Information to Action

Strengthening EPA Citizen Science Partnerships for Environmental Protection

National Advisory Council for Environmental Policy and Technology (NACEPT)

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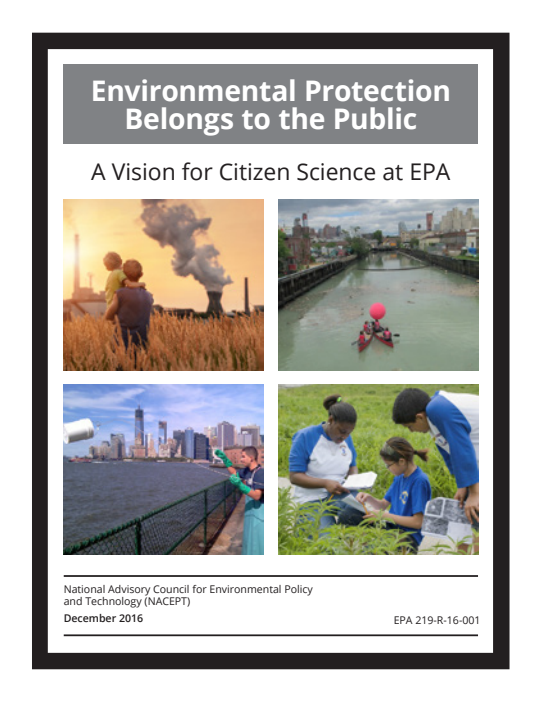

Information to Action—Strengthening EPA Citizen Science Partnerships for Environmental Protection is the follow-on document to the National Advisory Council for Environmental Policy and Technology's (NACEPT) 2016 report to the EPA Administrator, *Environmental Protection Belongs to the Public—A Vision for Citizen Science at EPA.*

The previous report is available at www.epa.gov/faca/nacept-2016-report-environmental-protection-belongs-public-vision-citizen-science-epa.

Cover Photos

Top Left: Participating in the Colorado River Watch program. ***Photo credit:*** Michaela Taylor.

Top Right: The campus of the Smithsonian Environmental Research Center in Edgewater, Maryland, contains numerous colonial archaeological sites. Citizen scientists sift through soil to uncover artifacts that will provide insight about how the land was used by previous owners. ***Photo credit:*** Copyright 2017 Smithsonian Environmental Research Center.

Bottom Left: From *The Crowd & The Cloud*, a four-part public television series on citizen science, viewable at www.crowdandcloud.org. Jose Barros (left), President of Tropical Audubon, and Paul Bithorn participating in the Audobon Christmas Bird Count in the Florida Everglades. The Bird Count began in 1900 and is one of America's longest running citizen science projects. Instead of killing birds for bragging rights, founder Frank Chapman suggested counting, eventually generating data that can show environmental change over time. ***Photo credit:*** Nathan Dappen/Courtesy The Crowd & the Cloud, supported by the National Science Foundation.

Bottom Right: Local teens from a Rockaway school visit the Gateway National Wildlife Refuge, near New York City, as part of a project run by the New York Phenology Project. They plot pollinator numbers to help restore local habitat following Superstorm Sandy and see science, technology, engineering and mathematics disciplines come to life in a real-world setting. ***Photo credit:*** Sean Feuer/Courtesy The Crowd & the Cloud, supported by the National Science Foundation.

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www.epa.gov/faca/strengthening-epa-citizen-science-partnerships-environmental-protection

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The NACEPT members would like to thank Dr. Alison J. Parker, ORISE Research Fellow hosted by the U.S. Environmental Protection Agency; Ms. Shannon Dosemagen, President and Executive Director, Public Laboratory for Open Technology and Science; and Mr. Daniel Bator, ASPPH Environmental Health Fellow hosted by the U.S. Environmental Protection Agency, for their energy and diligence during the writing, editing and production of this report.

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Soil is sifted by citizen scientists to uncover the mysteries of how this land was used by the Sellman and the Kirkpatrick-Howat families, dating back to the 1700s. The land is now part of the campus of the Smithsonian Environmental Research Center.
Photo credit: Copyright 2017 Smithsonian Environmental Research Center.

Transmittal Letter to the Administrator

The poet Muriel Rukeyser said, "The universe is made of stories, not of atoms." During the researching and writing of this report, the National Advisory Council for Environmental Policy and Technology (NACEPT or Council) discovered three important things about citizen science. First, it is a universe of stories about people participating in science in ways that are voluntary and meaningful and that bring change. Second, the universe of citizen science is a rapidly expanding one, driven in part by emerging technologies that allow the public—in the words of Dr. Caren Cooper, author of the new book *Citizen Science: How Ordinary People are Changing the Face of Discovery*—to take the pulse of the planet and promote community-based problem solving. Third, there is magic in the way citizen science connects citizens and science, and EPA can tap that magic more effectively to connect the Agency with the public.

In its first report to EPA on citizen science in December 2016, *Environmental Protection Belongs to the Public—A Vision for Citizen Science at EPA*, the Council recommended that the Agency proactively and fully integrate citizen science into the work of EPA. In this second report, NACEPT has focused on how EPA might best move citizen science from data and information to action. The Council recommends that the Agency fully embrace action in response to citizen science and collaborate with the governments and governing bodies of states, tribes, territories, and local and external organizations, with a focus on open technology.

Based on our interviews with citizen science practitioners and experts, the NACEPT members strongly believe that a laissez faire approach by EPA will be insufficient. EPA must advance a positive, proactive agenda—to work in partnership with communities and state, territorial and tribal governments in ways that strengthen citizen science infrastructure and standardize citizen science methods. As we prepared this report, the Council members learned that the keys to success are for EPA to focus on effective communication and authentic collaboration. One of the great benefits that citizen science offers EPA is the opportunity to leverage the expertise, networks and resources of other parties.

EPA's leadership role is crucial. This NACEPT report contains recommendations for how to create the conditions in which citizen science can flourish at EPA; in communities; in state, territorial and tribal environmental programs; and in the many partner organizations that work to protect human health and the environment. The benefits of using citizen science approaches to accelerate scientific research and data acquisition, improve science literacy, and connect citizens to EPA's missions are clearly defined by recent congressional legislation (the Crowdsourcing and Citizen Science Act of 2016, part of the American Innovation and Competitive Act).

In the coming years, every level of government and organization will write its own story in the rapidly expanding universe of citizen science. We on the Council appreciate the opportunity to present this report and its recommendations to EPA. We hope that, going forward, the citizen science stories that EPA and other governments and organizations write will be stories whose happy endings are the strengthening of the economic, environmental and health dimensions of the communities and people they serve.

Respectfully,

William G. Ross, Jr.
Chair
National Advisory Council for Environmental Policy and Technology

Cassandra Martin and her family suffer from asthma, but she joined with neighbors to count trucks emitting pollutants as part of the West Oakland Environmental Indicators Project, which resulted in positive changes in local air quality. Now she shares lessons about the value of community science with local teens each summer, using science, technology, engineering and mathematics knowledge to track particles above ground and in BART train stations. **Photo credit:** Courtesy The Crowd & the Cloud, supported by the National Science Foundation.

Executive Summary

This report was developed by the National Advisory Council for Environmental Policy and Technology (NACEPT or Council), which consists of 25 members representing academia; business and industry; nongovernmental organizations; and state, local and tribal governments. NACEPT conducted extensive interviews in the process of developing its most recent recommendations about citizen science. These recommendations outline the ways in which EPA can foster collaboration and partnership to use citizen science information and data for action that improves human health and the environment. The Council has provided high-level, overarching recommendations in this report for strengthening collaborations to support pathways of moving citizen science from information to action. Specific implementation actions should be determined internally within the Agency and enacted throughout EPA's programs and regions. Below, the Council highlights recommendations that are explored in more depth in the body of the report.

The large number of citizen science projects that exist offer high-impact opportunities for EPA to apply citizen science to its mission. The diversity of citizen science projects across various media can be applied to the diversity of the Agency's programmatic responsibilities, and EPA can utilize new, lower cost technologies as innovative tools to address priority problems and challenges. Bold thinking will allow EPA to create valuable new avenues for citizen science use and address the vision in the Agency's strategic plan that all parts of society will have access to accurate information that will allow effective participation in managing their human and environmental health risks.

Cultural Shift to Citizen Science

The world is changing, and EPA will require an evolutionary shift to use its available resources to efficiently and effectively address current and future environmental challenges. This shift will require the Agency to apply innovation to its business model. Citizen science is an effective tool to achieve this, and EPA leadership must integrate this powerful movement into the Agency's core mission and work. Various EPA regions and programs have begun to experience the potential of citizen science. Although the use of citizen science data and networks is not yet an EPA cultural norm, citizen science is becoming a prominent factor in environmental and public health. The Agency cannot afford to be left behind; therefore, NACEPT's recommendations cannot be viewed as "add-ons." EPA must immediately implement those recommendations that do not require additional funding and develop strategies to leverage resources for those that require additional funding or adjustments. This bold change on EPA leadership's part will help the Agency to address the environmental challenges it faces and protect public health and the environment.

Invest in partnerships and collaboration to move citizen science from data and information to action

Citizen science is catalyzing collaboration; new data and information brought about by greater public participation in environmental research are helping to drive a new era of environmental protection. As the body of citizen-generated data and information in the public realm continues to grow, EPA must develop a clear strategy to lead change and encourage action beyond the collection of data. EPA should recognize the variety of opportunities that it has to act as a conduit between the public and key partners, including state, territorial, tribal and local governments; nongovernmental organizations; and leading technology groups in the private sector. The Agency should build collaborations with new partners, identify opportunities to integrate equity into all relationships, and ensure that grassroots and community-based organizations are well supported and fairly resourced in funding strategies.

Key recommendations under this theme:

- **Recommendation 1.** Catalyze action from citizen science data and information by providing guidance and leveraging collaboration.
- **Recommendation 2.** Build inclusive and equitable partnerships by understanding partners' diverse concerns and needs, including prioritizing better support for grassroots and community-based partnerships in EPA grant-funding strategies.

Increase state, territorial, tribal and local government engagement with citizen science

The Agency should reach out to tribes, states, territories and local governments throughout the country to understand the best practices and strategies for encouraging and incorporating citizen science in environmental protection. For states and territories looking for ways to engage in citizen science, EPA can help design strategies that recognize the community perspectives while building capacity in state and territorial governments. Recognizing the direct connection between EPA and tribes, the Agency should seek tribal input and support tribes in using citizen science for environmental priorities. EPA should help to increase awareness for citizen science and where jurisdictional efforts already exist, assist in making citizen science accessible through local government agencies. EPA should more proactively listen to the voices of local stakeholders and encourage partners to embrace a vision for citizen science to accelerate the achievement of environmental goals. As part of this approach, EPA should find ways to define and communicate the Agency's role as a resource in helping communities achieve environmental outcomes.

Key recommendations under this theme:

- **Recommendation 3.** Provide EPA support and engage states and territories to better integrate citizen science into program goals.
- **Recommendation 4.** Build on the unique strengths of EPA-tribal relationships.
- **Recommendation 5.** Align EPA citizen science work to the priorities of local governments.

