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Citizen Science as a Tool for Biodiversity Monitoring

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Citizen Science as a Monitoring Tool

Monitoring to assess spatial and temporal trends in biological diversity is increasingly important as human populations and resource use expands. Most monitoring is carried out by government agencies charged with managing natural resources and by non-governmental organizations (NGOs) with missions to conserve biodiversity (e.g., Partners In Flight). Citizen Science is a venue through which volunteers participate in research, often through data collection over a variety of temporal and spatial scales. Citizen Science operates on the principle that nature enthusiasts of all ages and skill levels can make important, reliable contributions. Citizen Science can be structured to span a range of non-competing goals, from informal public education (i.e., emphasis on "citizen") to hypothesis-driven research (i.e., emphasis on "science"). As a tool to collect biodiversity data, Citizen Science is a particularly powerful way to monitor across broad geographic and temporal scales. Using Citizen Science for biodiversity monitoring harbors the potential to change public attitudes about science, the environment, and conservation, as active participation in monitoring is an informal education experience. Citizen Science permits the monitoring to be integrated into hypothesis-driven research, promoting an understanding and appreciation of the scientific method and the nature of scientific inquiry (Bonney 2004, Krasny and Bonney 2005, Bonney and Dhondt 1997, Trumbull et al. 2000, Evans et al. 2003, Brossard et al. in press, Trumbull et al. in press). The experience can also promote environmental awareness and an interest in responsible stewardship of biological systems. In

this paper, we focus on monitoring avian species, yet the tool we describe can be used for any type of biodiversity monitoring.

Key components of Citizen Science Monitoring

The goals of Citizen Science projects vary, but Citizen Science is a flexible tool that can be adapted to various purposes and operating environments (Table 1). The Cornell Lab of Ornithology (CLO) has a number of successful Citizen Science projects (Tables 2). An examination of their features can be used to design new monitoring programs in the Citizen Science paradigm.

Establishing Goals - As with any monitoring program, goals and objectives must be clearly formulated prior to initiating monitoring. Yoccoz et al. (2001) outline 3 basic questions that must receive adequate answers before monitoring begins: (1) Why monitor? (2) What should be monitored? And (3) How should monitoring be carried out? Usually monitoring objectives are to (a) identify the system state and (b) provide information on system response to management actions (Yoccoz et al. 2001). If the answer to "why monitor" is tightly linked to assessing management policies or informing management decisions, then monitoring should be integrated with adaptive management (Walters 1986). With a clear answer to "Why monitor," it becomes easier to determine what quantitative variable(s) to monitor and according to what sampling design. After deciding what to monitor, the next step is to determine how to carry out the monitoring and whether a Citizen Science approach can accomplish the tasks. There may be some limitations on the types of variables volunteers can monitor (e.g., abundance or distribution of species is easier to collect than detailed demographic data or behavioral data). The use of multiple volunteers, unequal and non-random sampling over space and time, and inherent variation in detectibility are root sources of bias. To minimize detection error and observer error, researchers can explicitly estimate detection probability for survey methods and use indices that incorporate (or methods that standardize) observer effort.

Identifying Target Communities for recruiting participants – Drawing upon existing community organizations is an ideal way to create a new network of monitoring volunteers. In the United States, affiliation with formal civic or social groups is on the decline (Putnam 2000), which may hinder recruitment efforts. Table 3 summarizes CLO's successful recruiting targets.

Recruiting and Marketing Strategies – Once target communities are identified, many strategies can be followed, ranging from relying on word-of-mouth to paid advertisements in all forms of media. CLO has had success with direct mail campaigns, invitations to existing email lists, on-line announcements (blogs, traditional web sites, online news), promotional pamphlets, spokespersons, and/or formal presentations at museums, nature centers, zoos, and festivals. CLO has also recruited from product–based tie-ins (e.g., bird feeders), agreements with clubs/associations (like recruiting from the North American Bluebird Society), press releases to all forms of media (newspapers, magazines, newsletters, radio, TV), particularly during related events (e.g., Earth Day) or in declaring our own events (e.g. Great Backyard Bird Count). A cost-effective and successful promotional method has been writing articles for popular magazines (e.g. Birds and Blooms) .

