Crowdsourcing Conservation:

How to Use Community Science to Advance Public and Private Conservation

The Center for
Growth and **Opportunity**
at Utah State University

Crowdsourcing Conservation: How to Use Community Science to Advance Public and Private Conservation

Authors:

Jennifer Morales[a]
Emmy Heywood[b]
Logan Krebs[c]
Micah Safsten[d]

September 2022

Policy Paper

The Center for Growth and Opportunity at Utah State University is a university-based academic research center that explores the scientific foundations of the interaction between individuals, business, and government.

We support research that explores a variety of topics from diverse perspectives. Policy papers are published to stimulate timely discussion on topics of central importance in economic policy and provide more accessible analysis of public policy issues.

The views expressed in this paper are those of the author(s) and do not necessarily reflect the views of the Center for Growth and Opportunity at Utah State University or the views of Utah State University.

a Jennifer Morales is a research manager at the Center for Growth and Opportunity at Utah State University. She studies how public and private institutions can work together to be good stewards of the environment.

b Emmy Heywood is an undergraduate student fellow at the CGO, majoring in Economics.

c Logan Krebs is a former graduate student fellow at the CGO. He completed his Master of Economics degree at Utah State University in 2022.

d Micah Safsten is a former graduate student fellow at the CGO. He recently completed his Master of Economics degree at Utah State University. His undergraduate degree is in Political Science.

The Center for Growth and Opportunity at Utah State University

Contents

Introduction **1**

What is Crowdsourced Conservation? **2**

Case Studies: Internet-enabled Projects and Emerging Technologies **4**

Mobile Phone Applications and Interactive Data 4

Volunteered Geographic Information 6

Artificial Intelligence 7

Biotechnology 8

How Are Crowdsourced Projects Contributing to Better Conservation Outcomes? **9**

Regulatory Hurdles **11**

Non-Regulatory Hurdles **13**

Policy Recommendations **14**

Conclusion **16**

Introduction

America is known for its big conservation projects—setting aside huge swaths of land in public parks and passing legislation like the Clean Air and Clean Water Acts.[1] The first national park in the world was created in the United States, and renowned environmentalists like John Muir, Aldo Leopold, and Theodore Roosevelt have inspired generations of Americans to engage with and protect our outdoor heritage.[2] Current conservation efforts in the US are part of a long and proud tradition.

Large-scale conservation of landscapes and unique geological features formed the initial focus of conservation policy in the United States.[3] Yellowstone was designated as the first National Park in 1872, setting precedent for conservation policy throughout the next century and a half. Since then, the United States has created 63 national parks plus additional protected sites, totaling 84 million acres of protected land, an area larger than all but four states (Alaska, Texas, California, and Montana).[4] While a significant portion of land is protected for conservation, decisions about how to sustainably manage that land and the species that live on it still need to be made. Successful conservation policy also must recognize the interconnectedness of species across public-private boundaries. Those decisions are challenging because it is difficult to collect data on the many different ecosystems and species in the country.

Conservation is a field where data is particularly sparse and often difficult to obtain because of the large geographic range of plants and animals, their remoteness, and their movements. The cost of collecting ecological data is also large, requiring scientists to travel to remote destinations and manually collect observations.[5] But data-driven management is valued by the federal government, which has a mandate to use the "best available scientific information" when making certain conservation decisions.[6] Despite the value policymakers place on conservation data, the federal government has not created a funding and regulatory environment that is capable of fully utilizing the most promising method for collecting this data—crowdsourcing.

Crowdsourcing allows decentralized groups of people to combine their individual efforts into projects that can have large-scale impacts. This policy paper examines the literature on whether crowdsourcing and related participatory science projects can be used to advance conservation efforts, especially those of the federal government. We begin by explaining what crowdsourced conservation is and give a brief overview of where and how it is used in the US. Next, we examine the impact of technological innovation on crowdsourcing through several case studies. Finally, we

1 "Clean Air Act Overview," EPA.gov, November 21, 2018, https://www.epa.gov/clean-air-act-overview/clean-air-act-text; "Summary of the Clean Water Act," EPA.gov, March 29, 2018, https://www.epa.gov/laws-regulations/summary-clean-water-act.

2 Roderick Nash, "The American Invention of National Parks," *American Quarterly* 22, no. 3 (1970): 726–35, https://doi.org/10.2307/2711623.

3 Robert B. Keiter, "Toward a National Conservation Network Act: Transforming Landscape Conservation on the Public Lands into Law," *Harvard Environmental Law Review*, Forthcoming, University of Utah College of Law Research Paper No. 259 (2018), Available at SSRN: https://doi.org/10.2139/ssrn.3171678.

4 Rocío Lower and Rebecca Watson, "How Many National Parks Are There?," National Park Foundation, n.d., https://www.nationalparks.org/connect/blog/how-many-national-parks-are-there.

5 Lynne Caughlan and Karen L. Oakley, "Cost Considerations for Long-Term Ecological Monitoring," *Ecological Indicators* 1, no. 2 (December 2001): 123–34, https://doi.org/10.1016/s1470-160x(01)00015-2.

6 Dennis D. Murphy and Paul S. Weiland, "Guidance on the Use of Best Available Science under the US Endangered Species Act," *Environmental Management* 58, no. 1 (2016): 1–14, https://doi.org/10.1007/s00267-016-0697-z; US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, *Magnuson-Stevens Fishery Conservation and Management Act 2007 Bluebook*, 16 U.S.C. § (2007), https://media.fisheries.noaa.gov/dam-migration/msa-amended-2007.pdf.

provide recommendations to policymakers on how to use crowdsourced projects to achieve the government's conservation goals.

We find that crowdsourcing has potential to be a beneficial bottom-up conservation tool, made increasingly useful by leveraging emerging technologies. Two key benefits of technology-enabled crowdsourcing are data collection at a lower cost and network building through the use of volunteers. The federal government can use crowdsourcing to promote conservation by partnering with universities and private conservation actors to determine the most important long-term conservation data needs and by making all data from federal crowdsourced projects open access.

What is Crowdsourced Conservation?

Crowdsourced science is a subset of citizen science, which engages public volunteers in the scientific process by having them carry out tasks normally performed by professionals. These tasks can include data collection, classification of data or images, or other hands-on activities that advance a scientific goal. Citizen science is unique in that it can be carried out by non-experts. This widens the pool of individuals who can engage in scientific projects and often lowers the cost of collecting the data necessary for scientific studies.