Leverage external organizations for expertise and project level support

Collaborations between communities and other external organizations—including educational institutions, civic organizations, and community-based organizations—are accelerating the growth of citizen science. Because EPA's direct connection with members of the public often is limited, the Agency could benefit significantly by consulting with key external organizations to leverage citizen science efforts to provide the greatest benefit for the protection of human health and the environment. EPA should look to external organizations as vital connections to communities engaged in collaboratively led scientific investigation to address community-defined questions, referred to as community citizen science. External organizations can help EPA in assessing gaps in community-driven research and help the Agency to design effective support tools and best management practices for facilitating effective environmental citizen science programs.

Visitors observing plants at the National Aquarium in Baltimore, Maryland. ***Photo credit:*** *National Aquarium.*

Key recommendations under this theme:

- **Recommendation 6.** Co-create EPA citizen science priorities through consultation with external organizations.
- **Recommendation 7.** Create EPA policies, incentives and guidance that encourage engagement with stakeholders in citizen science projects.

Encourage transparency through open data and advanced technology policies

As citizen science increasingly builds on open data and advanced technology, EPA should extend efforts to increase public engagement in environmental research and protection through embracing transparent and accessible data and tools. The growing technology sector is an important but underutilized partner for expanding the scope and impact of citizen science, and EPA should enhance these collaborations while carefully managing expectations and transparency in public-private partnerships. EPA can strategically engage and understand the future ramifications of citizen science by providing training and encouraging expertise for EPA employees on advanced technologies.

Key recommendations under this theme:

- **Recommendation 8.** Expand public engagement in EPA work by prioritizing open licensing and making data and tools more transparent, accessible and usable.
- **Recommendation 9.** Encourage EPA collaboration with the private sector and other stakeholders on big data initiatives with careful consideration for transparency and EPA's governmental role.
- **Recommendation 10.** Build EPA expertise in advanced technology to facilitate collaboration and strategically engage in citizen science at national and international levels.

A Trout Unlimited volunteer in North Central Pennsylvania captures stream quality data as part of Trout Unlimited's Eastern Shale Gas Monitoring Program. Trout Unlimited members use an EPA-developed checklist, and their data are trusted sufficiently to be used by universities and government environmental agencies. **Photo credit:** Courtesy The Crowd & the Cloud, supported by the National Science Foundation.

Opposite page: *From* The Crowd & The Cloud*, a four-part public television series on citizen science, viewable at www.crowdandcloud.org.* **Photo credit:** Courtesy The Crowd & the Cloud, supported by the National Science Foundation.

CHAPTER ONE: Introduction

What is citizen science?

As discussed in the National Advisory Council for Environmental Policy and Technology's (NACEPT or Council) first report on citizen science,[1] in the last decade, a surge of enthusiasm has led to thousands of projects and efforts that engage members of the public in scientific research, allowing millions of volunteers and community researchers to contribute to science and policy and take advantage of technology advances that expand the boundaries of public participation in scientific research. Many organizations have adopted the term "citizen science" to describe a range of related efforts, and this term is gaining acceptance in public use. Other related terms and approaches include civic or community science, community-based monitoring, popular epidemiology, participatory sensing, crowdmapping, public participation in scientific research, public science, community environmental policing, street science, do-it-yourself or DIY science, participatory science, crowd science, open science, and crowdsourcing. These approaches often are rooted in different disciplines or emphasize different goals, but common to all is an emphasis on openness, democratization of science, and the mobilization of diverse people and communities. Citizen science is an approach to environmental information that actively and genuinely encourages and solicits public input in the scientific process and incorporates data and information generated outside of traditional institutional boundaries.

In citizen science, the public participates voluntarily in the scientific process, addressing real-world problems in ways that may include formulating research questions, conducting scientific experiments, collecting and analyzing data, interpreting results, making new discoveries, developing technologies and applications, and solving complex problems. EPA has engaged in citizen science primarily by working with community groups engaged in community citizen science. Community citizen science is collaboratively led scientific investigation and exploration to address community-defined questions, allowing for engagement in the entirety of the scientific process. Unique in comparison to citizen science, community citizen science may or may not include partnerships with professional scientists, emphasizes the community's ownership of research and access to resulting data, and orients toward community goals and working together in scalable networks to encourage collaborative learning and civic engagement.

> **"[Citizen science] has always been valuable to encourage citizens of all ages to participate in science; to appreciate it, learn about it, and maybe someday make a career in it."[2]**
> **–Djanette Khiari, Water Research Foundation**

The importance of community citizen science (many times driven by community groups and civil-sector intermediary organizations) and the power of this type of methodological process are in providing people with the tools to ask their own questions, collect their own data, and advocate for themselves.

Educating elementary school students about sustainable and healthy communities outside the school in Oakland, California.
Photo credit: *Ryder Freed.*

Citizen science is more than the participation of volunteers in research. It is a model for the democratization of research and policy making. In addition, it is an environmental movement that is changing the way the government and institutions interact with the public.

Citizen science and other crowdsourcing approaches that promote open collaboration offer the opportunity to educate, engage and empower members of the public to apply their curiosity and contribute their talents to advancements in science and technology. Active volunteers, community researchers and environmental advocates can provide broad geographic observations and information that could not otherwise be obtained by agencies because of time, geographic and/or resource constraints.

For purposes of brevity, throughout this report, the term "citizen science" is used to include both institutionally driven citizen science and community citizen science. The term "citizen science" also includes volunteer monitoring and other related approaches.

Recent history in citizen science

In September 2015, EPA asked NACEPT to develop recommendations on how the Agency might best use citizen science for the protection of the environment and health. Three overarching questions framed the review:

1. How can we sustain and improve current EPA projects and programs?
2. How can EPA invest in citizen science approaches for the greatest gain?
3. How can EPA help increase the impact of knowledge and data generated via citizen science?

NACEPT's First Report: *Environmental Protection Belongs to the Public—A Vision for Citizen Science at EPA*

In response to the 2015 charge from EPA, NACEPT explored current activities in citizen science both within and outside the Agency, interviewed citizen science practitioners and stakeholders in a diverse set of

Students working on a water quality project.
Photo credit: *Colorado River Watch.*

organizations, and drafted a set of recommendations. During this process, the Council obtained feedback from senior career staff at EPA, as well as external experts in the field.

In December 2016, NACEPT transmitted to the EPA Administrator its report, *Environmental Protection Belongs to the Public: A Vision for Citizen Science at EPA* (referred to hereafter as "the 2016 NACEPT report"). The report highlighted the transformational potential of citizen science for environmental protection and identified citizen science efforts as the best approach for the Agency to connect with the public. NACEPT assessed EPA's approach to citizen science in the context of current activities and recommended that the Agency proactively and fully integrate citizen science into the work of EPA.

The report was the first comprehensive review of how citizen science supports the core work of EPA and helps to frame technical, policy and social issues that need attention. The Council strongly recommended that EPA take a proactive approach to citizen science to be better prepared for a transition in how environmental data are collected and shared. A key recommendation was that EPA integrate citizen science into the core work of the Agency, including community engagement, environmental education, screening (condition indicators), research, management, regulatory decisions and standard setting, and enforcement.

In the 2016 NACEPT report, the Council recommended that EPA embrace citizen science as a core tenet of environmental protection, articulate and implement a vision for citizen science at EPA, and take a collaborative approach to citizen science. NACEPT recommended that EPA:

- Invest in citizen science for communities, partners and the Agency, including improving technology and tools and building technical capacity.
- Enable the use of citizen science data by adopting

Crowdsourcing and Citizen Science Act of 2016

Recent legislation—specifically, the Crowdsourcing and Citizen Science Act of 2016 (www.congress.gov/bill/114th-congress/house-bill/6414/text)—provides clear congressional authority and direction that encourages federal agencies to use citizen science. This congressional interest in citizen science is an important impetus for EPA to expand and broaden its current citizen science activities.

The underlying rationale presented in the Act is that "granting Federal science agencies the direct, explicit authority to use crowdsourcing and citizen science will encourage its appropriate use to advance Federal science agency missions and stimulate and facilitate broader public participation in the innovation process, yielding numerous benefits to the Federal Government and citizens who participate in such projects."[a]

The Act also lists some of the unique benefits of crowdsourcing and citizen science projects "including accelerating scientific research, increasing cost effectiveness to maximize the return on taxpayer dollars, addressing societal needs, providing hands-on learning in STEM, and connecting members of the public directly to Federal science agency missions and to each other[.]"[b]

[a]Crowdsourcing and Citizen Science Act, 15 U.S.C. § 3724 (2016).

[b]Crowdsourcing and Citizen Science Act, 15 U.S.C. § 3724 (2016).

Educating elementary school students about sustainable and healthy communities inside the school in Oakland, California. ***Photo credit:*** *Ryder Freed.*

a positive, cooperative agenda that increases the use of citizen science data, adopt standards for citizen science data, and provide guidance and communicate data quality needs for different data uses.

- Integrate citizen science into the work of the Agency, including its regulatory functions.[3]

In May 2017, NACEPT assembled four workgroups to build on the research and recommendations from the 2016 NACEPT report. Each workgroup represented core focus areas around which EPA citizen science collaborations could take place: (1) state, territorial, tribal and local partnerships; (2) open technology and data; (3) nongovernmental organizations; and (4) moving information to action. During the summer and fall of 2017, workgroups conducted extensive interviews and research into each focus area to develop recommendations.

Since the release of the 2016 NACEPT report, enthusiasm for citizen science approaches has continued. According to a 2017 Pew Research Center report, 16 percent of Americans report some participation in citizen science.[4] In addition, institutions around the United States interested in embracing citizen science as a central tenet of environmental research have made additional contributions. Organizations, including the RAND Corporation, Harvard Law School and EPA's National Environmental Justice Advisory Council, also are interested in embracing citizen science as a way to broaden interaction and participation in scientific research among individuals, communities and governments. These groups have recognized that the unique environmental challenges facing local communities require approaches that can harness the shared commitment of partnerships to achieve action beyond research.

RAND Corporation Report on Community Citizen Science

In late 2017, the RAND Corporation released *The Promise of Community Citizen Science*, which highlights the unique capacity and promise of community citizen science projects that "tend to be action-oriented, highly collaborative, or independently led by citizen volunteers, with research conducted to support interventional activities or policy change."[5] The report situates community citizen science in a larger context of a society in which the idea of expertise is being broadly challenged. The report also provides historical context for volunteer involvement in science, from early models of self-financed science to the rise of government research spending and "big science" after World War II. Citizen science broadly, and community citizen science specifically, represents a questioning of this traditional model of science and a new need for broader public involvement. RAND emphasizes the potential for community citizen science to achieve change by "building community capacity, promoting education, strengthening community engagement, or influencing decision-making."[6] RAND also describes case studies in Flint, Michigan; Sunset Park, New York; the Gulf States; and across Pennsylvania that highlight the potential for community citizen science to not only generate data, but also effect change. The report recommends that institutions broaden traditional measures and processes for science to account for the unique barriers and benefits of working with the public; for example, incentivizing community-engaged research and modifying peer-review processes.

