

## The critical role that citizen scientists can play in identifying adaptation strategies to climate change

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Climate change is a topic that is very much under discussion these days. While some still question its reality, for many who believe such change is occurring, the focus has shifted to figuring out what can be done to adapt to its probable effects. Developing such strategies and tools can be accomplished using predictive models and requires massive quantities of data. People in all walks of life, scientists or not, can be valuable partners in collecting these data.

Human activities are strongly implicated in the changes that researchers are observing globally in climate patterns and land conditions. A recent report by the United Nations Intergovernmental Panel on Climate Change (IPCC 2007) states with “very high confidence” (meaning more than 9 out of 10 chances of occurring) that increasing levels of greenhouse gases, associated with fossil fuel combustion and land use changes since the mid-1800s, have produced a net warming in the Earth’s atmosphere. Indeed, projections suggest a warming of the global average temperature of 2 to 6 °C over the next century. Additionally, significant changes to biological systems have been observed on all continents in the past few decades that have been strongly linked to anthropogenic climate change (Rosenzweig et al. 2008). These analyses reflects a consensus within the scientific community regarding the role of greenhouse gases in observed global warming.

In order to develop adaptation strategies, we need to know as much as possible about how such changes in global temperatures might affect local environments. The need may be particularly acute in those areas of the globe most prone to desertification, defined by the UN Convention to Combat Desertification as “land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors including climatic variations and human activities.” This is because climate change is a potentially strong driver of desertification: directly, through increasingly severe droughts caused by higher temperatures; and indirectly, through inappropriate land uses caused as scarce dryland resources like water become even scarcer. Not only that, on an international policy level, it is increasingly recognized that strategies undertaken to mitigate desertification are likely to help populations adapt to climate change, and vice versa (ENB 2007a, 2007b).

In our work with Cooperative Extension and similar outreach organizations, our roles are to educate the public about our natural resources and the challenges that currently face natural resources management. Our experience has been that frequently, facts about the current state of our natural resources and climate system and anticipated changes for the future are overwhelming to our constituents. We often encounter resistance to these facts or strong emotions including depression or despair. Another common reaction among extension program participants is dissatisfaction with programs that educate without providing guidance towards action and empowerment. One of the questions we get most often is, “So, what can we do?”

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The need to identify adaptation strategies for a changing climate and environment is immediate. Adaptation means taking steps to lessen our vulnerability to climate change. Examples include finding ways to reduce water use in response to anticipated increasingly dry conditions and clearing vegetation from homes in anticipation of increased wildfire risk. Such strategies can perform two very important functions: 1) to move society in a positive direction in response to environmental conditions for which humans are mainly responsible; and 2) to provide concrete, hands-on actions that individuals can undertake, thereby fostering feelings of involvement and engagement in helping address these problems.

The contribution such individuals can make is very real. To identify adaptation strategies, we first need to better understand the complex connections between climate variability and environmental processes at both local and global scales. This is no trivial task. Only since the mid-1950s, with the development of complex systems science, chaos theory, and high-powered computers, have we had the theory and the number-crunching power we need to begin to understand and tease out these connections. Such analyses require massively diverse and distributed collections of data – generally, the greater the number of data points, the broader the spatial scale, and the longer the period of record, the more accurate and valid the results of such analyses can be.

One very workable strategy for amassing the quantity and diversity of data necessary to develop adaptation strategies is to involve citizen scientists. Citizen science is a relatively new concept, defined as “projects or ongoing program of scientific work in which individual volunteers or networks of volunteers, many of whom may have no specific scientific training, perform or manage research-related tasks such as observation, measurement or computation”<sup>3</sup>. One very clear benefit of involving citizen scientists in collecting data for research or management projects is that it greatly increases the scale of projects that can be undertaken due to the amount and spatial coverage of data that can be collected. The benefits go both ways, too; citizens who get involved in such projects improve their science literacy, develop increased understanding of environmental issues that affect them directly, and, in the best cases, become motivated to take direct, positive personal action (Wilderman et al. 2004).