While the boundary between crowdsourcing and other types of citizen science is blurry, crowdsourcing normally includes an open call for contributions from a large, decentralized "crowd" of volunteers.[7] Crowdsourcing is a process in which problem-solving or data production responsibilities are distributed across a large group of volunteers. There is a specific task or goal to be accomplished, and volunteers may have varying motivations for joining projects. Often, the internet is used to recruit and facilitate collaboration between volunteers.[8]

Crowdsourced science taps into the creative energy of communities, taking a collaborative approach to conservation by pooling efforts and expertise. New York's Billion Oyster Project is one example of a successful private citizen science project. Started in 2014 with a goal to restore one billion oysters in New York Harbor by 2035, Billion Oyster Project has recruited a network of 10,000 volunteers, 6,000 students, 75 restaurants, and 100 NYC schools. These volunteers recycle oyster shells, install oyster reefs, monitor oyster health and water quality, contribute to research, and support K–12 STEM curriculum as well as career and technical education (CTE) programs.[9]

Participatory conservation projects like the Billion Oyster Project have a long history in the United States.[10] Environmental data collection by volunteers is probably the most common type of participatory conservation project. Volunteer data collection began as early as the late 1800's, through the National Weather Service's Cooperative Observer Program (COOP), which is still

7 Andrea Wiggins and Kevin Crowston, "From Conservation to Crowdsourcing: A Typology of Citizen Science," in *44th Hawaii International Conference on System Sciences*, (44th Hawaii International Conference on System Sciences, 2011), 1–10, https://doi.org/10.1109/HICSS.2011.207.

8 Daren C. Brabham, *Crowdsourcing*, MIT Press Essential Knowledge Series (Cambridge, MA: The MIT Press, 2013).

9 "OUR STORY," Billion Oyster Project, n.d., https://www.billionoysterproject.org/our-story.

10 Kristine F. Stepenuck and Linda T. Green, "Individual- and Community-Level Impacts of Volunteer Environmental Monitoring: A Synthesis of Peer-Reviewed Literature," *Ecology and Society* 20, no. 3 (2015), https://www.jstor.org/stable/26270236.

running today.[11] COOP gathers records of meteorological observations from farmers and other volunteers, helping to establish baseline historical climate conditions for much of the country.

Over the past two decades, researchers, educators, and government officials have increasingly taken advantage of technologies that allow more people to participate in citizen science. Disciplines that utilize crowdsourced projects range from disaster management, where government agencies ask volunteers to provide information about the extent and intensity of earthquakes and wildfires, to astronomy, where volunteers help advance our understanding of the universe by using photos from telescopes to classify galaxies.[12] In 2020, several crowdsourced projects sprung up to help scientists understand and combat the Covid-19 pandemic. The American Lung Association created an open access citizen science study to help combat the spread of the virus, and crowdsourced data helped researchers determine how well people practiced social distancing.[13]

Crowdsourcing relies on big "crowds" of people to contribute and volunteer. Technologies like the internet have enabled project designers to create platforms for these crowds of people to organize around conservation goals they're interested in. SciStarter is one such internet platform. It matches volunteers with projects based on location, level of experience, and topic of interest. SciStarter helps almost 100,000 registered citizen scientists, plus millions of onsite visitors, participate in over 3,000 projects that have been registered independently or with federal government, NGO, or university partnerships.[14] Projects range from hosting an air quality sensor, to classifying faint galaxies in the Fornax cluster, to photographing cicadas. The internet has created an opportunity for the creators of Scistarter to bring small-scale conservation efforts to volunteers across the world.

Technological innovation has supercharged tools like crowdsourcing, enabling conservationists to organize and analyze vast amounts of data and reach wider groups of volunteers. The collection of data at a lower cost and the building of networks are two key areas in which technological innovation has proven crucial to crowdsourced conservation.

11 "Cooperative Observer Program," NOAA, National Weather Service, accessed June 10, 2021, https://www.weather.gov/ama/coop#:~:text=The%20National%20Weather%20Service.

12 Michael F. Goodchild and J. Alan Glennon, "Crowdsourcing Geographic Information for Disaster Response: A Research Frontier," *International Journal of Digital Earth* 3, no. 3 (April 15, 2010): 231–41, https://doi.org/10.1080/17538941003759255; Kate Land et al., "Galaxy Zoo: The Large-Scale Spin Statistics of Spiral Galaxies in the Sloan Digital Sky Survey," *Monthly Notices of the Royal Astronomical Society* 388, no. 4 (August 21, 2008): 1686–92, https://doi.org/10.1111/j.1365-2966.2008.13490.x; "The Science Behind the Site," Zooniverse, https://www.zooniverse.org/projects/zookeeper/galaxy-zoo/about/research.

13 "COVID-19 Citizen Science Study," American Lung Association, https://www.lung.org/lung-health-diseases/lung-disease-lookup/covid-19/action-initiative/covid-citizen-science-study; Tonya R. Moon, "Help Predict COVID-19's Spread in Your Community," socialdistancing.stanford.edu, accessed January 12, 2021, https://socialdistancing.stanford.edu/.

14 "About SciStarter," SciStarter, accessed July 10, 2020, https://scistarter.org/about.

Case Studies: Internet-enabled Projects and Emerging Technologies

The following sections highlight crowdsourcing projects that use technology to achieve conservation goals.

Mobile Phone Applications and Interactive Data

Perhaps the most well-known crowdsourced project in the conservation realm is the online database 'eBird' developed by the Cornell Laboratory of Ornithology and launched in 2002. The goal of the database is to show the abundance and distribution of bird species in order to provide data-driven approaches to conservation and science. Currently, volunteers contribute to the database using a mobile app to document bird sightings. The project is global in scale and has over 500 million observations uploaded.[15]

The program, however, did not begin with much success. Underpowered computers hampered progress after the initial launch, and those working at eBird found it difficult to motivate birdwatchers to contribute to the database. Birdwatchers lacked understanding of how the data would be used and the impact such use could have. Through trial and error, eBird was able to adapt, eventually developing a mobile app in 2012 that made contributing to the database more convenient and provided a platform for eBird to create a two-way street with birdwatchers. Data could now be contributed but also organized and given back to birdwatchers in the form of maps and migration information.[16] Participant feedback and academic reviews have found that project design greatly influences volunteer participation and retention.[17] The ability to sustain long term projects that allow for iterative adjustments is important for creating effective crowdsourcing programs.

The current eBird app works by allowing birdwatchers to upload observations of bird species from smartphones or computers. The observations from dispersed volunteers are added to the database. Through allowing contributors to add bird observations and providing a way to instantly update the online database, the eBird app has worked as an effective tool that uses large numbers of volunteers to provide up-to-date information important to conservation.