Harvard Law School Emmett Environmental Law & Policy Clinic's *A Manual for Citizen Scientists Starting or Participating in Data Collection and Environmental Monitoring Projects*

In September 2017, the Harvard Law School Emmett Environmental Law & Policy Clinic published *A Manual for Citizen Scientists Starting or Participating in Data Collection and Environmental Monitoring Projects*. This manual is a practical guide for citizen scientists that includes technical suggestions for project design and implementation, explanations of legal and technical frameworks, and a look at laws and regulations with potential implications for environmental monitoring projects. The manual focuses on "those projects designed to remediate environmental problems that threaten community health and well-being."[7] As such, the goals of this manual are to support action beyond data and information gathering or generation. These may include citizen actions such as promoting education, stimulating public awareness, informing legislators, notice and comment rulemaking, petitioning for rulemaking, filing citizen suits, and stimulating future agency action. These also may include government actions such as a criminal prosecution, civil trial or administrative adjudication or to form the underpinnings of natural resource management decisions, planning for future activities, regulatory decisions, regulations/standards or enforcement.

An individual deploying a device to monitor for cyanobacteria.
Photo credit: *Mark Howarth, Candlewood Lake Authority.*

National Environmental Justice Advisory Council's *Recommendations and Guidance for EPA to Develop Monitoring Programs in Communities*

Often, one of the main drivers for community citizen science is environmental justice, a social movement that focuses on the fair distribution of environmental benefits and burdens regardless of race, color, national origin or income when developing, implementing or enforcing environmental laws, regulations and policies. The National Environmental Justice Advisory Council (NEJAC) is a Federal Advisory Committee that provides independent advice and recommendations on the issue of environmental justice to the EPA Administrator and other Agency officials. In October 2015, EPA asked NEJAC to provide advice and recommendations on how EPA can address the needs of communities when providing monitoring data through negotiated enforcement settlements and permits; NEJAC also was asked how the Agency can provide environmental data that are meaningful and relevant to communities and support these communities in improving their environmental conditions.

In its report in response to EPA's request, NEJAC recommends that the Agency collect timely and useful data, provide accessible and accurate data, deliver monitoring reports in ways most accessible to the affected community, and build community capacity.[8] NEJAC provides specific and actionable recommendations about how to allow a community to better understand a facility's environmental impact and act on data and information made available under settlement agreements or permits to improve community outcomes and advance environmental justice. NEJAC identifies website design features that would increase communities' ready access to data posted on a website and provides examples of effective websites. This report also presents other useful and meaningful ways of providing data and information to communities and recommends usable formats for data and information. Finally, NEJAC recommends forms of technical assistance that would help communities in gaining a greater understanding of the significance of environmental data.

Citizen scientists dig at an archaeological site at Shaw's Folly during the summer of 2015. **Photo credit:** Copyright 2015 Smithsonian Environmental Research Center.

Opposite page: *The archaeology laboratory at the Smithsonian Environmental Research Center hosts public dig days for citizen scientists. Citizen scientists are sifting through the soil dug up at an archaeological site in front of the Sellman House on Smithsonian Environmental Research Center grounds in July 2017.* **Photo credit:** Copyright 2017 Smithsonian Environmental Research Center.

CHAPTER TWO: Invest in Partnerships and Collaboration to Move Citizen Science From Data and Information to Action

A call for action

Citizen science is changing the way the government interacts with the public. Citizen science is making environmental protection more socially relevant, while accelerating and enabling participation and open collaboration between communities, institutions and the private sector. It allows contributions to environmental and health research that would otherwise be impossible, including data and information to fill current gaps, early warning of environmental issues and problems, and data and information on problems not adequately covered by monitoring networks. The surge of new scientific knowledge and public involvement enabled by citizen science presents an opportunity for EPA to improve support for groups hoping to use citizen science data and information to generate actionable outcomes. These outcomes exist across the spectrum of EPA's core work, including community engagement, environmental education, screening (condition indicators), research, management, regulatory decisions and standard setting, and enforcement.

Successful action cannot be achieved in isolation. It is built from trust, collaboration and innovation, all of which are catalyzed by citizen science. The work of EPA could benefit greatly from existing relationships that states, territories, tribes, local governments, nongovernmental organizations, colleges and universities, extension programs, and other organizations have with communities and individuals engaged in citizen science projects. These groups can serve as intermediaries between scientists, policymakers, communities and individuals. Improved support of citizen science outcomes can be achieved through strong investment in partnerships and collaboration with key stakeholders whose work aligns with EPA's mission of protecting human health and the environment.

> **"Communities who engage in citizen science are often trying to be recognized as people who have something important to contribute. They are often trying to document what they are experiencing in a way that regulators will notice. They understand that science talks and will be heard while they will not because they are poor or black or women. That is not to say that science isn't relevant—it is—but they're asking for more than that. They're asking for the EPA to protect them and to respect them as people who can credibly be believed in terms of what they are experiencing."[9]**
> **–Dr. Gwen Ottinger, Drexel University**

EPA must evolve to be more efficient and effective to succeed in addressing current and future environmental challenges. An evolutionary shift requires identifying and committing to new ways to apply innovation in EPA's

"Water quality issues are community issues. Monitoring and the data collected can be used to understand and address issues, as well as to document water quality successes. Has this worked? Resulted in positive results? Yes, natural resource agencies and natural resource nongovernmental organizations have used the citizen-collected data."[10]
–Peggy Compton, Wisconsin Water Action Volunteers Stream Monitoring Program

business model, in addition to systematic intention, persistence, communication and resource allocation over a critical period. Integrating citizen science data into the Agency's existing structure must be supported by strategic collaboration and empowerment vertically and horizontally to ensure the proper protection of human health and the environment. Various EPA regions and programs have begun to realize and experience this potential. The use of citizen scientist networks and data is not yet an EPA cultural norm and not yet systematically accepted or utilized across the country. Citizen science, however, is becoming a prominent factor in environmental and public health, with or without EPA, and the Agency cannot afford to approach this from the sidelines. Therefore, the recommendations issued by the Council must not simply be viewed as "add-ons" to current duties and programs. To utilize citizen science to its fullest extent, EPA will need clear commitment and leadership from EPA's programs and regions. The Agency can and must immediately implement those recommendations that require no additional funding. At the same time, EPA must develop strategies to leverage current and future resources for recommendations that need additional funding or programmatic adjustments. It will mean bold change, but a change that will produce results for public health and the environment and directly meet current and future challenges.

"Citizens help us find and track pollution, identify needs for cleanups, watch over sensitive environmental areas, educate each other, and sometimes even train others."[11]
–Gary Burlingame, Philadelphia Water Department

Tim McArthur (left) and Alex Korff of Science Systems and Applications, Inc. make final adjustments during the installation of the portable, low-cost air monitors (P-pods) in Kansas City, Kansas, on October 18, 2017, for a year-long air monitoring study. ***Photo credit:*** *EPA Region 7 Digital Team.*

Bold action required to target new citizen science work to help achieve environmental priorities

The Agency should strategically identify high-impact opportunities for applying citizen science to EPA's mission. Currently, a large number of citizen science projects focus on biology and conservation, and others monitor water and air pollution, but a growing number of innovative projects address other ecological and public health issues, such as digital health tools (AIR Louisville asthma collaboration and study, www.airlouisville.com), monitoring invasive species (Pacific Northwest Invasive Plant Council, www.pnw-ipc.org), studying the microbial composition of the human gut (American Gut Project, americangut.org), drug discovery from the soil (The University of Oklahoma Citizen Science Soil Collection Program, www.whatsinyourbackyard.org), and improving understanding of weather (Community

"Science, even when done by citizens, has a purpose to produce reliable data and facts upon which sound decisions can be made. We should not depreciate the meaning of science and how science is done. Citizens can understand this. It should be maintained as unbiased and objective and disciplined."[11]
–Gary Burlingame, Philadelphia Water Department

Collaborative Rain, Hail & Snow Network, www.cocorahs.org).

There is huge potential to apply citizen science and crowdsourcing to the diversity of EPA's programmatic responsibilities, each meriting strategic thought and experimentation. For example, the development of new, lower cost technology—such as wearable air pollution sensors or water test strips that change color to indicate the presence of lead, dissolved oxygen, bacteria and other contaminants—often opens up opportunities to apply these innovative tools to help find solutions to the priority problems and challenges that the Agency must address.

Bold thinking by EPA can result in valuable new avenues for citizen science. This can help to advance the element of EPA's strategic plan that envisions that "all parts of society—communities, individuals, businesses, and state, local and tribal governments—have access to accurate information sufficient to effectively participate in managing human health and environmental risks."[12] **Table 1** presents some promising areas for EPA and its partners to explore, areas in which citizen science may offer the most effective way to gather needed data and engage communities in solving environmental problems. This list provides examples and is not comprehensive. Rather, it is intended as a starting point for discussion.

Recommendation 1. Catalyze action from citizen science data and information by providing guidance and leveraging collaboration.

Action resulting from data and information gathered through citizen science can be realized through a wide range of uses (**Figure 1**). Understanding how citizen science data and information can be used to achieve a desired action is critical to finding opportunities to catalyze the flow of data and information to action. This involves identifying groups that have data and information to provide, the actions that can be achieved, and who can influence the utility of data and information to achieve a specific action (**Figure 2**).

When data and information can achieve action by individuals and communities, EPA should support collaborative efforts by developing guidance to help

Table 1. Future EPA Opportunities to Use Citizen Science for Environmental Protection

Drinking water	In a December 2016 report, the President's Council of Advisors on Science and Technology described how science and technology could more effectively help to ensure the safety of the Nation's drinking water. One of the recommendations was for EPA, working with other agencies, to "develop and support research to enable efforts to expand measurement and monitoring of drinking-water supplies in the United States by actively funding citizen-science activities such as home water testing, with an emphasis on including activities focused on drinking-water sources, small systems, and private wells."[13] Figuring out how to efficiently monitor drinking water at the tap for contaminants like lead is a high priority that must involve home residents.
Groundwater	The Wisconsin Well Water Quality Interactive Viewer (www.uwsp.edu/cnr-ap/watershed/Pages/WellWaterViewer.aspx) is a tool that helps people better understand the state's groundwater resources, particularly households that rely on private wells as their primary water supply. This "citizen science" data set primarily comprises well water samples voluntarily submitted by homeowners and collected by state agencies during the past 25 years. Anyone can use the online portal to view the spatial distribution of 14 different water quality parameters. This impressive state effort, which could be replicated in other states, allows comparisons of water quality in different towns or counties, raises awareness of local groundwater quality issues, and encourages well testing in areas where few data exist.