Many very successful examples of citizen science projects exist within the United States and around the globe, some of which have been in existence for decades. For example, the NestWatch program (<http://www.nestwatch.org>), based out of the Cornell Laboratory of Ornithology, enlists individuals to monitor active bird nests. The data are used to disentangle the relationships between declines in fledgling survival, reproductive success, and species numbers, changing climate conditions, and other factors such as land use change (Evans et al. 2005). Scientists are currently analyzing these data to determine whether birds are breeding earlier in the year in response to warmer temperatures. In another project, data amassed through the North American Breeding Bird Survey (<http://www.pwrc.usgs.gov/BBS/>), collected nearly entirely by volunteers since the 1880s, have also been used to quantify birds’ responses to already changing climate conditions. For example, Winkler et al. (2002) found that tree swallows are laying their eggs approximately nine days earlier than they did 30 years ago, apparently in response to warmer temperatures. Breeding Bird Survey data are also being used to predict species’ response to future conditions (e.g., Peterson 2003).

Indeed, records of phenological events provide an excellent means of assessing climate change. Phenology refers to periodically recurring biological phenomena, like the timing of birds’ nesting or

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<sup>3</sup> from the article "Citizen science," published online in *Wikipedia, The Free Encyclopedia*. See: [http://en.wikipedia.org/w/index.php?title=Citizen\\_science&oldid=217951162](http://en.wikipedia.org/w/index.php?title=Citizen_science&oldid=217951162) (accessed April 24, 2008).

migration, or when plants leaf out, burst into bud, or flower. The timing of these events is strongly influenced by temperature, moisture, and photoperiod. For example, in middle and higher latitudes around the globe, leaf-out and flowering have been documented to occur days and even weeks earlier than in previous decades, and these changes have been directly linked to warmer spring temperatures (e.g., Badeck et al. 2004).

The recently established USA National Phenology Network (<http://www.usanpn.org>) and the associated Project Budburst (<http://www.budburst.org>) are collaborative research programs designed to engage both professional and citizen scientists—students, stewards of public and private lands, amateur naturalists, gardeners, and other outdoor enthusiasts—to help compile data on phenological responses of plants and animals to weather and climate. Observations made by individuals will be used by scientists to learn about the responses of individual plant species to climatic variation locally, regionally, and nationally, and to detect longer-term impacts of climate change by comparing the current results with historical data. Many insights into plant and animal response to changing climate and landscape conditions have already been gleaned from such volunteer-collected datasets (e.g., Ledneva et al. 2004, Crimmins et al. 2008; see sidebar, previous page).

These examples show how people from all backgrounds with an interest in their surroundings, by honing their own skills of observation, can play a fundamental role in answering gnawing questions about how our environment will respond to climate change. The scope, spatial extent, and consistency of the datasets collected by citizen scientists are crucial to the ability of scientists to develop accurate models, assessments and predictions regarding climate–environment interactions. Indeed, datasets with these characteristics are rarely accomplished by scientists or government programs alone, as the costs and efforts required are often prohibitively expensive. Such rich datasets can also play a critical role in identifying adaptation strategies, providing scientists with the data they need to make predictions about future conditions.

### **Addendum: The goldmine in legacy datasets**

“Legacy datasets” are sets of observations of all types collected by individuals who may or may not have a formal science background. Often these datasets were collected out of sheer curiosity, without clear scientific questions or the intent that they would someday be formally analyzed. However, they can be quite thorough and sometimes very long in record, even spanning multiple decades. When interpreted with care, they can provide a valuable window into the past and strengthen formal monitoring programs.

One remarkable legacy dataset that has been used in formal scientific analyses is the record of plant species in bloom along the Finger Rock trail in the Catalina Mountains north of Tucson, Arizona, collected by Dave Bertelsen. The data represent an enormous effort. Covering a major elevation gradient, a 20-year period, and a comprehensive record of all species in bloom, they contribute invaluable information at a scale very few individuals would ever attempt. Using this dataset, scientists demonstrated clear patterns in the seasonality of alpha diversity (species richness) of species in bloom across an elevation gradient (Crimmins et al. 2008). This diversity was strongly influenced by precipitation at lower elevations and by temperature at upper elevations. In addition, over the course of the study, average summer temperature showed an upward trend, as did the number of species in bloom in summer at the highest elevations.

These findings contribute to a significant gap in phenological research and knowledge—that is, along elevation gradients. We strongly agree with authors of similar studies: such datasets are worth the effort to manipulate and analyze, because they can provide valuable long-term records for regions previously under-sampled by scientists (Ledneva et al. 2004).

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