More recent technology has emerged that allows eBird to develop interactive maps with real-time updates on species near app users and tips on where to find hotspots for different birds. The recent adaptations have been especially helpful in exciting and attracting new contributors. eBird shows that technological innovations that organize data and provide ways for contributors to engage with a database for personal use can be pivotal for crowdsourcing.[18]

The database has proven especially helpful in creating opportunities for conservation researchers to work directly with communities to improve habitat for species. Data collected through Cornell's eBird app allowed researchers from The Nature Conservancy (TNC) to map bird migration patterns through California's Central Valley. Before eBird-informed decision making, The Nature

15 eBird – Discover a New World of Birding. . .," accessed July 10, 2020, https://ebird.org/home.

16Anders Gyllenhaal, "Cornell Effort to Protect Birds Uses Crowdsourced Sightings," *New York Upstate* (*The Washington Post*, April 30, 2019), https://www.newyorkupstate.com/ithaca/2019/04/cornell-labs-effort-to-protect-birds-uses-crowdsourced-sightings.html.

17 Duncan C. McKinley et al., "Citizen Science Can Improve Conservation Science, Natural Resource Management, and Environmental Protection," *Biological Conservation* 208 (April 2017): 15–28, https://doi.org/10.1016/j.biocon.2016.05.015.

18 Anders Gyllenhaal, "Cornell Effort to Protect Birds."

Conservancy had been buying land to convert into wildlife sanctuaries in California. When they reviewed eBird's database, conservationists realized the birds they were trying to create habitat for only passed through California a few weeks out of the year. They could pay local farmers and landowners to flood their fields for a few weeks at a cost nearly 85 percent less expensive than buying the land outright.[19]

From 2014 to 2019, farmer participation in TNC's BirdReturn program increased from 50 to 100 farmers, with over 55,000 acres along the 450-mile long Central Valley being temporarily flooded a few weeks out of the year. These temporary wetlands have been wildly successful; not only have the birds returned, but renting rather than buying habitat saves money.[20] These data-informed conservation tactics spawn creative and cooperative solutions to conservation challenges.

In addition to private programs like eBird, the federal government has also reaped the benefits of crowdsourcing. The National Map, a program organized by the US Geological Survey uses crowdsourcing to gather data in order to create a collection of interactive national maps of the US used by scientists, federal agencies, and private recreationists.[21] The project, officially known as The National Map Corps (TNMCorps), began in 2012 as a way to involve citizen scientists in collecting, editing, and verifying data.[22]

Contributions from citizen scientists focus on man-made structures and must undergo data quality checks and a tiered editing process before they can be accepted. High-caliber volunteers are given opportunities to work as editors with the potential to earn virtual badges in recognition of their work.[23] The project has gathered support from thousands of people, and over 150,000 submissions and edits have been made.[24] The project is a valuable resource for conservation efforts because it enables better land management practices and provides up-to-date information about building density in areas critical to endangered species.[25] This information can impact policy decisions and is particularly important because habitat loss is a major threat to biodiversity.[26]

Similar to eBird, TNMCorps uses crowdsourcing along with the latest GIS software to produce interactive maps. TNMCorps is proactive in its initiatives to motivate volunteers. Social media, virtual badges, and volunteer leaderboards are all forms of technology-aided gamification that help to excite volunteers about collecting data.[27] TNMCorps shows that investing in communities and networks of volunteers can increase participation and benefit conservation.

---

19 Anders Gyllenhaal, "Cornell Effort to Protect Birds."

20 Orin J. Robinson et al., "Integrating Citizen Science Data with Expert Surveys Increases Accuracy and Spatial Extent of Species Distribution Models," *Diversity and Distributions* 26, no. 8 (2020): 976–86, https://doi.org/10.1111/ddi.13068.

21 Elizabeth A. McCartney et al., "Crowdsourcing the National Map," *Cartography and Geographic Information Science* 42, no. sup1 (August 10, 2015): 54–57, https://doi.org/10.1080/15230406.2015.1059187.

22 "The National Map Corps | Crowdsourcing Map Data," www.citizenscience.gov, n.d., https://www.citizenscience.gov/the-national-map-corps/#.

23 McCartney et al., "Crowdsourcing the National Map."

24 "The National Map Corps | Crowdsourcing Map Data."

25 McCartney et al., "Crowdsourcing the National Map."

26 Adam J. Eichenwald, Michael J. Evans, and Jacob W. Malcom, "US Imperiled Species Are Most Vulnerable to Habitat Loss on Private Lands," *Frontiers in Ecology and the Environment* 18, no. 8 (2020): 439–46, https://doi.org/10.1002/fee.2177.

27 Benedikt Morschheuser, Juho Hamari and Jonna Koivisto, "Gamification in Crowdsourcing: A Review," *2016 49th Hawaii International Conference on System Sciences* (HICSS), 2016, pp. 4375–4384, https://doi.org/10.1109/HICSS.2016.543.

Volunteered Geographic Information

Volunteered Geographic Information (VGI) is another technological tool used in crowdsourced conservation projects. VGI is content created by individuals that includes geographic location details such as geotagged photos, tweets, or other content. It also includes volunteer-submitted data points, like those documenting the location of endangered species in a participant's community. It can be actively or passively gathered. eBird is an example of actively gathered VGI, where participants intentionally upload geographic data for a specific conservation purpose. This type of data has been used by scientists, academics, park managers, and federal agencies to advance conservation goals and several studies examine its usefulness and reliability.[28]

VGI holds promise for park managers who can use crowdsourced data to analyze seasonal visitation patterns to protected areas and then use those insights to make more informed management choices. One study based in Hawaii Volcanoes National Park uses passively gathered VGI—crowdsourced public images from Flickr—to bolster visitor log data. Geotagged photos that show what part of the park a visitor passed through are used to supplement traditional visitor data, which is usually only collected at entrances. This creates a more accurate picture of resource use throughout the park.[29]

Researchers analyzed geotagged photos from Flickr to assess how changes in infrastructure and environment influenced visitor use within the park. Their analysis helped to provide park managers with the information needed to plan for resource strains and make other management decisions.[30]

The dearth of visitor data in protected areas is considered "a main limitation in implementing proactive management strategies to minimize visitor impact on resources."[31] Crowdsourcing can provide that data at a lower cost, without commissioning professional surveyors to go out and observe visitor behavior in real time. It gives managers access to more accurate information about visitor use and its effects on ecological features within park boundaries.