Training Participants – Once enrolled in the monitoring initiative, volunteers may require varying levels of training, depending on their previous experience and the monitoring protocol. Training can be very important to improving or ensuring data quality. Training media can be written (printed or on-line) tutorials, video, animation, or person-to-person.

Retention - For financial, logistical, and scientific data quality considerations, retaining volunteers in Citizen Science projects is important. Volunteer retention is higher when they receive feedback, when their feedback is respected, and when they are part of a community.

Feedback to Participants – The most important factor to sustaining a monitoring project that relies on Citizen Science is to provide prompt feedback on the status of the monitoring efforts. Feedback can be as simple as a written or verbal acknowledgement (e.g., "Thanks for participating") or as sophisticated as online dynamic queries of the data. Other types of feedback include communicating how each participant fits into the whole project, newsletters featuring individual contributions of selected participants (e.g., drawings by children), and static online data presentations, such as tables, charts, and maps of data features.

Feedback from participants – Although participants serve the primary function of obtaining and reporting observational data, many will seek involvement in other aspects of monitoring. Most frequently, participants may have input into field protocols. Occasionally participants may have feedback into other areas, such as the formation of monitoring objectives or recruitment and marketing strategies, especially if these topics

are similar to their own professions. Not all feedback may be useful or result in changes to the Citizen Science project, but all feedback should be thoughtfully acknowledged.

Creating a Community among Participants – Demonstrating how individual efforts fit into a larger framework and providing venues for participants to interact is important to ensuring volunteers feel valued and value the goals of the project. CLO Citizen Science projects host email listservs and online discussion boards where participants can discuss the project. For example, during the height of the breeding season, the bluebird-L listserv receives approximately 15-20 emails per day.

Data Collection and Organization – There are many options for gathering, organizing, and storing data gathered by participants in Citizen Science. The simplest option for gathering data is to use paper forms. Paper forms are generally easy for participants to use but labor-intensive for project staff who must manually transcribe and enter data into a database or spreadsheet (e.g., Microsoft Excel, Microsoft Access, FileMaker Pro). Manually processing written paper forms can be an acceptable option for small-scale monitoring or pilot projects, but prohibitive for large-scale monitoring efforts due to the expense of data entry.

Optical mark recognition (OMR) technology, such as that used for standardized testing in public schools, uses paper form containing "bubbles" filled in with a pencil. OMR forms can be automatically converted to digital data, but often manually editing is required due to high error rates in the scanning process. Some modern OMR software allows custom forms to be duplicated by photocopying or distributed electronically and printed by participants. One drawback of OMR technology is the limited density of information that can be put onto a single form.

Optical character recognition (OCR) technology allows participants to carefully print numbers and characters in demarcated areas on paper forms. As forms are scanned, character recognition software converts the numbers and characters into digital data. Like the OMR technology OCR software allows custom forms to be photocopied and electronically distributed. Participants will probably find OCR technology easier to use than OMR.

An option that can eliminate paper forms is the use of Adobe PDF forms and version 7.0 or later of Adobe Reader. The free Adobe Reader application allows PDF forms created in Adobe Acrobat Professional (v7.0) to be keyboarded in and their digital content emailed to a project or saved on disk. Adobe tools allow the data submitted from PDF forms to be compiled

into a simple spreadsheet document. This solution is free for participants and relatively inexpensive for those running the project. However, participants need Adobe Reader version 7.0, which is not in widespread use as of this writing. This approach might be ideal in a situation where a project could distribute CDs containing the free Adobe Reader software along with other material for project participants.

A simple on-line solution to data collection is to use on-line survey software (or purchase an online survey service such as www.keysurvey.com) to produce on-line data collection forms by treating the forms as surveys. Online data validation may be limited using this approach. It will also be difficult to reliably match data submitted by the same user across time since survey software does not typically utilize the concept of user login and instead tends to treat users as anonymous.

