed a three-hour field trip with pre- and post-site activities that provide skill development, the research context, and multiple learning opportunities. An on-line database was developed with Hands on the Land, which allows students to view all data collected (www.handsontheland.org/monitoring/projects/ozone/ozone_bio_search.cfm). Quality control is provided in the design of the study, since each plant is monitored by three different student pairs. If there are discrepancies in the data, trained park staff visit the plants in question to determine the actual condition. This saves time, since often only one plant needs to be checked rather than 30.

The project has been so successful that the protocol is being replicated through an "Advanced Atmospheric Study" under the direction of GLOBE (www.globe.org). The park continues to monitor the plants, and even though the original research is completed, some of the questions asked by students have resulted in new research questions. One question posed by a 7th grade student—"What does ozone damage on a plant do to its nutritional value when it is eaten by animals?"—did spur a separate study that was published in the journal *Environmental Pollution* (Burkey et al. 2006). This citizen science study has grown to become the focus of several teacher training workshops each year, and a project that has been replicated at over 80 schools across the country.

Conclusion

A *Best Practices Manual to Citizen Science* is scheduled to be published in fall of 2007 by the Association of Nature Center Administrators (ANCA). A portion of it will also be available on the internet on the website of the Great Smoky Mountains Institute at Tremont (www.gsmit.org).

Citizen science is not the answer to all research needs, and is not necessarily less time-consuming or expensive than doing the work one's self. Its benefits can be that the educational component often justifies funding a project that cannot otherwise find funding. The citizen scientists can also increase a project's scale, both temporally and spatially.

Additionally, by involving the right groups in your citizen scientist team, you may increase the buy-in to research results by important constituents. Following best practices that are discussed in the soon-to-be-published manual can help one avoid pitfalls and shortcomings, allowing your project to be a greater success.

Reference

Burkey, K.O., H.S. Neufeld, L. Souza, A.H. Chappelka, and A.W. Davison. 2006. Seasonal profiles of leaf ascorbic acid content and redox state in ozone-sensitive wildflowers. *Environmental Pollution* 143:3, 427–434.