Table 1. Future EPA Opportunities to Use Citizen Science for Environmental Protection *(continued)*

Disaster response and recovery	Several federal agencies (Federal Emergency Management Agency, U.S. Geological Survey, National Oceanic and Atmospheric Administration) are now tapping citizen science and crowdsourcing in domestic and global responses to hurricanes, earthquakes and floods. Volunteers provide timely information for emergency responders on the ground and contribute to research related to the environment, hazards and disasters. For example, after the Caribbean hurricanes Irma and Maria in September 2017, thousands of volunteers worldwide helped analyze satellite imagery through an online citizen science platform (Zooniverse).[14]
Microplastics	The EPA-sponsored expert workshop in June 2017 on microplastics (www.epa.gov/trash-free-waters/microplastics-expert-workshop-report) highlighted the need to better understand the distribution of microplastics (plastic particles less than 5 millimeters in size) in water and improve understanding of their potential effects. Citizen science offers the potential to raise awareness of the issue of microplastics among citizens and have volunteers help to monitor microplastics in water bodies. For example, since 2013, the Adventure Scientist Global Microplastics Initiative (www.adventurescientists.org/microplastics.html, run by a nongovernmental organization, has helped to train thousands of volunteers around the world to help monitor microplastic pollution in marine and freshwater ecosystems.
Electronic waste (e-waste)	As the use of electronic products has expanded during the past 20 years, there is a dramatic need to improve environmental stewardship. One of the fastest growing components of municipal solid waste, e-waste has low recycling rates despite the fact that almost all of e-waste is recyclable.[15] It is possible that a citizen science approach, which engages individuals and households, could improve understanding of waste streams and define intervention points in the management of electronics throughout the product lifecycle both in the United States and abroad.
Toxic chemicals	New technologies allow the public to collect information about personal exposure to chemicals. For example, lightweight silicone wristbands now are being tested to measure environmental exposures to toxic organic chemicals.[16] Scientists hope to use these kinds of new tools to better understand people's exposure to pesticides, flame retardants, fragrances and endocrine disruptors.
Indoor air pollution	Citizen science approaches can be invaluable in monitoring indoor environments. For example, a local neighborhood in Northeast Denver, working with scientists, started a citizen science project to investigate local indoor air quality for perchloroethylene (PERC) and radon—gases that enter homes from groundwater and soil.[17] The goal is to help a local community "understand if they are at risk, raise awareness of air quality issues, and test a low-cost method for PERC detection that could allow anyone to screen their home."[18]
Stormwater and green infrastructure	In the same way that citizen science contributes to urban forestry, there is potential to apply this approach to urban stormwater. Citizen science provides an excellent opportunity for local residents to learn about green infrastructure, contribute new data about the presence and performance of these low-tech stormwater management techniques, and potentially help lead to technology improvements and exploration of new ways of approaching stormwater issues. More information about green infrastructure and community engagement can be found in EPA's *Green Infrastructure in Parks: A Guide to Collaboration, Funding, and Community Engagement* (www.epa.gov/sites/production/files/2017-05/documents/gi_parksplaybook_2017-05-01_508.pdf).
Abandoned mines	There are approximately 500,000 abandoned hard-rock mines across the United States, primarily in the 12 western states, which pose potential risks to human health and the environment. Federal agencies, such as the U.S. Geological Survey and Bureau of Land Management, are working to identify abandoned mines and assess the need for environmental cleanup.[19] Given the magnitude and scope of these issues, it is likely that citizen science approaches could supplement the work of technical experts in both field work and analysis of remote sensing data.

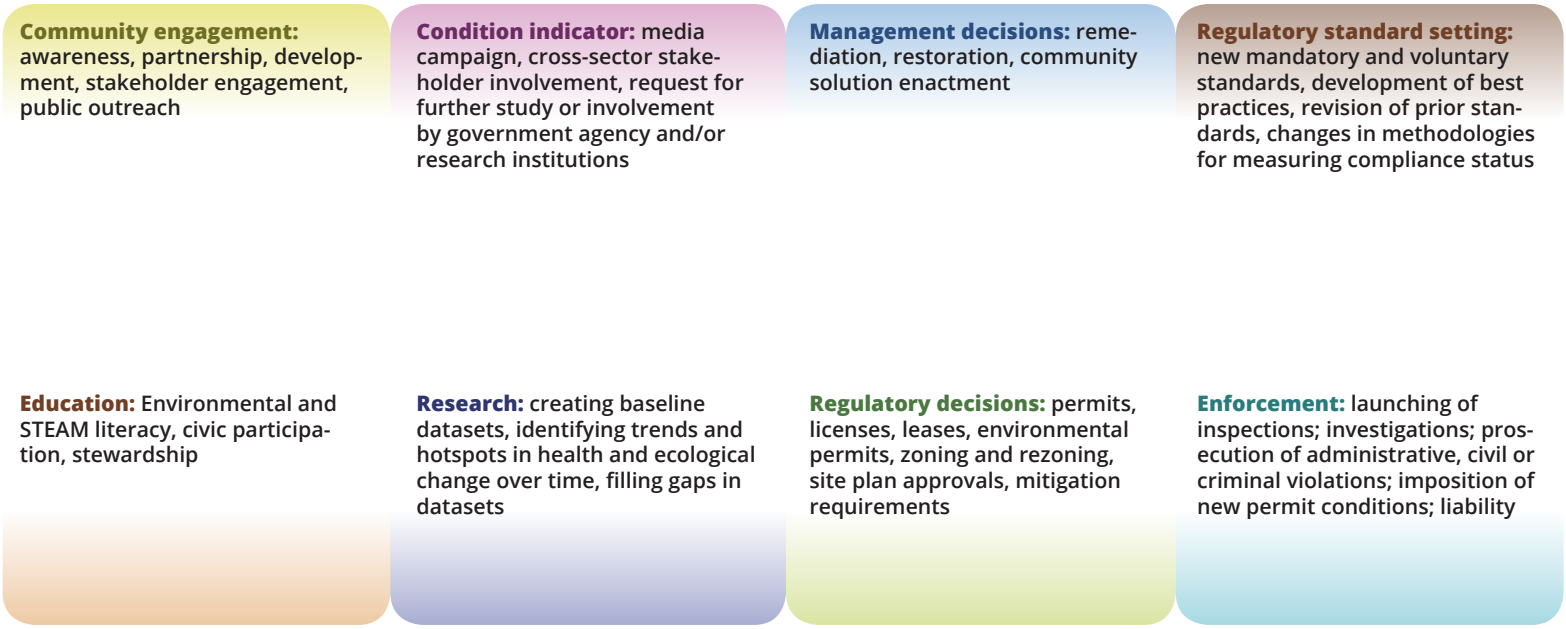

Figure 1. The spectrum of citizen science data use.[3]

> **"Input and collaboration with citizens and volunteers can help to collect and provide some of the critical data and information necessary to support the needs of environmental protection."[20]**
> **–Barry Woods, Retired Technical Assistance Provider**

individuals and local communities move from data collection to action. This guidance may take the form of a roadmap or toolkit and should include information about accessible contacts at local, state, territorial, tribal and national environmental agencies and support for increasing the value and use of data and information collected in citizen science projects.

Who has the information?

A wide range of groups can collect and use citizen science data, including local community organizations; nonprofit organizations; state, territorial, and tribal governments; federal agencies; and various combinations of these groups. Data and information gathered by citizen science projects can be initiated and implemented almost entirely by nonprofessional scientists or by institutions aided by EPA, as well as through collaborations by organizations of all types.[3] Therefore, EPA's efforts to encourage, support and utilize citizen science would be more successful if these efforts are predicated on strong collaborative relationships with each of these groups.

Who can act?

Often, whether or not an outcome can be achieved will hinge on the capacity and level of participation and partnership from collaborating groups. For instance, a group interested in using citizen science to increase the scientific literacy of children in a tribal community may benefit from partnering with local tribal leaders in science, technology, engineering and mathematics education or a local teachers' union. Partnerships and

> **"An honest dialog and a solid partnership with the public would be very beneficial to obtain valuable data and establish trust of the public in science. The ultimate goal being to protect 'public' health, we need to include the 'public' in science."[2]**
> **–Djanette Khiari, Water Research Foundation**

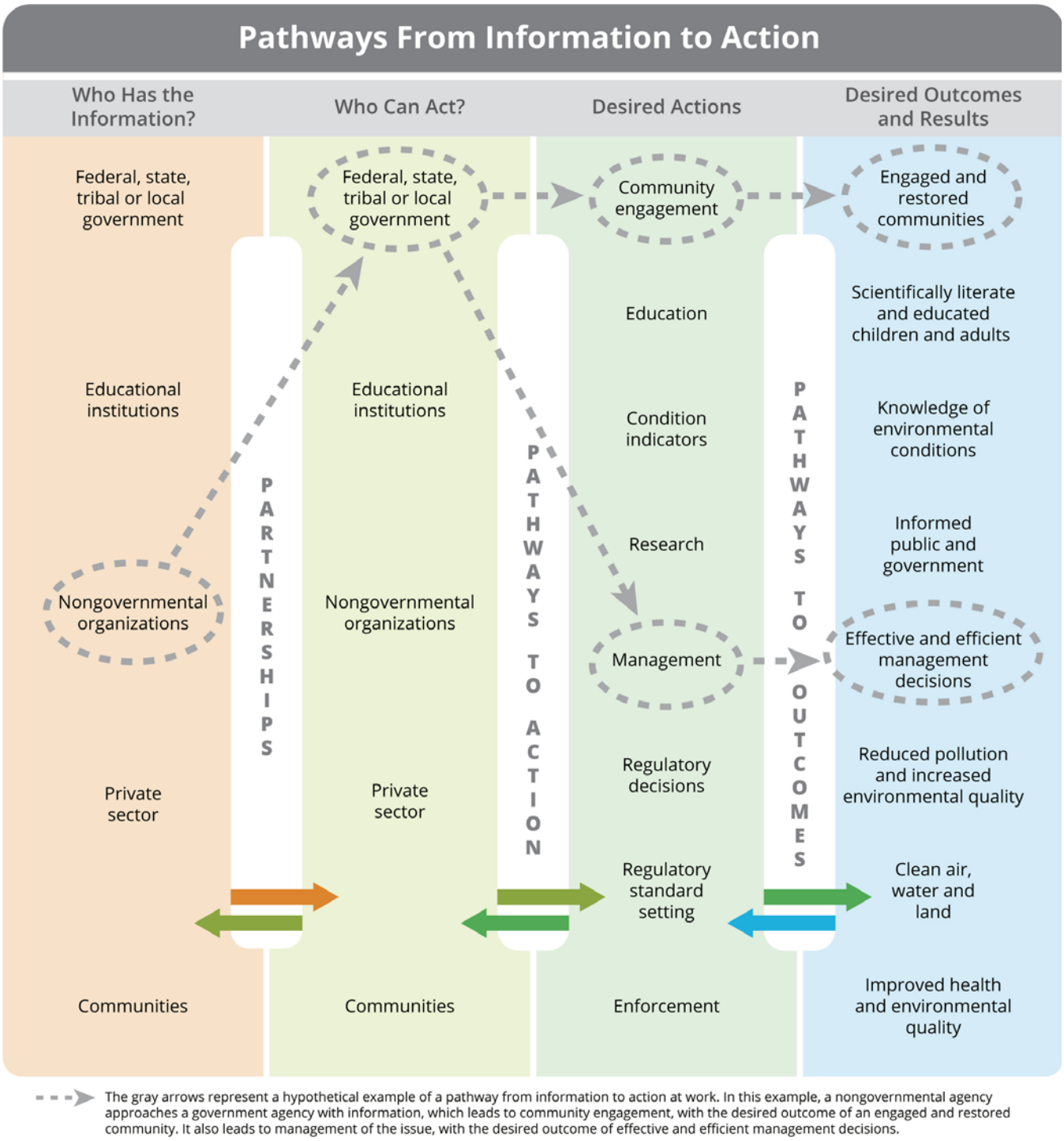

Figure 2. Pathways from information to action.