Custom-written on-line data entry is another option that Citizen Science projects might utilize to gather information. Custom web applications can offer forms that can be completed by any user with a web browser and an internet connection. Data submitted via on-line entry can by validated as the participant enters it. Furthermore, data submitted on-line can be saved directly to a database without any oversight by project staff.

Dissemination of Results – Part of a monitoring program's objectives should be to inform management decisions and perhaps to test hypotheses. Thus, the final success of a project can be judged by how well the results have been disseminated. CLO Citizen Science projects have produced numerous peer-reviewed publications, handbooks for land managers, theses, and government reports (Appendix 1). In addition, CLO also publishes two periodicals, *BirdScope* (a quarterly newsletter) and *Living Bird* (a quarterly glossy magazine) with circulation of tens of thousands, which have brought hundreds of articles about project results to participants over the years.

Other examples – While there are many organizations operating Citizen Science projects, we highlight here a few organizations each operating several citizen science projects. Like CLO, Bird Studies Canada (www.bsc-eoc.org) and the British Trust for Ornithology (www.bto.org) operate many bird-related Citizen Sience projects. NatureWatch (www.naturewatch.ca) is a cooperative between Nature Canada, University of Guelph, and Environment Canada's Ecological Monitoring and Assessment Network. NatureWatch has volunteer monitoring networks for amphibians (FrogWatch), to promote awareness of soil ecology (WormWatch), and

pheonology projects related to climate change (PlantWatch and IceWatch). Journey North (www.learner.org/jnorth/) focuses on the involvement of students in monitoring wildlife migration and phenology across a range of taxonomic groups. MonarchWatch (www.monarchwatch.org) is a gateway to several different types of monarch butterfly monitoring projects.

Limitations of Citizen Science – Poorly planned monitoring projects that collect data simply for the sake of "gathering more information" will come under criticism (Yoccoz et al. 2001). Yet, data can often be made useful *a posteri*. Even anecdotal reports can be of critical importance. For example, Krajick (2003) reported in Science that incidental observations by birders on both coasts of North America were responsible for helping identify causes of declines in Ivory Gulls (*Pagophila eburnea*). Nevertheless, a monitoring program with well-developed goals will be more useful and less risky than one with simple goal of collecting more information. Furthermore, the impetus to properly plan monitoring has a greater imperative when the selected method is a Citizen Science because it is necessary to counter the common assumption that volunteer networks are only useful for informal education. Furthermore, the validity of data and subsequent conclusions are likely to be questioned when monitoring is carried out via Citizen Science. With any volunteer-based project, issues of observer bias and error must be taken into account.

Although blanket criticisms of reliance on volunteers as a methodological tool are unfounded, there are true limitations on the types of variables and degree of precision that volunteers can collect. These limitations are best countered by exploiting the benefits in the trade-off of large-scale, coarse (low precision) data collected via Citizen Science with small-scale, high precision data collected by traditional means.

CLO has developed Citizen Science into a credible discipline, as reported in *Science* (Bhattacharjee 2005). Citizen Science permits researchers to match their field methods to the scale of their questions, which can encompass a larger temporal and spatial framework than traditional science.

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program at the Cornell Lab of Ornithology. The Cornell Lab of Ornithology is a nonprofit membership institution whose mission is to interpret and conserve the earth's biological diversity through research, education, and citizen science focused on birds. CLO programs work with citizen scientists, government and non-government agencies across North America and beyond.

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Table 1. Citizen Science projects can be adapted to a variety of needs because they are flexible and vary along several dimensions.

