International citizen science: making the local global

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The Earthwatch Institute is an international non-profit organization that works with scientists and scientific institutions to develop citizen-science-based research and environmental monitoring programs. Each year, Earthwatch supports close to 80 different projects in more than 30 countries and recruits over 3000 volunteers to aid scientists in collecting data. Participants recruited by Earthwatch seek to tap into their passion for learning about science by volunteering to act as assistants for authentic research projects.

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Citizen-science programs have been successful in mobilizing volunteers to collect specific types of data at diverse locations and provide snapshots and time series of changing environmental conditions (eg World Water Monitoring Day, Audubon's Christmas Bird Count; Dickinson *et al.* 2010). This is particularly true in North America and the UK, where volunteering and engaging with nature are relatively common activities among the general public and where there are numerous scientists and organizations willing to organize citizen-science projects. The Earthwatch Institute, a non-profit organization founded in Boston, Massachusetts, in 1971, aims to extend citizen science internationally through the inclusion of both local and global programs, as well as supporting projects led by local scientists. In these programs, four discrete types of activities are associated with successful global citizen-science programs, with each activity having a specific set of valuable outcomes (Figure 1). Positive feedback loops occur when these activities are combined within the same program and their synergy leads to greater impacts. Discrete kinds of outcomes have been identified and monitored to track progress against objectives, identify lessons learned, communicate successes, and help motivate both scientists and volunteers.

Here, opportunities for globalizing citizen science through this model are explored using three case studies from Earthwatch-sponsored projects. These examples highlight not only the different types of people who become citizen scientists but also the different ways in which science is used to solve local environmental problems, alter the behavior of local stakeholders, and change policies at higher levels.

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Grevy's zebra conservation: counting wildlife, livestock, and parasites in Samburu, Kenya

Listed as Endangered by the International Union for Conservation of Nature, Grevy's zebras (*Equus grevyi*) now number fewer than 2500 individuals in the wild. Populations have declined by more than 80% over the past 20 years, and are now mainly restricted to small pockets of suitable habitat within conservancy lands in Kenya and Ethiopia. The Earthwatch program to sustain the remaining wild populations of Grevy's zebras within these community-owned conservancy lands (as well as in private or government-owned protected areas) involves developing increased awareness, management skills, and an appreciation of the value of zebra conservation among local communities.

In 2002, a citizen-science program was initiated in Kenya that relies on both local and international volunteers to track zebra population dynamics as well as to identify threats, such as predation, habitat degradation, competition from domestic livestock, poaching, and disease. To date, over 650 participants have recorded zebra locations, calculated time and activity budgets, noted stripe patterns for "sight–resight" analyses to generate important life-history information, and measured parasite levels to evaluate key forces limiting population growth rates (Muoria *et al.* 2005).

Program participants included teams of local community wildlife "scouts", trained by project scientists, who actively collected field data on zebras, with an emphasis on recording mortality events and measuring parasite loads (Figure 2). Other participants in the project were international volunteers interested in the conservation of African megafauna, zookeepers who wanted to learn more about the animals they care for in captivity, and teams of African conservation professionals seeking experience in practical field science. This broad base of participants gained a better understanding of the role landscapes outside protected areas play in maintaining wild zebra populations, the needs of the resident human communities, and the importance of gaining the support of local communities for biodiversity conservation.

One of the findings of these studies was that cattle herding prevented Grevy's zebras from drinking at preferred times and limited their access to better rangeland. Information from field research and community engagement with local and international volunteers served as a feedback loop, stimulating the development of local action to minimize disturbance to the zebras and leading to a change in livestock grazing and water-hole use patterns by herders (Rubenstein 2010). Through engagement in the participatory program, local communities have embraced the concept of community conservancies where integrated wildlife–livestock tactics are practiced. This has led to the creation of wildlife set-asides within community-owned lands (ie conservancies) with Grevy's zebra as the flagship species. In addition to gathering data, the local scouts also serve as valuable "ambassadors", linking communities to government and non-governmental scientific organizations. Armed with the latest inferences of their research, the scouts help reduce local zebra–livestock conflicts that periodically arise over grazing and water use. By participating in community-wide discussion, scouts provide valuable insights into management actions that are likely to be effective. At a regional level, the information derived from the project has been incorporated into the general management plans for the Samburu, Buffalo Springs, and Shaba National Reserves, while at the national level, leaders of the project are contributing to the National Grevy's Zebra Conservation and Management Strategy launched by the Kenya Wildlife Service in 2008. The program's large-scale impact has fostered a sense of pride and commitment among all the stakeholders and participants.