VGI has also been a helpful tool for initiatives outside of the United States. In Kenya, the Wildbook platform allows volunteers to upload photos and other information about wildlife. Volunteer contributions to the platform have resulted in more accurate species censuses for species including the Grevy's Zebra. That data is now used by the IUCN Red List, the official body that tracks the conservation status of species around the world.[32] The Wildbook platform has gathered data on whales, sharks, sea turtles, seals, and lynx using publicly available social media images and volunteer-submitted photos.[33]

The Hawaii Volcanoes National Park project shows how passive crowdsourcing like VGI can glean extra insights about conservation without requiring volunteers to gather data for the specific

28 Noam Levin, Alex Mark Lechner, and Greg Brown, "An Evaluation of Crowdsourced Information for Assessing the Visitation and Perceived Importance of Protected Areas," *Applied Geography* 79 (January 2017): 115–26, https://doi.org/10.1016/j.apgeog.2016.12.009.

29 Chelsey Walden-Schreiner, Yu-Fai Leung, and Laura Tateosian, "Digital Footprints: Incorporating Crowdsourced Geographic Information for Protected Area Management," *Applied Geography* 90 (January 2018): 44–54, https://doi.org/10.1016/j.apgeog.2017.11.004.

30 Walden-Schreiner, Leung, and Tateosian, "Digital Footprints."

31 Walden-Schreiner, Leung, and Tateosian, "Digital Footprints."

32 Tanya Berger-Wolf et al., "Wildbook: Crowdsourcing, Computer Vision, and Data Science for Conservation," Bloomberg Data for Good Exchange Conference, September 24, 2017, https://arxiv.org/pdf/1710.08880.pdf.

33 Berger-Wolf et al., "Wildbook: Crowdsourcing."

purpose of advancing conservation. Artificial intelligence (AI) is another technology that may be able to leverage incidental data for conservation purposes. The next section outlines several ways AI can be implemented alongside crowdsourced projects to advance conservation.

Artificial Intelligence

Artificial intelligence is becoming increasingly useful for conservation-based crowdsourcing—especially in making the process of data management more efficient. Artificial intelligence is a blanket term for a collection of computational technologies that make decisions "which normally require a human level of expertise."[34] It is used to perform tasks like data analysis and image recognition, in which humans set initial parameters and then allow an algorithm to classify data autonomously. Many citizen science projects currently have volunteers comb through crowdsourced images, identifying and counting species. AI could make these types of tasks irrelevant by automatically sorting and identifying images, allowing volunteer and researcher time to be reallocated to other important tasks.

For example, Wildlife Insights, a global conservation platform where volunteers can upload images of wildlife, has trained artificial intelligence models to filter out blank images and classify hundreds of vertebrate species. Blank images can account for up to 80 percent of camera trap datasets, so automatically sorting these out allows researchers to complete projects considerably faster.[35] Image recognition is far from perfect and many AI projects like this rely on human work to label data before the automated processes can function properly.[36]

Not every project is well suited for AI assistance and there are important tradeoffs to consider. Manually completing simple tasks provides an avenue for novice volunteers to engage with a project and learn while doing. Developing successful AI algorithms and analyzing huge datasets is also a costly and time-consuming task. For some large-scale projects AI can save valuable time and create large gains in efficiency. But for smaller, less well-funded projects, participant engagement and low-cost methods may be preferable.

Large tech companies are joining in the effort as well, attempting to use their massive computational resources and expertise to advance conservation. In 2017, Microsoft created its AI for Earth initiative, which has dispensed more than 500 grants to scientists working on conservation projects in 81 countries. One of the two main types of grants provides data labeling services that prepare datasets for AI processing.[37]

Scientists can also use AI and machine learning techniques to build models important to conservation research. For example, one project in South Korea used a deep neural network to predict

34 Darrell M. West, "What Is Artificial Intelligence?" *Brookings*, October 4, 2018) https://www.brookings.edu/research/what-is-artificial-intelligence/.

35 "About Wildlife Insights Artificial Intelligence Models," Wildlife Insights, accessed December 21, 2020, https://www.wildlifeinsights.org/about-wildlife-insights-ai.

36 Roh, Yuji, Geon Heo, and Steven Euijong Whang, "A Survey on Data Collection for Machine Learning: A Big Data - AI Integration Perspective." *IEEE Transactions on Knowledge and Data Engineering* 33, no. 4 (2021): 1328–47, https://doi.org/10.1109/tkde.2019.2946162.

37 Brandon Vigliarolo, "AI for Earth: How Microsoft Is Using Azure to Build a More Sustainable World," TechRepublic, April 22, 2019, https://www.techrepublic.com/article/ai-for-earth-how-microsoft-is-using-azure-to-build-a-more-sustainable-world/; "AI for Earth – Microsoft AI," accessed December 21, 2020, https://www.microsoft.com/en-us/ai/ai-for-earth-grants.

habitat suitability for four amphibian and seven bird species.[38] They built their models based on a massive set of crowdsourced observational data from volunteers supplemented by other available environmental data. The new model allows conservationists to identify habitat for endangered species, which is key to sustaining biodiversity.

Crowdsourcing allows large-scale data collection at a cheaper cost, and AI can sort, analyze, and create models based on that data. AI techniques can be combined with crowdsourcing at several stages of the research process and have the potential to increase efficiency and accuracy.[39]

Biotechnology

The rapidly advancing fields of biotechnology and genetic engineering also have potential applications for crowdsourced conservation. Revive and Restore is a company that uses newly-developed genomic technology to solve wildlife conservation challenges caused by inbreeding, exotic diseases, and climate change. They also work to bring back endangered and extinct species with genetic engineering.[40] For example, the company partners with the Fish and Wildlife Service's National Black-footed Ferret Conservation Center to help the endangered ferret species.[41] They have been sequencing DNA for four individual black-footed ferrets to discover traits that, if passed on, will help the species recover. The group successfully cloned a black-footed ferret for the first time in 2020.[42]

Volunteer citizen scientists and professionals analyze the black-footed ferret's genetic information for gene sequences that may be contributing to the ferret's loss of genetic diversity and susceptibility to disease. Volunteers interested in participating log in to a website housing genetic data on the ferrets. They attempt to answer any of the questions driving the research project and then email in any findings.[43] Volunteers for this highly specialized crowdsourcing project do need some prior expertise in data analysis or genetics to effectively participate. For those who do not directly specialize in ferret genomics, Revive and Restore provides helpful instructions and examples, enabling them to participate. Crowdsourced science is playing an instrumental role in efforts to help the black-footed ferret, as volunteers work together with professionals to comb through genetic data.