"[Citizen science] has triggered pollution track down, area cleanup, best management practice improvements, community awareness."[11]
–Gary Burlingame, Philadelphia Water Department

collaboration at this level across the spectrum are essential to effectively use citizen science data and information to generate action. To help facilitate the movement of data and information into action, EPA should work with partners to identify opportunities that effectively align the goals of citizen science initiatives with the expertise required to achieve desired outcomes.

What action can occur?

Citizen science data and information can provide a basis for organizations and communities to take action. The 2016 NACEPT report illustrates a spectrum of citizen science data use that touches on different areas of EPA's work, from community engagement, education, screening (condition indicators), research, management, regulatory decisions, regulatory standard setting and enforcement.[3] The spectrum can, therefore, provide a useful framework for approaching a desired action of groups.

"[Citizen science is] involving the public in providing information from their location as scientists cannot vet everywhere all the time. Important information can be overlooked if the public is not involved."[2]
–Djanette Khiari, Water Research Foundation

Actions to outcomes

Effective citizen science efforts are ones that generate action translated into measurable outcomes.

Outcomes often can be directly linked to areas within the spectrum of citizen science. For instance, an education-related project that exposes farmers to information and assessment tools on seed varieties can help improve knowledge in crop selection and allow these farmers to better cope with unpredictable weather conditions. The measurable outcomes from this type of project may include improved crop resilience, increased efficiency of water use and on-farm inputs, and decreases in excessive agricultural runoff. Identifying clear pathways to action can improve the efficiency and effectiveness of EPA's citizen science support and build stronger collaborations with groups seeking to move information to action (**Figure 2**).

"Our citizen science program is partially funded by the National Oceanic and Atmospheric Administration. It is purely educational, although we are looking into trying to find funding to broaden our reach to engage the public in data collection that helps identify if there are issues that need to be addressed."[21]
–Kris Stepenuck, Ph.D., Lake Champlain Sea Grant Program, The University of Vermont

In many ways, EPA already supports action through citizen science data and information (**Figure 3**). Well-established EPA programs already engage the public in collecting and using data for environmental protection, and in many ways, citizen science is built into legislation governing environmental protection, including the Clean Water Act, Clean Air Act, Safe Drinking Water Act, Superfund Amendments and Reauthorization Act, and Resource Conservation and Recovery Act. These laws sometimes "invite citizen science into public decisions," and in many of the resulting systems and processes, communities can play an important role in the collection of data.[22] Although they are not identical, these acts all allow EPA to communicate with the public and for the public to interact with the Agency. They also often grant the public access to data and enable the public to get involved in reviewing permits or take direct action for a cleanup or other response.[23]

"The volunteers…collect information that was used by the state to list waterbodies as impaired in the required biennial report to EPA."[21]
–Kris Stepenuck, Ph.D., Lake Champlain Sea Grant Program, The University of Vermont

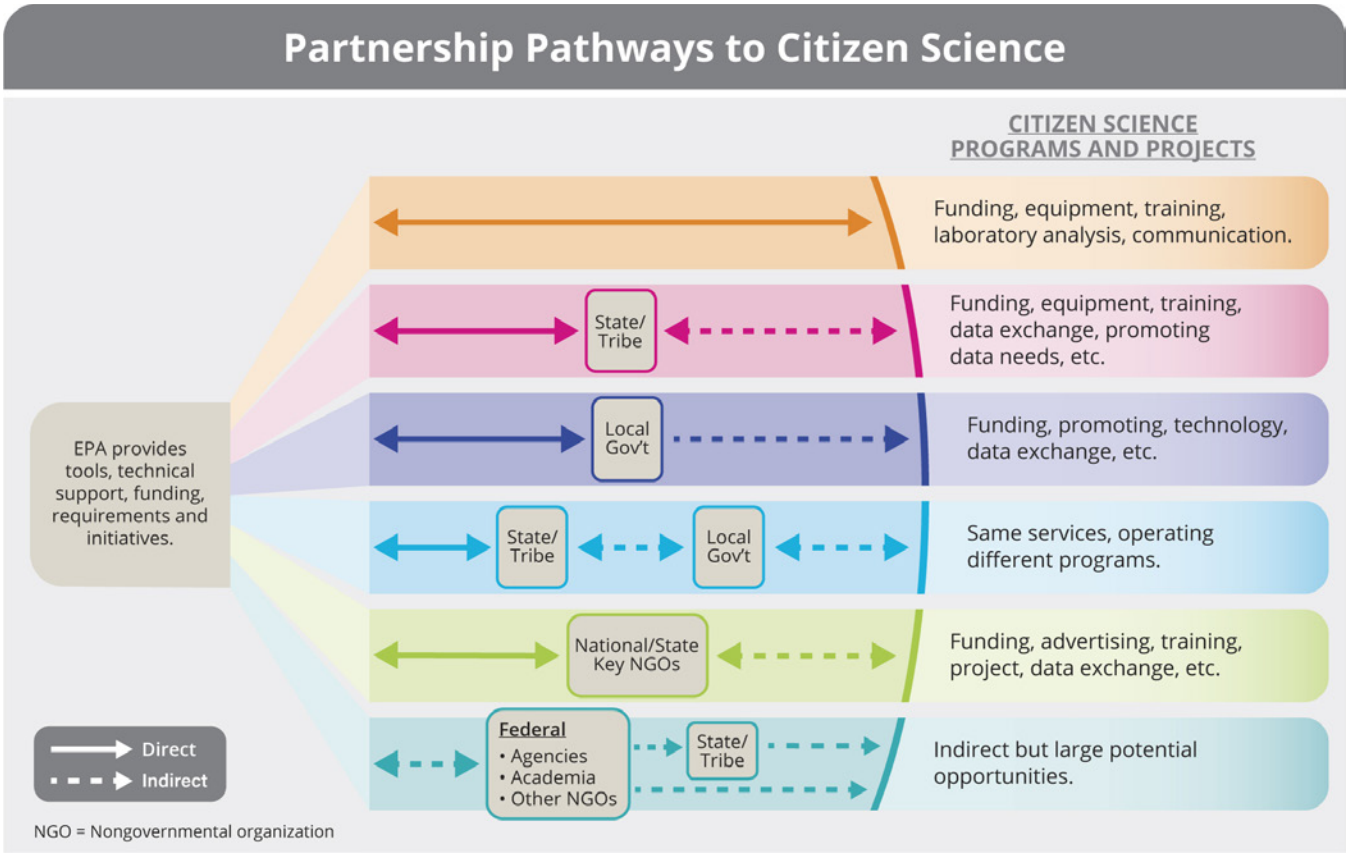

Figure 3. EPA contributes to a broader network of citizen science programs and projects.

EPA plays a key role in a larger network of government and nongovernment groups that—by working together—can vastly expand the amount and quality of citizen science work that supports environmental protection. EPA provides valuable support (either directly or indirectly through partners) for citizen science projects. A larger and more systematic approach at EPA would help build the capacity in external organizations that interact directly with individuals and communities. The types of EPA support needed include funding, equipment, training, technical assistance, guidance, data management and laboratory analysis.

Citizen science is supported by legislation and regulations that provide a framework for close collaboration between government and the public. Some examples in which environmental legislation and EPA process provide for public participation follow:

1. Superfund legislation provides for the development of studies to collect data to determine the extent of contamination. Violators pay or reimburse for these studies. This legislation "encouraged greater citizen participation in making decisions on how sites should be cleaned up."[24]
2. The Contaminant Candidate List in the Safe Drinking Water Act allows EPA to incorporate data and information in decision making using citizen science involvement by allowing citizens and scientists to nominate contaminants to be studied.
3. The Information Collection Rule in the Safe Drinking Water Act provides for citizen science involvement because users of resources are required to collect data to fill EPA data gaps.
4. Sanitary surveys are required under the Total Coliform Rule and other Safe Drinking Water Act rules. The community often leads this effort (every 3

"The Clean Water Act ensures citizen participation in the water quality monitoring and analysis realm."[21]
–Kris Stepenuck, Ph.D., Lake Champlain Sea Grant Program, The University of Vermont

Case Study. A Community-Academia-Industry-Government Collaboration Success Story

A Puerto Rican stream ("quebrada") *in the city of Caguas runs through a Searle/Pfizer pharmaceutical plant and the El Verde Housing Development. Part of the city storm water system drains into it, and it discharges to the Rio Caguitas, a very important potable water source. Recently, this stream began to intermittently demonstrate odor and changes in flow, and residents of the El Verde Housing Development were suffering from wastewater backflow into their bathrooms and kitchens.*

A Searle/Pfizer employee responsible for environmental compliance and community affairs became concerned and worried that the plant's neighbors would accuse them of dumping into the quebrada*, so he submitted a formal complaint to EPA's Caribbean Environmental Protection Division. To respond to the complaint, an EPA scientist visited the area but could not find evidence of contamination or any information that could be used in the stream's assessment. He recommended that the Searle/Pfizer employee contact an expert in water quality issues at the Center of Environmental Research of the Inter-American University of Puerto Rico. The university agreed to help if, in exchange, Searle would support a group of students in a field study to advance their education and experience with field assessments. They put an EPA intern in charge of the project and designed a study to gather information about the type of contamination and its source and to map the* quebrada's *origin and course as altered over the years. They gathered data on microbial and chemical water quality parameters during a 1-year period and conducted indicator and tracer studies and traced connections. This work aroused the curiosity of neighbors, as it is not every day one sees people opening manholes in the middle of the night and adding things to them, and immediately affected members of the community joined the efforts. An older resident provided prior knowledge about the area before it had been developed and with that information, the research team was able to trace the stream to a spring under a sports stadium.*

Community leaders suggested contacting the municipality because it had permitted and constructed most of the stormwater system. Representatives from EPA and the university asked staff from the small water system for ideas, and they suggested a localized workgroup with representatives from commonwealth, regional and municipal agencies and the community. Commonwealth agencies appointed representatives, and the mayor appointed representatives from local offices. Agency representatives were to research their agency's responsibility or authority for the quebrada*. The workgroup discovered that the public works and fire departments were responsible for maintenance, and the cultural department identified historical maps of the stream. Each of the workgroup members became excited to contribute to the effort.*

Ultimately, it was discovered that there were no cross connections or deliberate environmental abuse; rather, the sewer system of the city was overwhelmed with the increase in population. During high use or rainy days, sewers overflowed and drained into the quebrada*. EPA was able to negotiate compliance agreements with the responsible municipal and commonwealth authorities. The municipal government collaborated with the Puerto Rico Aqueduct and Sewer Authority and worked together to give priority to improvements to the wastewater system as part of a transactional agreement. The data collected by the partners were used to prepare Preliminary Engineering Reports to ask for rural development funding and the State Revolving fund support. The maps prepared by the students and EPA intern still are used for planning within this area of the city. Because of the increase in awareness in the community, additional sources of contamination were identified. EPA used the data and information collected by the community to initiate two enforcement actions, including one against a gas station that was improperly discharging water from a car wash.*

to 5 years, depending on the source) to gather data on the demographics, structure, sources, compliance and economics of the system.