Dimension	**Value**
Geographic scope	local ⇨ regional ⇨ national ⇨ continental ⇨ global
Temporal scope	snapshot (days) ⇨ seasonal (months) ⇨ ongoing, continuous
Skill level of participants	basic skills ⇨ amateur (enthusiast) ⇨ professional
Protocols and methods	simple (e.g., single step, single variable) ⇨ complex (e.g., collection of multiple variables or hierarchically structured data)
Financial	free; monetary contribution required to participate
Participant time commitment	opportunistic/incidental ⇨ regimented, but one period only ⇨ regimented, repeated short periods ⇨ regimented, repeated and long periods
Technology	paper forms ⇨ electronic data forms ⇨ online data submission (WWW)
Educational objective	environmental awareness; science literacy
Monitoring objective (population)	occurrence (presence data) ⇨ distribution (presence and absence data) ⇨ index of abundance ⇨ true abundance; local density
Monitoring objective (demographic)	fecundity; juvenile survival; adult survival; dispersal; breeding behavior

Table 2. Examples of Citizen Science Networks

Volunteer Monitoring Networks and Citizen Science Projects at Cornell Lab of Ornithology

	Project FeederWatch[1]	**Great Backyard Bird Count**	**eBird (aVerAves)**[2]
URL	www.birds.cornell.edu/pfw/	www.birdsource.org/gbbc/	www.ebird.org/aVerAves/
Geographic scope	national (Canada, United States)	national (Canada, United States)	continental (North America)
Temporal scope	Seasonal	annual snapshot	continuous, ongoing
Participant skill level	basic bird identification skills	basic to advanced bird identification skills	basic to advanced bird identification skills
Protocols and methods	relatively simple	simple	supports multiple protocols; simple to complex
Financial	participation fee	free	free
Participant time commitment	parts of two consecutive days as often as every week during winter	5 minutes – 4 days/year	determined by participant
Technology	scannable paper forms; WWW	WWW	WWW
Objective	distribution, index of abundance	distribution	abundance; distribution

Table 2. Continued

	The Birdhouse Network	**House Finch Disease Survey**	**House Finch Nest Survey**
URL	www.birds.cornell.edu/birdhouse/	www.birds.cornell.edu/hofi/	www.birds.cornell.edu/hofins/
Geographic scope	national (United States, Canada)	national (United States, Canada)	national (United States, Canada)
Temporal scope	seasonal	continuous, ongoing	seasonal
Participant skill level	nest monitoring skill required	bird identification skills	nest finding, nest monitoring skill required
Protocols and methods	beyond simple, but not complex	simple	beyond simple, but not complex
Financial	participation fee	free	free
Participant time commitment	at least several days annually	determined by participant	at least several days annually
Technology	WWW	paper forms; WWW	paper forms
Objective	demographic (fecundity, juvenile survival); breeding behavior	distribution, index of abundance of diseased individuals	demographic

Table 2. Continued

	Golden-winged Warbler Atlas Project	**Urban Bird Studies[2,3]**	**BFL**
URL	www.birds.cornell.edu/gowap/	www.urbanbirds.org	www.birds.cornell.edu/bfl
Geographic scope	regional	international	national (United States, Canada)
Temporal scope	seasonal	continuous, ongoing	seasonal
Participant skill level	advanced	basic to advanced	amateur/professional ornithologist
Protocols and methods	complex	relatively simple	complex
Financial	free	free	free
Participant time commitment	several days annually	determined by participant	at least several days annually
Technology	paper forms	paper forms; WWW	paper forms; WWW
Objective	distribution; index of abundance	education; environmental awareness; abundance; distribution; index of abundance; breeding behavior	index of abundance

[1] Project materials in French and English.

[2] Project materials in Spanish and English.

[3] Urban Bird Studies is a suite of five projects targeted for urban landscapes: Birds in the City, PigeonWatch, Crows Counts, Dove Detectives, and Gulls Galore.

Table 3. Summary of target audiences for recruiting and partnerships.

Children:	After-school programs
	School clubs
	Scouts, boys/girls clubs, etc.
	Schools; in-class programs
Adults:	Civic groups (Rotary, Kiwanis, etc.)
	Neighborhoods, neighborhood organizations, villages
	Members of non-profit conservation organizations (e.g., Audubon)
	Members of non-profit hobby organizations (e.g., garden, birding, etc.)
	Customers of particular retail stores (e.g., Wild Birds Unlimited)
	Retirees
	Participants in other Citizen Science projects

Appendix 1

Articles about the Citizen Science Process by CLO Staff

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