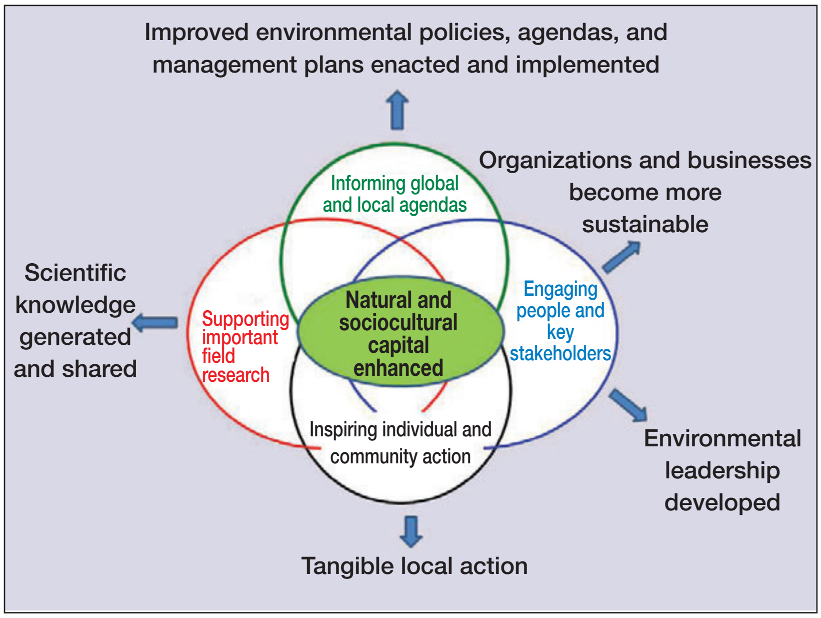

Figure 1. *The four spheres of activity that lead to successful outcomes in citizen-science programs. These spheres can be mutually reinforcing through feedback loops and, when acting in concert, are often effective in achieving lasting impacts through enhanced goods and services derived from both natural and human environments. For example, scientific outcomes can direct local action and feed into management plans, and management planning can help identify scientific analyses and necessary community actions. Discrete outcomes can be identified that assess progress against targets for these activities. These outcomes are important for the program's external evaluators, including local partners, participants, and funders.*

Sustainable coffee, sustainable livelihoods

As a result of the intensification of coffee-production throughout much of Costa Rica in the early 1980s, large areas of biologically diverse shade coffee were converted to modern conventional sun or low-shade coffee. Elevated amounts of synthetic inputs and the removal of shade trees and ground cover allowed Costa Rica's Los Santos region to become one of the world's most productive coffee-growing areas. More recently, however, the Los Santos region, which is located southwest of San José, has experienced a decline in coffee bean crop yields, degraded soils, and serious landslides and erosion resulting in both loss of property and life, making it clear that these methods are unsustainable.

A participatory research program initiated by Earthwatch, Starbucks Coffee Company, and CoopeTarrazú (a farmers' cooperative that supports small-scale, local coffee producers) was designed following discussions with local cooperatives, agronomists, producers, and coffee buyers. Since 2006, over 260 volunteers have collected data on coffee bean yield and quality, soil quality, shade trees, and arthropod diversity from 40 coffee fields to identify relationships between producer inputs, management practices, and coffee production. The 40 local producers also performed soil analyses and used logbook registers to document crop inputs (ie fertilizer, pesticides, and herbicides) and production on their coffee farms during a 3-year period (Figure 3). The research results are therefore a product of thousands of hours spent by citizen scientists counting coffee beans, measuring plants, and collecting soil samples, along with information about farm management practices gathered directly from the farmers.

The citizen scientists gained knowledge about sustainable agriculture and the relationship between environmental sustainability and the power of their purchasing behavior. Research outcomes from volunteer-collected data have included identifying management practices that (1) involve large quantities of agrochemicals (Castro *et al.* 2012) and (2) lead to soil degradation and consequent reduced production. Using the tools and insights gained through this research, farmers are now reducing

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Figure 2. *Local wildlife scouts learning how to collect samples from a dead plains zebra (*Equus quagga*). Trained members of local communities are able to collect data over a greater spatial and temporal range than could be accomplished by scientists alone.*

inputs and adopting more sustainable practices. Many of the participating farmers drew upon their expertise to become increasingly engaged at different levels of management within CoopeTarrazú, and now serve on the current cooperative board.

The involvement of senior Starbucks agronomists, executives from within the coffee cooperatives, and thought leaders among the farming community was critical to the design and implementation of the program, ensuring local interest and participation over the course of the project. Gaining the support of the cooperative board and coffee farmers was a frequent point of conversation between project leaders and senior community leaders, especially before the program's results yielded valuable management recommendations. Local workshops involving the coffee producers, local agronomists, and cooperative managers identified areas of concern among coffee producers; the research design explicitly addressed these concerns and results were shared with individual producers and cooperatives.

Having producers work alongside citizen scientists allowed both to gain a stronger understanding of the other's perspectives and interests. Both had a vested interest in the livelihoods of the other; the citizen scientists, many of whom were coffee consumers, wanted to be sure the product was sustainably produced while the producers wanted customers to understand what maintaining sustainable rural livelihoods entails. Employees of corporations with coffee in their supply chain (eg Starbucks) became champions of sustainable coffee production with other key stakeholders.