EPA should recognize the variety of ways that it already engages in citizen science through well-established partnerships and leverage these relationships for additional impact. The Agency should integrate additional citizen science work within current EPA processes. At EPA and in scientific research generally, data and information collected by citizen science often goes unrecognized; for example, Cooper et al. found that 50 percent of what is known about migratory birds and climate change is

> **"Our field staff consider water quality data gathered by operators of small systems to help them optimize operations for public health and environmental protection."[25]**
> **–Joy Barrett, Rural Community Assistance Partnership**

based on citizen science data but not described that way in publications.[26] When data and information collected by the public are used, EPA should recognize the source of the data by citing citizen science in reports, publications and policies. Standardizing this language will help to validate the scientific merit of citizen science data and information and highlight the variety of ways that EPA already engages the public. By doing so, the Agency can make it easier for EPA managers and staff to understand and implement new opportunities.

There are a growing number and variety of citizen science projects supported by the Agency and its different program areas as shown in **Table 2**. Additionally, EPA often collaborates with external organizations to implement citizen science projects that help further the Agency's mission of protecting human health and the environment. **Table 3** illustrates some examples of these collaborations.

Action Item

EPA should demonstrate and communicate how citizen science already contributes to action for environmental protection and support individuals and organizations in achieving action through a toolkit or roadmap.

Table 2. EPA Citizen Science Addressing Environmental Challenges Across Media and Programs

Air	**Mobile App to Collect Wildfire Smoke Health Effects** www.epa.gov/air-research/smoke-sense-study-citizen-science-project-using-mobile-app The Smoke Sense app is an EPA crowdsourcing tool that collects data on the health effects of wildfire smoke on participants and what actions these participants are willing to take to lower smoke exposure. EPA will use these data to determine the extent to which exposure to wildfire smoke affects health and productivity and develop health risk communication strategies that improve public health on smoke days.
	Ironbound Community Citizen Science Toolbox ironboundcc.org/what-we-do/community/environmental-justice The Ironbound Community Corporation deployed air sensors for community volunteers to collect data and then use the results. The air quality data collected from the sensors benefit the Ironbound community by allowing residents to investigate and learn about pollutants of concern, increasing community awareness of air quality issues, and providing data needed to advocate for improved air quality.
	Air Sensor Toolbox www.epa.gov/air-sensor-toolbox The Air Sensor Toolbox advises citizen scientists and others how to select and use low-cost, portable air sensor technology and understand results from monitoring activities.
	Air Pollution Monitoring for Communities cfpub.epa.gov/ncer_abstracts/index.cfm/fuseaction/recipients.display/rfa_id/587 Six research organizations were awarded EPA's Science to Achieve Results grants to help communities learn more about local air quality and explore data quality, durability and uses of low-cost air pollution sensor technology. Research Triangle Institute, for example, is creating a framework for communities near Denver to design and conduct air quality monitoring studies.
Chemicals	**Mobile App to Monitor Bees** www.epa.gov/citizen-science/hivescience The HiveScience mobile app allows beekeepers to submit hive health reports and Varroa mite counts and request kits to send honey samples to EPA. These data may allow EPA to track hive health through analysis of honey samples and Varroa mite infestations across regions in real time. It also will provide information about the real-world effectiveness of the miticides registered by EPA.

Table 2. EPA Citizen Science Addressing Environmental Challenges Across Media and Programs *(continued)*

Land	**Gardenroots** gardenroots.arizona.edu Community members living near the Iron King Mine and Humboldt Smelter Superfund sites in Dewey-Humboldt, Arizona, worked with a researcher to investigate the uptake of arsenic in commonly grown vegetables, evaluate arsenic exposure and potential risk, and report results in an effective and meaningful way. As a result of the study, community members could make educated choices about the type of garden vegetables they would grow and eat and leveraged the results to encourage government officials to take action and be more stringent in their cleanup efforts. A small EPA Office of Research and Development grant helped to fund an early stage of this study.
Water	**Volunteer Water Quality Monitoring** Volunteers from various organizations collect water quality data to help improve the health of various water bodies. An example organization that performs this type of work is the Chesapeake Monitoring Cooperative (www.chesapeakemonitoringcoop.org). EPA grants often support these organizations in their monitoring efforts.
	Cyanobacteria Monitoring www.cyanos.org Members of the Cyanobacteria Monitoring Collaborative track harmful algal blooms (HABs) using a mobile app called bloomWatch. They collect cyanobacteria samples, submit images of the cyanobacteria to an online tool, and then interact with others online to confirm the identity of the cyanobacteria under the cyanoScope program. The cyanoMonitoring program allows them to monitor cyanobacteria over time (i.e., cyanoMonitoring builds on cyanoScope, which in turn builds on bloomWatch). The work of these citizen scientists provides information to government agencies to help address HABs when they occur. The cooperative receives in-kind support from EPA research programs.
	Regional Equipment Loan Program EPA's Region 2 loans out and provides training for water monitoring equipment to citizen scientist groups to conduct their work. Citizen science groups in Region 2 must apply for the loan, have a Quality Assurance Project Plan in place, and provide regular updates on the work being carried out with the loaned equipment.
	Hurricane Preparedness geopub.epa.gov/RAINE/PDF/Mattapoisett_Community_Engagement.pdf EPA engaged with the City of Mattapoisett (Massachusetts) to assess the vulnerability of the city's drinking water systems to salt water intrusion from sea level rise and storm surge. Boy Scouts in the city set up flood markers on utility poles to show the water levels from the past two hurricanes. These markers allowed residents to understand how high water levels reached and the extent of the flooding.
Other Environmental Projects	**LEO Tribal Crowdsourcing Tool** www.leonetwork.org The Local Environmental Observer (LEO) Network is a map application to crowdsource information from tribes on unusual animal, environmental and weather events by allowing tribal members to share stories and pictures. LEO allows citizen scientists to connect, raise awareness and find answers from experts about significant environmental events. This application received support through grants from EPA's Office of Research and Development and Office of International and Tribal Affairs.
	Environmental Violations Crowdsourcing Tool www.ivan-imperial.org The Identifying Violations Affecting Neighborhoods (IVAN) Network is an online crowdsourcing tool that collects environmental complaints in participating California communities. Government agencies address these complaints during monthly environmental task force meetings, which EPA attends. Two of the California communities that use IVAN received EPA environmental justice grants to start their environmental task forces.

Information in Table 2 provided by EPA. For more information about citizen science at EPA, please visit www.epa.gov/citizen-science. EPA staff members may find additional information on the Agency's intranet at intranet.ord.epa.gov/innovation/citizen-science.

Table 3. Examples of Successful Current or Historic EPA Collaborations

Collaborators	Collaborative Activities	Markers of Success
Colorado EPA, Colorado Department of Public Health and Environment, and Colorado River Watch	Collect metals, nutrient and macroinvertebrate data to remove waterbodies from impaired listings, provide alternative restoration strategy, and develop and refine multimetric macro index for use attainment	Waterbody segments added to or removed from impaired listings; macroinvertebrate use assessment criteria refined; data gaps in water quality and macro data narrowed; 87% more waterbodies assessed via Clean Water Act protocols than otherwise possible; more comprehensive 305(b) reporting
California EPA, Riverside-Corona Resource Conservation District (RCD), Orange County Coast Keeper, and Inland Empire RCD	Monitor water quality on the Santa Ana River	Data used in local resource management decisions
Hawaii EPA, Hawaii Department of Health, and Surfrider Foundation—Kauai Chapter (an example of one of Surfrider's Blue Water Task Force citizen science monitoring projects)	Monitor water quality and perform pollutant loading studies	Purchased probes; funded interns; identified bacteria sources from livestock and cesspools and pesticide use by GMO seed corn and coffee companies
Wisconsin EPA, Wisconsin Department of Natural Resources, and The Rock River Coalition	Stream Teams collect data that are used by the Wisconsin Department of Natural Resources in assessment decisions	Developed uniform data collection protocols for volunteers and state employees; coalition continued to fund positions based on the value of the effort; developed a user-friendly database
Virginia EPA—through specific programs— and Virginia Department of Environmental Quality, which supports local citizen science efforts	Use citizen science data to list or delist waters from impaired waters and for 305(b) reporting	Action taken at local level, such as fixing leaking sewer lines; achieved increased number of total maximum daily load goals; more cooperation at local level; funding for an annual operating budget to support citizen science that includes re-granting, 1.5 full-time equivalents and equipment
Alabama EPA, Alabama Water Watch, and Alabama Department of Environmental Management	Develop water chemistry, *Escherichia coli* and biotic indices for impaired listings and delisting to address pollution	Monitored 2,000 sites on 800 waterbodies during the course of more than 25 years with 6,000 certified monitors, resulting in some of the lengthiest data sets in the state; use of data by researchers, consultants, educators and the public
California EPA and Alpine Watershed Group	Understand and participate in the local Superfund site and monitor for total maximum daily load development for impaired waters	Created a water pollution literate community; engaged community in Superfund site; developed a path toward waters meeting uses

Table 3. Examples of Successful Current or Historic EPA Collaborations *(continued)*

Collaborators	Collaborative Activities	Markers of Success
New Jersey EPA, New Jersey Department of Environmental Protection, Lopatcong Creek Initiative, New Jersey Highlands Coalition, and Delaware River Watershed Initiative	Develop a watershed restoration and protection plan	Developed a community that is taking ownership of its river, which requires local buy-in for local, state or federal entities to benefit; restored native trout stream by reducing *E. coli* and total phosphorus levels
New Mexico EPA and Bosque Ecosystem Monitoring Program	Monitor the Middle Rio Grande through Albuquerque and educate K–12 and university students about river; inform pueblos, irrigators, land and water managers, stakeholders, and the public about the health of the river, ditches and aquifers; prioritize research and identify areas of concern	Collected quality data using state and federal protocols; data used by the University of Mexico, New Mexico Environment Department, Bernalillo County, and Albuquerque Metropolitan Arroyo Flood Control Authority; reached 200 students across seven schools spanning the diversity of Albuquerque
Chesapeake Bay EPA, Alliance for the Chesapeake Bay, and Save Our Streams (Izaak Walton League)	Restore habitat and monitor water quality	More waterways meeting uses than before start of project; some ecological systems returning to health; positively changed some land and management practices
Colorado EPA, Roaring Fork Conservancy, Mountain Studies Institute, Western Slope Conservation, and more	Collect macroinvertebrates, nutrient or other water quality samples for Clean Water Act decisions or project-effectiveness monitoring	More samples and work were completed for the same cost; decision was made and action taken because of the data provided; waterbodies were restored and protected

Recommendation 2. Build inclusive and equitable partnerships by understanding partners' diverse concerns and needs, including prioritizing better support for grassroots and community-based partnerships in EPA grant-funding strategies.

Understanding barriers to partnerships and collaborations with EPA

A necessary factor in a good partnership is a shared understanding of the role of each partner organization. Interviews with a wide variety of organizations made clear that many current and potential collaborators are not clear about EPA's role. This uncertainty stems from EPA's ad hoc approach to engaging in citizen science, resulting in different experiences for and perceptions of current and potential collaborators. Potential collaborators do not know if and when the Agency is available to partner on citizen science efforts, and many organizations tend to think of EPA only as a regulatory agency and not as a resource. Moreover, there is a lack of understanding on how to approach the Agency or engage EPA in a new partnership, especially when the potential partner is a small or local organization.