These technologies allow for connections between researchers and dispersed volunteers that would have been impossible or much more costly to achieve just a few decades ago. As the case studies show, there are many crowdsourced projects that use these newer possibilities for connection to advance conservation objectives.

The wide variety of crowdsourced projects means that project designers need to carefully decide what factors are most important to the project. Some may only require short term contributions

38 Jehyeok Rew et al., "Habitat Suitability Estimation Using a Two-Stage Ensemble Approach," *Remote Sensing* 12, no. 9 (2020): 1475, https://doi.org/10.3390/rs12091475.

39 Jennifer Wortman, "Making Better Use of the Crowd: How Crowdsourcing Can Advance Machine Learning Research," *Journal of Machine Learning Research* 18 (2018): 1–46, https://www.jmlr.org/papers/volume18/17-234/17-234.pdf.

40 "About Us," Revive & Restore, March 25, 2019, "https://reviverestore.org/about-us/.

41 James Temple, "Can Crowdsourced Science Help Save the Black-Footed Ferret?" *Vox*, June 18, 2014, https://www.vox.com/2014/6/18/11628088/can-crowdsourced-science-help-save-the-black-footed-ferret.

42 Alex Fox, "Elizabeth Ann Is the First Cloned Black-Footed Ferret," *Smithsonian Magazine*, February 22, 2021, https://www.smithsonianmag.com/smart-news/elizabeth-ann-first-cloned-black-footed-ferret-180977065/.

43 "How to Participate," Revive & Restore, n.d., https://reviverestore.org/how-to-participate-alternate/.

to gather the data they need, while other projects will benefit from long term data collection and iterative projects that can be tweaked over time to better engage volunteers and meet conservation goals. The next section examines whether crowdsourced projects have meaningfully contributed to conservation goals.

How Are Crowdsourced Projects Contributing to Better Conservation Outcomes?

For many crowdsourced projects, the contribution to conservation outcomes is difficult to quantify and consists mainly in providing more data at a lower cost. That data is then used to fulfill conservation goals. Given the difficulty of gathering conservation data, this alone is a valuable contribution. Some projects, like the Billion Oyster Project and TNC's BirdReturn program, have directly observable conservation benefits like increased species occurrence and improved habitat.

Data-informed decisions are essential to creating effective conservation outcomes, and data is where crowdsourcing likely makes the most impact.[44] Crowdsourcing provides more and cheaper data for many conservation projects and can increase the spatial and temporal resolution of datasets.[45] But because data from many crowdsourced projects is produced by non-experts, it is reasonable to ask if it is credible. Several studies have compared the accuracy and reliability of crowdsourced data to that of professionally produced data, especially for projects that focus on geographic distributions of animals, plants, or human populations.[46] They find that crowdsourced data can be a valuable and reliable source of information, especially when supplemented with other traditionally-gathered data.

Crowdsourced data does have specific limitations that need to be addressed to ensure accuracy. It often suffers from sampling, selection, or other statistical biases because participants are volunteers who are not evenly geographically distributed and may fail to update data at consistent intervals.[47] However, when these weaknesses can be controlled for, crowdsourced data provides important information about conservation objectives, especially when combined with expertly collected

44 Christopher R. Field and Chris S. Elphick, "Quantifying the Return on Investment of Social and Ecological Data for Conservation Planning," *Environmental Research Letters* 14, no. 12 (2019): 124081, https://doi.org/10.1088/1748-9326/ab5cae.

45 Christopher S. Lowry and Michael N. Fienen, "CrowdHydrology: Crowdsourcing Hydrologic Data and Engaging Citizen Scientists," *Ground Water* 51, no. 1 (2013): 151–56, https://doi.org/10.1111/j.1745-6584.2012.00956.x; Feifei Zheng et al., "Crowdsourcing Methods for Data Collection in Geophysics: State of the Art, Issues, and Future Directions," *Reviews of Geophysics* 56, no. 4 (2018): 698–740, https://doi.org/10.1029/2018rg000616.

46 Greg Brown et al., "Assessing the Validity of Crowdsourced Wildlife Observations for Conservation Using Public Participatory Mapping Methods," *Biological Conservation* 227 (November 2018): 141–51, https://doi.org/10.1016/j.biocon.2018.09.016. Solene Derville et al., "Finding the Right Fit: Comparative Cetacean Distribution Models Using Multiple Data Sources and Statistical Approaches," *Diversity and Distributions* 24, no. 11 (2018): 1657–73, https://doi.org/10.1111/ddi.12782.

47 Andrew J. Flanagin and Miriam J. Metzger, "The Credibility of Volunteered Geographic Information," *GeoJournal* 72, no. 3–4 (2008): 137–48, https://doi.org/10.1007/s10708-008-9188-y; Finn Danielsen, Neil D. Burgess, and Andrew Balmford, "Monitoring Matters: Examining the Potential of Locally-Based Approaches," *Biodiversity and Conservation* 14 (2005): 2507–2542, https://doi.org/10.1007/s10531-005-8375-0.

data.[48] There is a growing literature dedicated to improving the methods data analysts can use to ensure crowdsourced data is reliable.[49]

Even when datasets are imperfect, they are often still useful. The US Geological Survey and the Canadian Wildlife Service have a joint crowdsourcing effort called the North American Breeding Bird Survey (BBS). The project recruits volunteers to gather data on bird populations and migrations. The BBS database has been cited in peer-reviewed articles over 500 times, showing that it is a valuable source of information. It has also been cited by federal agencies in proposals to designate the Gunnison sage-grouse and black-backed woodpecker as endangered species. Federal agencies have been clear that while the database is not flawless, it is essential to their decision making. For example, the US Fish and Wildlife Service has said, "The BBS is the only long-term trend information available for the mountain plover [and] an imprecise indicator…Even so, we acknowledge that this is the best available information on trends for this species."[50]

The US Geological Survey's National Map has also found success using crowdsourced data.[51] The National Map enables scientific studies on myriad topics relevant to conservation interests. According to Google Scholar, 99 articles have cited just the hydrology section of the map, on topics ranging from the effects of stream flow on fish populations to sustainability of biofuel crop production.[52] Crowdsourcing also advances conservation by lowering costs through volunteer work. Researchers at the University of Washington estimated that the in-kind contributions of 1–2 million citizen scientists volunteering on biodiversity projects resulted in added economic value of up to $2.5 billion per year.[53]

The federal government has begun to recognize the potential of crowdsourcing to assist agencies as they work to meet their conservation goals. The Crowdsourcing and Citizen Science Act of 2016 was passed to "encourage and increase the use of crowdsourcing and citizen science methods within the federal government." The act created a central database of citizen science projects and includes a provision that agencies make crowdsourced data open access whenever possible.

