



Whitetail Deer
Photo Credit: Robert Costello

CITIZEN SCIENCE AND BIOPHILIC CITIES, THE GREAT EXPERIMENT

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Not so long ago ecologists looked upon urban areas as empty matrices, sterile wastelands isolated from natural wildlife habitat. Wildlife communities were considered to not have adequate habitat, refuges, or connecting corridors allowing animal movement around the urban cityscape. Only a small variety of animals inhabited our cities and their bio-depauperate parks, and quite a few of those animals were invasive species--Norway rats, house sparrows, starlings, domestic pigeons, house mice, Asian tiger mosquitoes, marmorated stink bugs. Parks were planted with trees originating from different continents--ginkgos, Norway maples, London plane trees, crepe myrtle. These unnatural habitats were useless to

most wildlife. Have you ever seen a crepe myrtle in bloom abuzz with North American bumble bees?

But life adapts and evolves, native species are returning to land claimed by humans, cities are becoming full of nature. With a bit of help from urban planners and species evolution, natureful cities create opportunities for native communities of organisms to recolonize the urban landscape and reestablish breeding populations. The return of nature to cities is visible, but the overall effect on wildlife and people remains unknown. Can cities provide much-needed habitat to declining species and help

reverse their spiral toward extirpation, or worse, extinction? Can city dwellers accept living with recolonizing fauna such as carnivores? How about large carnivores?! And what about the zoonotic diseases animals carry that can spill over to humans--rabies, hantavirus, lyme disease, Nipah, Ebola? To answer these questions requires long term monitoring of wildlife communities across a variety of urban landscapes to measure the effects of greening urban spaces.

This is where citizen science has the potential to be one of the most potent practices for measuring how biodiversity returns to urban areas and the effects on humans. We make this claim from our experiences as wildlife ecologists and educators working on a variety of citizen science projects across many different landscapes, from urban to wild. We imagined and built eMammal, the largest citizen science project for monitoring mammals. The geographic scale of eMammal required recruiting hundreds of volunteers and students and we used the data collected to study the ecological implications of human activities and our pets on wildlife. We have also investigated the personal gains citizen scientists experienced from their participation. From our research and experience we see citizen scientists as valuable partners in our efforts to understand uniquely urban wildlife communities. These communities are new suites of species inhabiting disturbed and reconstructed landscapes and the trophic roles each plays in less disturbed areas may not apply to urban environments. We need to acquire new knowledge about the interconnectedness of species in urban environments and we need citizen scientists in those areas to participate in advancing our understanding of how nature works

where so many human beings live.

Innately connected to the natural world, human health and well-being depend on healthy environments and the organisms inhabiting them. Monitoring the environment and correlating changes in plant and animal distribution and abundance to human activities and abiotic factors, such as land uses and climate change effects, is the only way we can know which strategies for making urban areas habitable for wildlife are working. Will biophilic cities create wildlife refuges and endemic communities of organisms, and will this have a positive effect on human health and well-being?

The commercial production chain of plants for urban, suburban and exurban landscapes has ecologically homogenized green spaces to the extent that planted lawns and parks in Phoenix, Arizona, Boston, Massachusetts and Daejeon (Korea) all share the same trees, shrubs and flowering plants, creating more of the same will not provide the most suitable habitats for endemic species. What would be the effects on faunal biodiversity should this practice change and a more mindful reconstruction of native habitats across urban landscapes became the standard? Answering this question requires analyses at different scales, from micro to macro, and collecting the data needed to inform us of the effects of our practices towards promoting and sustaining biodiversity is far greater than the capacity of a relatively limited number of ecologists. Documenting the flora and fauna in an urban landscape is the first giant step towards measuring changes over time and understanding urban wildlife habitat requirements.

The scale of documenting the biodiversity of even one urban landscape might seem daunting; however, there are ways to achieve this. First, programs are already in place for monitoring trees such as Tree Steward and Casey Trees in the Washington DC region. Monitoring birds, has been a popular activity for more than a century and there have been steady gains in understanding migratory species movements and bird reproductive success. In the U.S., the Christmas Bird Count, Great Backyard Bird Count, Neighborhood NestWatch, Feeder-Watch and eBird are a few of the projects contributing to monitoring avian communities. However, monitoring mammals requires a different strategy as most species are nocturnal and cryptic and difficult to observe with any regularity. eMammal and other projects working in urban spaces are using camera traps to capture the diversity, distribution and relative abundance of mammals. Camera traps utilize sensors to remotely detect animals as small as chipmunks and automatically photograph them. Tied to tree trunks, camera traps can remain vigilant for weeks and months at a time recording all the warm blooded animals and ground birds in motion within the field of view.

eMammal has successfully recruited hundreds of citizen scientists to deploy these devices at thousands of locations and assessed the effects of hunting, hiking, domestic dogs and cats and development on wildlife communities. As costs have dropped, these trail cameras have become so popular with the public it is estimated millions are sold each year in the U.S. So the tools, programs and method for monitoring birds and mammals are now within reach, yet this important and beloved fauna merely represents a fraction of biodiversity.