Additional barriers to partnerships with the Agency include a lack of staff dedicated to citizen science efforts, the inconsistency of EPA participation, and restrictions in EPA's scope of work. This limits and inhibits maximum use of citizen science data of a known quality. For example, Quality Assurance Project Plans (QAPPs) provide information regarding data quality, and EPA does not approve QAPPs for work not funded by the Agency. As an initial step to address this, EPA is

Students working on sea urchin studies with University of Hawaii Sea Grant. ***Photo credit:*** *Via the National Oceanic and Atmospheric Administration Citizen Science Community of Practice from Pelika Andrade/Hawaii Sea Grant.*

developing a quality assurance handbook to help guide quality assurance for those projects not funded by EPA. Further support would include criteria, a process and resources to review citizen science QAPPs and provide a "stamp" or certification that demonstrates EPA believes a particular QAPP would produce data of a known quality to answer data objectives stated in that QAPP or articulate areas that need improvement to reach that integrity. This certification would invite and encourage other data users to review, value and utilize these citizen science data sets that may not otherwise engage; EPA, states, tribes, local governments and all entities benefit the more data are discoverable. This type of review is not appropriate for every situation and would be a requested service EPA could provide, perhaps for feasible compensation. EPA also could assist states and tribes in developing a QAPP review and approval process that increases overall transparency and documents best management practices for all data generators.

EPA should develop and issue clear guidelines and policy for how nongovernmental organizations can approach the Agency with proposals for collaborative efforts, including a detailed description of the process small organizations should follow when soliciting EPA assistance in citizen science projects. To the extent that EPA is available as a resource, with outreach and communication efforts the Agency can counter the perception that it primarily is a regulatory agency.

Principles for equitable partnerships and collaborations can enhance credibility and trust and allow for consistent implementation of processes and procedures that guide the Agency's citizen science efforts. EPA should identify successful principles that guide equitable partnerships and align the Agency's principles to engage in equitable partnerships.

EPA generally requires those receiving funding to engage in partnerships that ensure that community-based organizations and nonprofit organizations are conducting projects that are responsive to communities' diverse needs. Often, however, the allocated resources are not sufficient to adequately support the assets that organizations and community partners are providing. EPA grants sometimes are too small to fairly compensate grassroots and community-based partnerships, even when those partnerships

Training volunteers to identify blue-green algae in a mobile laboratory near Squantz Pond in Connecticut. ***Photo credit:*** *Mark Howarth, Candlewood Lake Authority.*

are required. Equity in resource allocation across partners is necessary to ensure equitable partnership development. EPA should increase the amount of funding in each of these grant opportunities to provide better support for partnerships and should prioritize support for grassroots and community-based partners that are often under-resourced. Equity involves providing individuals and organizations with access (**Figure 4**) to the same opportunities and seeks to address and correct imbalances and uneven advantages and barriers.[27]

Challenges of this model include:

- The time commitment needed to cultivate authentic relationships;
- Resources needed to develop increased capacities for both the researcher and the community;
- Barriers to continued collaboration, including a lack of shared expectations about how information will be translated to action.

To overcome these challenges, an agreement between the researcher and community is central to facilitating decision making through alternative views and goals. Successful researcher-community collaboration includes tangible benefits to all partners. Sharing research responsibilities, resources and credit should be integral to power-sharing agreements. Responsibilities may include co-selection of the research topic, study priorities and outcomes; development of an analysis that includes researcher and community knowledge; data collection and analysis that incorporate the community perspective; translation and dissemination of data; and

"Community partners are uniquely qualified to co-develop and reap equitable, economic, and environmental benefits of collaborative research as these local experts possess the *in situ* knowledge and self-determination to affect successful outcomes."[28]
–Kevin Moore, Climate Resiliency Coordinator, New Jersey Environmental Justice Alliance

Figure 4. Equality versus equity.

Community-Engaged Research (CEnR): A Model for Principles for Equitable Partnerships[29,30,31]

Throughout the long history of collaboration between research and communities, environmental justice organizers and researchers have recognized that community-based research often can be defined and predetermined by the researchers. These projects frequently are conducted on communities, rather than with communities, and take on a top-down dynamic. Benefits for communities usually are not the core focus, but treated as ancillary benefits and not prioritized.

To redefine researcher-community dynamics, community organizers and researchers have characterized a different kind of research that emphasizes shared power between researchers and communities (**Figure 5**). In CEnR, co-developed research outcomes lift up both community and researcher priorities. This model includes a set of principles that define researcher-community interactions. Although this model was developed in the context of community-based research, it is applicable to citizen science and could be adopted as a model set of principles for equitable interactions among researchers, communities and research participants.

Principles[32,33]

- Recognizes community as a unit of identity.
- Builds on strengths and resources within the community.
- Facilitates collaborative partnerships in all phases of the research.
- Integrates knowledge and action for mutual benefit of all partners.
- Promotes a co-learning and empowering process that attends to social inequalities.
- Involves a cyclical and incremental process.
- Addresses health from both positive and ecological perspectives.
- Disseminates findings and knowledge gained to all partners.

co-development of an implementation plan to move from information to action. Resource sharing might include consultancies with community partners and stipends for local experts. Credit sharing may begin with the selection of co-investigators—one researcher and one community partner—and end with shared citations on publications in addition to the implementation plan.

"Researchers should not expect a community partner to put their credibility on the line unless the intention is to leave the community better off than it was because of the research."[34]
–Aureilia Laird, University of Maryland School of Pharmacy

Language is powerful, and terms used in grant proposals, community/researcher agreements, memoranda of agreement and other project documentation can negatively affect the power dynamic in a collaboration. For example, community partners should be referred to as research participants or researchers, not study subjects.

Action Item

EPA should communicate with collaborators and potential collaborators about the Agency's role as a resource and the obstacles that collaborators face in approaching EPA for collaborative work. EPA should research models and develop principles for engaging in equitable partnerships and develop a plan to shift grant-funding resources to adequately fund grassroots and community-based organizations.

	Collaborative Design	Iteration and Formative Evaluation	Summative Evaluation
Inform	Inform stakeholders about research (e.g., purpose, scope, duration or personnel)	Inform stakeholders of initial findings, initial challenges and opportunities	Inform stakeholders of summative research findings
Consult	Consult to determine existing evaluation practice and to document the programs under evaluation	Consult to determine stakeholder views on progress of research and document the development of evaluated programs since initial consultations	Consult to determine preferred dissemination routes
Involve	Involve stakeholder interests in the research design	Involve stakeholder interests in the iteration	Involve stakeholder interests in decisions about dissemination and future research needs/ possibilities
Collaborate	Collaborate on solutions to anticipated problems and on realizing and maximizing possibilities of the research	Collaborate on solutions to realized problems and identify gaps in the research and its findings	Collaborate on the dissemination of the findings to the higher education sector and relevant academic disciplines through conferences, reports and papers
Empower	Empower through building stakeholder evaluative capacity and by ensuring evaluation is designed so as to serve and maximize the interests of the stakeholders	Empower through providing stakeholders with a decisive voice in the assessment of the research project and the interactive redesign process	Empower through the effective dissemination of findings to inform stakeholder decision making and through the provision of an evidence-base for advocacy work

Figure 5. Community engagement continuum.

Source: Bower, K. 2017. "Introduction to Community Engaged Research." Presented at the Nuts & Bolts of Community Engaged Research Workshop, Baltimore, MD, December 1, 2017. Modified from: Agency for Toxic Substances and Disease Registry. 2011. *Principles of Community Engagement,* second edition. NIH Publication No. 11-7782. Washington, D.C.: Department of Health and Human Services, page 8.

Case Study. West End Revitalization Association: Demonstrating the Value of Community-Led Research to Address Environmental Justice Issues

National Institute of Environmental Health Sciences Research Program on Community-Engaged Research and Citizen Science

"In 1994, low income and minority residents of Mebane, North Carolina, established the West End Revitalization Association (WERA). WERA was formed in response to a long history of being denied access to city water and sewer, and a planned road that would destroy neighborhoods without mitigation. To address residents' civil rights and environmental justice concerns, WERA created an innovative research paradigm called community-owned and managed research (COMR). WERA combines COMR with collaborative problem-solving (CPS) to empower low-income minority communities to produce scientific data and translate research into action.

"Citizen involvement included:

- Managing the research process.
- Becoming certified community monitors, including:
  - Conducting household surveys and community mapping.
  - Collecting drinking water and surface water for fecal pollution testing.
- Mentoring youth through a career development program (DREAM Network)."[35]

A mapping group in Val Verde, California. **Photo credit:** Public Lab/Shannon Dosemagen.

Opposite Page: The Crowd & the Cloud *public television series host Waleed Abdalati (center) with Mariel and Angel Abreu during the Audubon Christmas Bird Count on location in the Florida Everglades. Angel and Mariel are enthusiastic birders and live out their tour group's slogan, "Nature is Awesome!"* **Photo credit:** Geoff Haines-Stiles/Courtesy The Crowd & the Cloud, supported by the National Science Foundation.

CHAPTER THREE: Increase State, Territorial, Tribal and Local Government Engagement With Citizen Science

Local, state, territorial and tribal governments have shown a high level of interest in using citizen science to improve environmental protection. The technological advances responsible for the increasing prevalence of low-cost apps and other data collection tools have clearly increased the number of citizen science projects that have been or are being implemented. There has been a corresponding increase in the level of interest among local communities in undertaking such projects.

> **"Reflecting the often local nature of community citizen science efforts, state and municipal government agencies have connected with citizen science, particularly around environmental monitoring issues."[36]**
> **–The Promise of Community Citizen Science**

There are many examples of data collected by citizen scientists that have been translated into action, primarily through partnerships and collaboration with local, state, territorial and tribal agencies. Citizen-monitoring activities include, among other actions, the classification of species ("endangered") and bodies of water ("impaired"), which can lead to interventions. Other examples include total maximum daily load monitoring, watershed assessment and planning, nonpoint source efforts, habitat restoration, waste reduction, establishing restoration goals and success, and conducting outreach and education programs.

Recommendation 3. Provide EPA support and engage states and territories to better integrate citizen science into program goals.

State and territorial governments can be powerful allies in EPA's efforts to promote and support citizen science at the local level. Many states and U.S. territories such as Puerto Rico and the U.S. Virgin Islands have citizen science activities in their environment programs that contribute to protecting human health and the environment; historically, these have focused on water monitoring. Other state and territorial agencies that deal with natural resources often also engage in citizen science efforts that support conservation, such as invasive species monitoring. Some key environmental legislation, such as the Clean Water Act and the Safe Drinking Water Act, requires states to solicit public participation and respond to data and information generated by citizen science.[37] State agencies are mandated to monitor the gathering of data for compliance by the regulated community. Currently, these data (collected by private water systems or a contracted laboratory) are not necessarily understood to be citizen science data; however, some members of the public do consider these data to be theirs. Moreover, the extent to which states and territories consider citizen science data is not well documented.