48 McKinley et al., "Citizen Science Can Improve Conservation Science."

49 Roman Lukyanenko et al., "Expecting the Unexpected: Effects of Data Collection Design Choices on the Quality of Crowdsourced User-Generated Content," *MIS Quarterly* 43, no. 2 (2019), https://doi.org/10.25300/MISQ/2019/14439; Nathan R. Prestopnik and Kevin Crowston, "Gaming for (Citizen) Science: Exploring Motivation and Data Quality in the Context of Crowdsourced Science Through the Design and Evaluation of a Social-Computational System," *2011 IEEE Seventh International Conference on e-Science Workshops* (2011), https://doi.org/10.1109/eScienceW.2011.14; Kazai, Gabriella, Jaap Kamps, and Natasa Milic-Frayling, "An Analysis of Human Factors and Label Accuracy in Crowdsourcing Relevance Judgments," *Information Retrieval* 16, no. 2 (2013): 138–78. https://doi.org/10.1007/s10791-012-9205-0.

50 Endangered and Threatened Wildlife and Plants; Withdrawal of the Proposed Rule to List the Mountain Plover as Threatened, 76 Fed. Reg. 27,756 (May 12, 2011) (50 C.F.R. Pt. 17), https://www.govinfo.gov/content/pkg/FR-2011-05-12/pdf/2011-11056.pdf#page=2.

51 McCartney et al., "Crowdsourcing the National Map."

52 At the time of writing, a Google search for this source turns up 99 citations. Clicking on those citations, shows the studies mentioned. USGS, National Geospatial Program Office, *The National Map—Hydrology* (2010), https://pubs.usgs.gov/fs/2009/3054/pdf/FS2009-3054.pdf.

53 E. J. Theobald et al., "Global Change and Local Solutions: Tapping the Unrealized Potential of Citizen Science for Biodiversity Research," *Biological Conservation* 181 (2015): 236–244, https://doi.org/10.1016/j.biocon.2014.10.021; John P. Holdren, *Memorandum to the Heads of Executive Departments and Agencies: Addressing Societal and Scientific Challenges through Citizen Science and Crowdsourcing*, Executive Office of the President, Office of Science and Technology Policy, September 30, 2015, https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/holdren_citizen_science_memo_092915_0.pdf.

Several federal agencies have already taken steps to incorporate crowdsourcing into their practices.[54] Doing so has allowed them to launch projects that would have otherwise been logistically impossible or too expensive to execute. The National Oceanic and Atmospheric Association has six current crowdsourced projects including a geocaching project that collects data at key ecological locations and a project tracking tides to help predict future floods.[55] The Forest Service has a citizen science resources page on their website that describes their own crowdsourced projects, plus links to government resources like the Federal Crowdsourcing and Citizen Science Catalog and the EPA's National Directory of Volunteer Monitoring Programs, privately funded platforms like SciStarter, and the Cornell Citizen Science Toolkit for designing your own projects.[56] Grants from the Environmental Protection Agency support crowdsourcing projects that monitor water and air quality, including a project collecting observations on the occurrence of wildfire smoke and its health effects.[57] Several federal agencies list their current crowdsourced projects online, with links to volunteer and there is now a central online database for federal crowdsourcing projects.[58]

There have also been some efforts to coordinate crowdsourcing practices across multiple agencies or the federal government as a whole. The Federal Community of Practice on Crowdsourcing and Citizen Science (FedCCS) is a collaboration of federal managers dedicated to sharing lessons learned and developing best practices for designing, evaluating, and implementing crowdsourced projects across the federal government.[59] The Crowdsourcing and Citizen Science Act of 2016 encourages agencies to designate a coordinator for their crowdsourcing projects, and encourages agency staff to participate in the FedCCS.[60]

The above examples show that crowdsourcing is a flexible and powerful tool to achieve conservation goals. The federal government has indicated that it values open-source crowdsourced data and participatory science and has benefited from such projects as it pursues its goal of conservation using the best available scientific data. The next section looks at how well the federal government has developed policies that enable its agents to pursue these goals and recommends strategies to better capitalize on the potential for crowdsourcing to be a valuable tool in the government's conservation arsenal.

Regulatory Hurdles

Federal crowdsourced projects are affected by several regulations, many of which were enacted without crowdsourcing specifically in mind. Regulations concerning privacy, information collection, and participant protection may have inadvertent effects on federal crowdsourcing and be an

54 Tammi Marcoullier, "USGS, Where Citizen Science Is for the Birds," Digital.gov, January 20, 2015, https://digital.gov/2015/01/20/usgs-where-citizen-science-is-for-the-birds/.

55 "Citizen Science at NOAA," National Ocean Service, accessed March 24, 2021, https://oceanservice.noaa.gov/citizen-science/.

56 "Citizen Science – Resources," US Forest Service, accessed March 30, 2021, https://www.fs.usda.gov/science-technology/citizen-science/resources.

57 "Examples of Participatory Science Projects Supported by EPA," Overviews and Fact Sheets, United States Environmental Protection Agency, April 18, 2019, https://www.epa.gov/citizen-science/examples-citizen-science-projects-supported-epa.

58 "Federal Crowdsourcing and Citizen Science Catalog," CitizenScience.gov, accessed March 29, 2021, https://www.citizenscience.gov/about/catalog/#.

59 "Federal Crowdsourcing and Citizen Science Community of Practice," Digital.gov, September 29, 2015, https://digital.gov/communities/crowdsourcing-citizen-science/.