■ Collecting data to improve climate-change policy recommendations in the Western Ghats of India

The Western Ghats (also known as the Sahyadris), a mountain range along the western coast of India, are considered to be an important biodiversity "hotspot". Despite covering only 5% of India's landmass, the Western Ghats support nearly 27% of the country's plant species but are also home to the highest human population density of any global biodiversity hotspot, including a large rural population whose livelihoods are primarily dependent on forest products. Only 23% of the original forested vegetation in the Western Ghats remains because of continuing habitat degradation, which threatens both biodiversity and the livelihoods of the region's people.

To detect changes in forest cover and develop management plans to mitigate any negative effects of these changes, Earthwatch worked with the Indian Institute of Science (IISc) to initiate an intensive forest monitoring and citizen-science program that engaged participants through an educational curriculum about climate change, its impacts, and ways to mitigate its effects (Barker *et al.* 2011). In 2007, a network of 12 permanent 1-hectare sample plots was created in evergreen and deciduous forests near the town of Sirsi, in the district of Uttara Kannada. Teams of 12 citizen scientists, primarily employees of HSBC India, each visited the site for 12 days to assist with field plot establishment and enumeration of trees (WebFigure 1). In total, more than 350 volunteers contributed to field research by helping to map all trees > 1.6 cm diameter at breast height within each plot and measuring their diameter. Soil carbon and leaf litter fall were also recorded.

The data collected so far have been used by IISc in the preparation of a case study for India's Second National Communication to the United Nations Framework Convention on Climate Change (Ministry of Environment and Forests 2012). This document contained an analysis of the non-timber forest products (NTFPs, including foodstuffs such as fruits or species used in medicines, green manures, and fencing) present in the permanent sample plots. Up to 60% of tree species and 40% of all stems were classed as NTFPs. An IISc-based appraisal of NTFP use by rural communities showed that 10–47% of households in forest-dependent villages regularly collect NTFPs.

Climate models indicate that forest cover type in Uttara Kannada is likely to change in the coming century, affecting rural community livelihoods. Management recommendations resulting from these studies include promotion of sustainable biomass extraction and grazing practices, livelihood diversification (eg a shift toward agroforestry), and promotion of reforestation/afforestation programs that incorporate NTFP-yielding species. This example demonstrates how data collected by citizen scientists can contribute to the formulation of high-level policy documents as well as to local management planning.

There was initial apprehension that affluent urbanites would see little value in participating in field research in rural forests. This concern proved to be unfounded; HSBC employees expressed high levels of interest in returning to help collect more data. One weakness of the program, identified by IISc and project staff, was a lack of direct contribution to the priorities listed by local communities; subsequent support to help establish both a medicinal plant nursery and a weather station improved the relationship with local communities. The contribution of the program to local livelihoods in addition to larger scale policies has been a strong feedback mechanism that has greatly increased local support for the program.

Several modifications to citizen-science protocols were required before the IISc science team deemed them satisfactory in terms of their data collection standards. Frequent data validation checks at the beginning of the program were essential, but once it became clear that quality data were being collected by the volunteers, the science team enthusiastically supported citizen science as a means of collecting data of value to science, managers, and corporate interests.

Conclusions

Successful international citizen-science programs that incorporate both local and foreign participants in conducting research, learning about science, and understanding the connections between new knowledge, conservation action, and policy can be designed and directed by local or international organizations. These collaborative programs can often lead to successful science, policy, and management planning (see Crabbe [2012] for an example in the marine environment).

Tangible, short-term success at the community level, as well as large-scale impacts, reinforces the perceived value of field research and experiential learning. Embedding local knowledge into a program from the start provides local context for ecological investigations, fosters local support, and – perhaps most importantly – yields a more complete understanding of local issues and solutions. The combined effect of these activities garners support and involvement from local scientists and members of the local community that translates into the development of successful, community-supported management strategies.

Initial skepticism with respect to the integration of international and local participants on the same research teams was generally unfounded. Projects that brought together groups both socially and in the field were often the most rewarding for participants.

Members of local communities were also skeptical about the value of working with scientists and volunteers. Historically, scientists have intervened in and provided solutions to environmental problems that are frequently at odds with commonly held beliefs and practices. The inclusion of local community members in the research teams and the hiring of community members to provide logistical assistance helps to build trust and leads to cultural sharing and acceptance of scientific outcomes and recommendations.

Figure 3. *Coffee producers from the Tarrazú region of Costa Rica assessing the quality of coffee; this was the first time that many of the producers had ever tasted coffee brewed from beans they grew. The results were linked to data collected by the producers and other volunteers to test how different management practices affected coffee yield and quality.*

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