How can the remaining be documented? One method is to intensively scour a park with citizen scientists and a few experts over a short period of time to collect and document plants, fungi and invertebrates and vertebrates. Experts sort and identify the collected specimens. In celebration of the 100th anniversary of the National Park Service in 2016, hundreds of these bioblitzes took place all across the country. This is a remarkable achievement considering the first National Park Service bioblitz took place in Rock Creek Park in 2007. Rock Creek Park is a jewel for biodiversity in downtown Washington, D.C. and many of the scientists that participated were from the Smithsonian Institution. Yet not every city has a Smithsonian Institution and enough taxonomic specialists to cover the biodiversity of a single park. Although bioblitzes document species, it should be noted very little science has emerged from these activities as they tend not to be driven by research questions. Other methods are necessary. One approach that gets around having experts identify species is to barcode specimens.

DNA barcoding is a high tech, yet inexpensive way to identify species. For most animals such as arthropods, sequencing a single gene from the mitochondria of an organism is enough information to identify a species. Similarly, plants can be identified at the species level from the sequences of a few genes. To identify a species from a DNA barcode, anyone can query Genbank, an online DNA sequence database, to find a matching sequence that is already identified at the species level. Thus matching barcodes does not require a taxonomic expert to identify species. Also, the equipment required to extract and prepare DNA is minimal, and DNA sequencing centers have capacity to manage high throughput barcoding.



At the grassroots level, DIY biolabs already exist that are capable, such as Genspace, which is set on barcoding the plants of Alaska. Even some high schools have barcoding programs. Consequently, citizen scientists could barcode Washington D.C. or any other city and maintain a database on biodiversity for perpetuity, resample at intervals and measure changes in biodiversity, species abundance and distributions.

Of course, there will be DNA barcodes that are not yet in Genbank. According to a recent gap analysis performed by the Global Genome Initiative at the Smithsonian's Natural History Museum, a listing of all known species includes 147,246 described genera, yet there are just 17,293 barcode flags on Genbank. Many new barcodes will not have matches, either because a species known to science has not been documented with DNA sequence data, or the species

that was collected is new to science. Both of these cases will undoubtedly occur with any ambitious barcoding project. It will be exciting for citizen scientists to discover new species right under our noses, and it will be important for them to help build the database in Genbank and detect newly invasive species.

The programs, technology and knowledge for documenting biodiversity at fine scale all exist. But what does participating in such an ambitious enterprise mean for the citizen scientists making observations with binoculars, sorting through camera trap photos, scouring the bushes in search of insects and sampling a tree leaf for DNA barcoding? Could the act of volunteering for science increase feelings of biophilia in urban people? Studies on the human dimensions of citizen science by eMammal and other projects provide a glimpse into the benefits derived

by participants. Several studies have shown that spending time in natural environments has a number of physiological and psychological benefits for people. So what happens when being in the woods is combined with collecting data? One eMammal study we published in 2016 assessed participant experiences and effects on knowledge, skills, attitudes and social networks. The findings show participants take satisfaction from participating in eMammal projects because they felt they were making a contribution; being in the woods was associated with a greater purpose. They also looked forward to seeing the photos of wildlife species that were hard to see in the wild and frequently mentioned discovering a whole new perspective on wildlife.

Without any targeted help from the project team participants showed modest, yet statistically significant gains in their knowledge about wildlife. They quickly became skilled at deploying camera traps as well. Within their social networks, participants were 85% more likely to share information on local wildlife and mammal conservation after volunteering, creating a ripple effect from one to many. Interestingly, there was a correlation between the number of carnivores captured in their camera traps and the degree to which the citizen scientists shared information within their social networks. It is unknown whether it was the opportunity to see and record charismatic carnivores, or simply capturing rarely seen mammals that triggered the behavior.

Collaborations between citizen scientists and a diversity of researchers could transform the way we think about urban environments and our decisions around land use, habitat reconstruction and recolonization by wildlife. On the human dimension

side, it is estimated 1.3-2.3 million citizen scientists participate in biodiversity studies annually in the U.S. and the number is growing. The human resources are available, technology makes unprecedented documentation of biodiversity possible, and more data can be collected with fewer scientists involved. And there are personal rewards for those that participate. Events like the first nesting pair of ravens in Washington D.C. this year, the first in a century, and red-tailed hawks successfully breeding on the National Mall are small, positive signs. The first half of the 21st century is the right time, if not an urgent time, to set the baseline for urban biodiversity, which future generations can build upon to increase human health and well-being through a healthy, biodiverse environment.



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