60 Crowdsourcing and Citizen Science Act of 2016, H.R. 6414, 114th Cong. (2016), https://www.congress.gov/bill/114th-congress/house-bill/6414/text.

obstacle for current and future projects. In order to identify the most cumbersome regulations, the Wilson Center, a congressionally chartered research organization, conducted an exploratory survey with federal agencies already involved in crowdsourcing—interviewing agency executives, program offices, field offices, and stakeholders.[61]

Chief among the regulatory concerns of the federal agencies surveyed was the difficulty of adhering to the Paperwork Reduction Act (PRA). Policymakers enacted the PRA in 1980 in an attempt to "improve management and efficiency in the federal government."[62] However, the law requires agencies involved in crowdsourcing to navigate a lengthy bureaucratic process, which can delay projects. When applicable, the law requires federal agencies to develop a formal information collection request, publish its plans in the federal register twice, solicit comments from the public, and ask the Office of Management and Budget (OMB) for approval. The law applies to virtually all federal crowdsourcing projects because agencies are required to submit an information collection request for projects involving more than 10 individuals.[63]

The Office of Management and Budget is responsible for creating detailed guidelines instructing agencies on how to comply with the PRA. The OMB has some latitude to adjust requirements based on circumstance and has updated policies to better accommodate web-based surveys and data search tools, which has probably helped some crowdsourcing projects. However, the OMB has been unwilling to significantly change information collection requirements in recent years, choosing to preserve regulatory processes that make crowdsourcing projects more difficult to implement. If the OMB chooses, federal crowdsourcing projects could benefit from a generic clearance approval, where the OMB classifies crowdsourcing projects as a category with less onerous requirements.[64]

In addition to difficulties with the PRA, federal agencies expressed concerns about privacy and information policy imposing a heavy regulatory burden. Although not all crowdsourcing initiatives collect personal information from volunteers, privacy can still be an unexpected challenge in many cases. Privacy law remains extremely complex and many agency staffers indicated a "lack of clarity as to what is and is not allowed to be collected from members of the public"—a difficult hurdle that keeps some staff members from pursuing crowdsourcing projects or collecting data that could be valuable.[65] Most often, a project that collects even a minimal amount of personal information requires adherence to several statutes.

The Privacy Act of 1974 governs the collection, use, and dissemination of information about individuals maintained by a federal agency as part of a system of records. Congress enacted the law as a way to implement fair information practices across all federal agencies. The act outlines requirements for any federal agency that develops or alters a system of records, a broad term defined as a group of records where information is retrieved by an identifier assigned to an individual, including names.[66] Agencies creating or changing such a group of records are required to submit a system of records notice (SORN) to the OMB as well as publish the SORN in the Federal Register. Once

61 "An Exploratory Study on Barriers," Wilson Center: Commons Lab, September 7, 2014, https://stipcommunia.wordpress.com/2014/09/07/an-exploratory-study-on-barriers/.

62 Robert Gellman, *Crowdsourcing, Citizen Science, and The Law: Legal Issues Affecting Federal Agencies*, Policy Series, vol. 3, Woodrow Wilson International Center for Scholars, 2015, p. 9.

63 Noam Levin, Alex Mark Lechner, and Greg Brown, "An Evaluation of Crowdsourced Information for Assessing the Visitation and Perceived Importance of Protected Areas," *Applied Geography* 79 (2017): 115–26, https://doi.org/10.1016/j.apgeog.2016.12.009.

64 Levin, Lechner, and Brown, "An Evaluation of Crowdsourced Information.

65 "An Exploratory Study on Barriers."

66 "Privacy Act of 1974," June 16, 2014, https://www.justice.gov/opcl/privacy-act-1974.

familiar with the process, most agency employees are quite efficient at submitting the required information, but the process can be time consuming for newcomers wanting to start a crowdsourcing project.[67]

The Privacy Act of 1974 worked as a prequel to the E-Government Act of 2002, which requires a privacy impact assessment (PIA) before an agency takes action to create a new privacy risk. Officially, new privacy risk is created when an agency collects electronic information from 10 or more persons or creates information technology systems responsible for collecting or maintaining volunteer information. Although each agency is responsible for creating their own PIA and are not required to submit the assessment to the OMB, complying with the act still takes valuable time and may become a larger burden in the future as more agencies implement information technology.[68]

Non-Regulatory Hurdles

The Wilson Center survey also identified non-regulatory hurdles, mainly identifying difficulties in developing viable plans for future projects. Several federal employees cited uncertainty about how to design crowdsourced projects relevant to their agency's mission, and uncertainty about how to navigate the process of creating a federal crowdsourced project. The Crowdsourcing Act of 2016 addressed these concerns by creating an online database of federal crowdsourced projects: citizenscience.gov.[69] As of early 2021, the database lists 488 active federal crowdsourcing projects and includes a toolkit to assist agencies in designing and maintaining their projects. It also links to the Federal Crowdsourcing and Citizen Science Community of Practice, where federal managers share case studies and best practices for crowdsourcing. This community and the corresponding project database together create a centralized location for federal crowdsourcing needs. This centralized database of crowdsourcing resources will help federal agencies build their capacity for crowdsourcing.

Private institutions can also help federal agencies design and implement crowdsourced projects. Businesses and universities are often subject to fewer federal regulations than government agencies. Some federal agencies have seen success by partnering with private organizations to implement crowdsourcing projects. This enables agencies to reap the benefits of crowdsourced projects while avoiding the onerous bureaucratic requirements of the federal government and allows federal agencies to rely on the expertise of researchers with project design experience.[70]

However, if private organizations are the primary party responsible for a project, they may retain ownership of the data. The Crowdsourcing Act of 2016 instructs agencies to make crowdsourced data publicly available whenever possible. Providing open data is a relatively robust norm in the crowdsourcing community, even among private organizations, but it is still possible that a private organization will choose not to publish data that would have been publicly available if a government agency were the primary project sponsor. If the US government is invested in

67 Gellman, *Crowdsourcing, Citizen Science, and The Law*.

68 Gellman, *Crowdsourcing, Citizen Science, and The Law*.

69 Holdren, *Memorandum*; Gellman, *Crowdsourcing, Citizen Science, and The Law*; Helen K. Liu, "Crowdsourcing Government: Lessons from Multiple Disciplines," *Public Administration Review* 77, no. 5 (2017): 656–67, https://doi.org/10.1111/puar.12808.

70 Gellman, *Crowdsourcing, Citizen Science, and The Law*.

providing public access data through crowdsourcing, lowering the bureaucratic cost of designing and implementing federally crowdsourced projects is a necessary step.

The federal government also has an opportunity to marshal volunteer contributions as an institution with vast jurisdiction and resources. Federally funded partnerships can encourage private organizations to pursue projects that otherwise might struggle to attract funding. An Intel survey of 200 business professionals working on environmental sustainability identified cost as the most significant barrier to implementing AI to solve conservation problems (33 percent of respondents).[71] Federal agencies are important conservation partners with mandates to use the best available science to pursue conservation outcomes, which can be better achieved by contributing their funding and institutional capability to private groups with on-the-ground ability to design projects and organize volunteers.

There is great potential to utilize volunteers to advance conservation outcomes. Millions of Americans interact with natural areas with conservation value every day. Federal managers should encourage crowdsourced projects within their agencies, and state governments should look to build mechanisms for organizing and implementing crowdsourced projects. Successful crowdsourced projects that rely on partnerships between the federal government and state and local governments already exist.

The Bat and Hummingbird Feeder Study is sponsored by the Fish and Wildlife Service, carried out by local volunteers in Tucson, Arizona, and used by state and local officials in developing their habitat conservation plans.[72] The project successfully uses federal expertise and funding paired with local knowledge to create better conservation plans at the state and local level. Potential for similar projects is as vast and varied as the ecosystems across each state.

Policy Recommendations

While crowdsourcing is becoming increasingly popular, more could be done to foster community involvement, data generation, and conservation by using funding and policy tools to encourage crowdsourced projects. At the federal level, exempting crowdsourcing projects from some of the intensive paperwork requirements or tailoring policies to account for this new tool will enable more federal managers to leverage the power of the crowd to solve conservation challenges.

To make government-sponsored crowdsourcing more feasible, it needs to become easier to undertake by federal agencies. These agencies have access to funding and resources that many private institutions do not have, but the burdensome requirements placed on these agencies often prevents them from participating. Some first steps have already been taken, including the Crowdsourcing and Citizen Science Act.[73] The legislative and administrative framework for using crowdsourcing

71 Todd Brady, "Intel Study: Applying Emerging Technology to Solve Environmental Challenges," Intel Newsroom, December 13, 2018, https://newsroom.intel.com/editorials/intel-study-applying-emerging-technology-solve-environmental-challenges/#gs.o4tkj8.

72 "Southern Arizona Bat-Hummingbird Feeder Monitoring Study," www.citizenscience.gov, accessed March 11, 2021, https://www.citizenscience.gov/catalog/403/#; "Backyard Bats: Bat and Hummingbird Feeder Study," Arizona Game and Fish, accessed March 11, 2021, https://www.azgfd.com/wildlife/backyard-bats/.

73 Holdren, *Memorandum*.

is nascent, but provides a solid starting point from which the government can organize, encourage, and track crowdsourced projects.[74]

Moving forward, Congress needs to better clarify which regulations apply to crowdsourcing projects, and advice about how to best navigate that process is needed. Such clarity could encourage more federal agencies to adopt crowdsourcing by providing employees with the knowledge and tools they need to feel confident in implementing projects in line with regulations.

Federal and state governments are responsible for myriad conservation goals, which they must implement across multiple ecosystems and in cooperation with various stakeholders. As climate change introduces new environmental stressors and population growth increases the interactions between humans and wildlife, their job is becoming harder. New and innovative tools like crowdsourcing can help government agencies accomplish their conservation mandates, especially when carried out with other stakeholders who have expertise in project design or other capabilities that complement federal goals.

Private groups' ability to assist federal conservation goals would be greatly improved if agencies commit to make all data from their citizen science projects open access. The data from crowdsourced projects can help federal mangers make better-informed decisions, but, if shared, that data can also help private conservation groups direct their efforts toward the most impactful actions. Open access federal data would also enable more academic studies, which are an important part of the best available scientific knowledge that the government relies on to make decisions.

We recommend that state governments develop crowdsourcing projects in partnership with businesses, community groups, and universities to pursue conservation goals. State governments have experience working with university extension experts and private landowners on conservation issues and recognize that partnering with various stakeholders is necessary to achieve conservation goals.[75] Crowdsourcing provides another way for government officials to harness the local knowledge of private citizens. People who reside in an area have a long-term interest in the success of conservation projects in their community. Crowdsourcing provides an opportunity to marry the long-term interests of community members to the goals of government agencies. State officials can advance conservation by encouraging their employees to develop partnerships and projects and by providing support as they navigate state-level regulatory hurdles.

The federal government is an institution with the ability to sustain long-term research projects, often beyond what private organizations are capable of. Identifying conservation needs and projects that would benefit from long-term data collection would allow the government to make the best use of its institutional resources to advance conservation. We recommend that federal agencies consult with professional associations of scientists like the Ecological Society of America or the Society for Conservation Biology to identify the most pressing conservation needs in order to ensure that crowdsourced projects actually advance scientific needs. As crowdsourcing grows as a conservation tool, efforts need to be made to evaluate projects by urgency, feasibility, and cost.

74 John McLaughlin, Jay Benforado and Sophia B. Liu, "Report to Congress Describes the Breadth and Scope of Federal Crowdsourcing and Citizen Science," www.citizenscience.gov, June 18, 2019, https://www.citizenscience.gov/2019/06/18/report-to-congress-2019/#.

75 Laura Van Riper, "The Interagency Creeks and Communities Strategy: Creating Healthy Streams and Wetlands by Bringing People Together," *Rangelands* 34, no. 4 (2012): 5–10, https://doi.org/10.2111/rangelands-d-12-00013.1; Elise S. Gornish and Leslie M. Roche, "The Value of Cooperative Extension for Involving Society in Restoration and Conservation," *Restoration Ecology* 26, no. 6 (2018): 1051–54, https://doi.org/10.1111/rec.12861.

Partnerships and collaboration will enable better crowdsourced projects by combining the unique institutional capabilities of various stakeholders.

Conclusion

In order to fully take advantage of the potential for crowdsourcing to advance conservation, we need to identify the unique capabilities of crowdsourced projects, match those to the most appropriate and pressing conservation needs, and employ the right actors and institutions to organize and execute the projects. Technologies that allow dispersed volunteers to contribute to projects require maintenance. Much of the conservation data that is needed is most valuable if provided on a long-term basis. The federal government and universities are the institutions most capable of providing long-term maintenance of such projects, while much of the innovation in technology comes from the private sector. In order to match our ability to connect dispersed volunteers to the most impactful conservation projects, collaboration between public institutions and private groups is needed.

Crowdsourcing has great potential to enable conservation at a lower cost while engaging the public. To achieve this, federal managers should encourage crowdsourced projects within their agencies and partner with state governments or private actors when appropriate. Agencies should also take seriously the provision to provide open access data from federal crowdsourcing projects. This would enable collaboration and data generation on a level that was impossible just 20 years ago.

Crowdsourcing ultimately provides a promising way for governments to leverage new technologies to more effectively carry out conservation goals. The challenge of being responsible stewards has always been complex, whether in the 1800s or the 2000s. Past generations laid the foundation for us to protect land, water, and species by setting aside land in public parks and creating standards for air and water quality. Flexible, decentralized tools like crowdsourcing that allow for unprecedented collaboration can help protect our natural heritage for the next century.