EPA intern collecting data in rural Puerto Rican communities. ***Photo credit:*** *Center for Environmental Education, Conservation and Research, Inter-American University of Puerto Rico.*

EPA should work with state and territorial environmental agencies to make citizen science a strategic priority. It is particularly important that EPA work closely with state and territorial organizations to fulfill the mission of environmental protection because these organizations have close connections with local communities and organizations; these groups can be EPA's conduit to local communities.

EPA programs such as the Clean Water Act and associated funding provide states with key pieces of study design and specific data and information needs, such as the information in 305(b) Integrated Reports. Effective study design with careful attention to the data and information needs of the Clean Water Act and other key environmental legislation allows monitoring programs to document and articulate measurable results and publish high-quality data.

EPA also should collaborate with those state and territorial environmental and natural resources agencies that encourage citizen science. A survey of state environmental agency websites was conducted for more information on state citizen science efforts, and outlined below are some examples of the range of citizen science work within four states. These examples are not comprehensive.

Colorado Citizen Science Activities

Colorado has an extensive range of citizen science efforts in and out of government.

Lead State Environmental Agency: Colorado Department of Public Health and Environment

Other Relevant Agencies: The Colorado Department of Natural Resources, which oversees Colorado Parks and Wildlife and the Colorado State Forest Service

Water Projects: Colorado Parks and Wildlife partners with a nonprofit organization, Earth Force, to coordinate volunteer water quality monitoring efforts across the state.[38]

Additional Information: The data from the Colorado River Watch program are used for watershed assessment reports for hundreds of watersheds across the state.[39]

Georgia Citizen Science Activities

Georgia uses a highly collaborative approach to engaging the public in environmental monitoring.

State Environmental Agency: Georgia Environmental Protection Division (EPD)

Other Relevant Agency: Georgia Department of Natural Resources

Water Projects:

- Georgia EPD runs the Georgia Adopt-A-Steam program that coordinates the training of volunteers across the state to monitor and take samples from local waterways. The program provides manuals, technical support and training in regional facilities and works with local organizations to build a network of citizen water monitors.[40]
- Georgia EPD hosts a river cleanup program that sponsors an annual, statewide cleanup day.[41]
- Georgia EPD works with the Georgia Lakes Society on an Adopt-A-Lake program to coordinate statewide monitoring of lakes.[42]

Other Activities:

- The University of Georgia has a citizen science CyanoTracker platform so that the public can easily provide actionable information for managers to choose areas for further analysis and testing.[43]
- The university also runs an Adopt-A-Wetland program to educate citizens on the importance of wetlands and train them to monitor wetland health.[44]

Additional Information:

- Georgia works in partnership with Alabama Water Watch to monitor watersheds that cross the state boundary.
- The Georgia Department of Natural Resources maintains a regional water quality database used by neighboring states to record baseline water quality and report trends over time.[45]

Michigan Citizen Science Activities

Michigan has a long history of using citizen science to improve water quality and conserve natural resources.

Lead State Environmental Agency: Michigan Department of Environmental Quality (DEQ)

Other Relevant Agency: Michigan Department of Natural Resources

Water Projects:

- MiCorps is a program run by the DEQ to support volunteer surface water quality monitoring. Under this program, there are volunteer groups to monitor lakes, streams and other surface waterbodies.[46]
- The DEQ also provides funding to local governments and nonprofit organizations for volunteer water quality monitoring efforts.[47]

Other Activities:

- The Alliance for the Great Lakes hosts an Adopt-a-Beach program.[48]
- A collaboration between the U.S. Geological Survey, National Geographic Society, National Oceanic and Atmospheric Administration, Great Lakes Observing System, and Sea Grant Michigan established FieldScope to allow citizen scientists to upload and interact with data about the water quality of the Great Lakes.[49]

Additional Information: Although data from citizen water quality monitoring efforts cannot be used for regulatory purposes, these data inform decisions for water use designation and further testing.

Virginia Citizen Science Activities

Virginia has a well-developed state program to support citizen science for environmental protection.

Lead State Environmental Agency: Virginia Department of Environmental Quality (DEQ)

Other Relevant Agencies: Virginia Department of Conservation and Recreation, Department of Forestry, Department of Game and Inland Fisheries

DEQ Water projects:

Virginia DEQ manages a citizen science water monitoring program that serves streams, lakes and rivers across the commonwealth. DEQ works with many local and nonprofit groups to train volunteers on water and ecosystem monitoring.[50]

DEQ also provides funding and support to local governments and nonprofit organizations for volunteer water quality monitoring efforts. Virginia Save Our Streams, for example, coordinates more than 600 volunteers collecting information on 250 streams and receives DEQ support.[51]

Other Activities: The University of Virginia's College at Wise runs the Citizen Science Initiative, which connects students and local community members to citizen science efforts that protect local waterways and ecosystems.[52]

Additional Information:

Virginia law directs DEQ to establish a citizen water quality monitoring program and provide technical assistance and funding to local monitoring groups.[c]

Although data from citizen water quality monitoring efforts cannot be used for enforcement decisions, these data inform decisions for water use designation and listing of impaired waters.

[c] Code of Virginia: *Citizen Water Quality Monitoring Program. Title 62.1, Chapter 3.1, § 62.1-44.19:11.*

EPA needs to help states and territories prioritize and integrate citizen science into their environmental efforts and programs. Starting with Agency-funded programs and mandates, EPA can provide guidance, ideas, principles, best management practices and/or incentives to state and territorial governments for leveraging citizen science. Just as the knowledge, comfort level and engagement with citizen science varies across EPA regions, state and territorial governments' citizen science experience varies, and these entities need support to embrace citizen science and integrate it as a strategic priority. EPA can require or encourage the consideration of citizen science data in funded programs and can provide more guidance and support to leverage citizen science data and information to action.

Action Item

EPA should help state and territorial governments make citizen science a priority and integrate citizen science efforts into goals and programs that relate to EPA's mission. This may include providing guidance, best management practices, principles, incentives, requirements, reporting and funding, as well as leading by example. EPA should identify instances of how these agencies are successfully using citizen science for action so that the Agency can publicize these success stories and help these entities derive greater benefit from their existing programs.

Recommendation 4. Build on the unique strengths of EPA-tribal relationships.

The *EPA Policy for the Administration of Environmental Programs on Indian Reservations*, signed in 1984, laid the groundwork to "give special consideration to Tribal interests in making Agency policy, and to insure the close involvement of Tribal Governments in making decisions and managing environmental programs affecting reservation lands."[53] The policy allows the Agency to work directly with tribes as sovereign entities, rather than as subdivisions of states, territories or local governments.

Tribal citizen science program activities protect public health and the environment within and around Indian country. Similar to state and territorial environmental citizen science programs, tribal programs depend on EPA's support, but EPA plays a unique role as a mediator between tribal nations, state and territorial governments, and other federal agencies. Often, EPA can help protect tribes from unwarranted actions, as was the case in 2017

Measuring flow changes in the inlet to an experimental slow sand filter being adapted for the Mulas community in Patillas, Puerto Rico. ***Photo credit:*** *Center for Environmental Education, Conservation and Research, Inter-American University of Puerto Rico.*

in Minnesota when EPA's Region 5 (Midwest) reviewed and denied regional general permits to the U.S. Army Corps of Engineers under the Clean Water Act because not enough time was given for tribal consultation and buy-in.[54]

Recognizing this unique role, EPA should ensure that citizen science resources are benefiting tribal communities by seeking tribal input in developing or reviewing programs that align program outcomes with tribal priorities. Because each tribe has a unique history and culture, citizen science tools and programs should be tailored to each tribe to effectively build capacity and enthusiasm for engaging their voices and skills. EPA support should emphasize the key role of tribes as partners in building on existing relationships to move data and information to action.

EPA's regional offices have direct connections with tribes and can help to facilitate support for citizen science throughout the country by aligning EPA program goals with tribal needs and capabilities. EPA should look to these relationship structures as opportunities to support tribes in developing policies and best practices in using citizen science for environmental protection. Recognizing that some tribes may be limited in their ability to monitor water quality, EPA Region 2 gave environmental justice communities and tribal nations priority for its Equipment Loan Program for Citizen Science Water Monitoring.[55] EPA should encourage all of its regional offices to take similar action-oriented steps that build capacity and trust.

Many tribal nations already use citizen science and are interested in expanding the types of applications.[3] EPA should learn from current best practices and strengthen its support for tribal governments that already are implementing or interested in implementing citizen science. Efforts should include but are not limited to:

- Incorporating citizen science programming support for the National EPA-Tribal Science Council, which comprises EPA representatives from each Agency program office and region, tribal representatives from each EPA region, and a representative of Alaska Native villages.
- Sharing the success stories from tribes that have achieved results using citizen science approaches.
- Developing tribal citizen science toolkits similar to other tribal-specific toolkits (e.g., green building, water quality)
- Facilitating tribe-to-tribe citizen science resource exchanges and knowledge sharing.

Tribal opportunities in citizen science also can be enhanced by creative funding strategies. For example, tribal science grants often require outreach. Tribal organizations may want to build citizen science into outreach components of proposals, and EPA should promote citizen science as an effective method for conducting scientific outreach.

Action Item

EPA should expand its support for tribal governments in using citizen science, especially through EPA's direct connections with tribes. EPA should seek tribal input in citizen science activities to ensure outcomes align with tribal priorities.

Recommendation 5. Align EPA citizen science work to the priorities of local governments.

Local governments—including large cities and small towns, county governments, and urban and rural communities—can play an important role in promoting and using citizen science. Local units of government are well positioned to raise awareness about environmental issues and can help lead environmental protection and education programs that deal with local concerns. A growing number of water and air monitoring programs are managed locally, many of which involve local government. Citizen science offers the potential to collect and leverage relevant data to inform local environmental decision making and actions to manage environmental health risks. Trends like smart cities (where municipalities use information and communications technology to increase efficiency, lower costs and enhance quality of life) offer great opportunities for increased public participation.

Demonstrating an air monitor to a group of people for the Kansas City Transportation Local-Scale Air Quality Study.
Photo credit: *EPA Region 7 Digital Team.*

"My research involved investigating small community water systems and community perceptions around the factors influencing their ability to comply with the surface and/or groundwater treatment and monitoring requirements of the Safe Drinking Water Act. Gaining interviews with EPA officials in the relevant region proved a bit difficult, as was probing for more detailed information beyond Agency-standard responses. Communities interviewed expressed frustration at being served noncompliance notices, but had little contact with EPA officials to even understand or know how to respond to the notices. Some of the EPA officials interviewed had overly generalized views of the communities as homogenous entities and failed to account for the diversity of socio-political struggles within the locale that prevented it from acting as a 'community' around the provisioning of water to households."[56]
–Sarah Opitz-Stapleton, Overseas Development Institute

Local governments are a primary conduit for EPA to reach communities and vice versa because local governments have established relationships with residents and organizations within communities. Through these relationships, they often have greater credibility with local residents and are more familiar with and responsive to the issues and challenges that local communities face. They already may have data that can be used to assess local problems and also may have other resources and capabilities (e.g., GIS expertise, equipment) that could be used to generate additional data. In some cases, local governments already may be engaged with community groups that are working to address local environmental and sustainability concerns.

Local governments and communities have great potential to collaborate with EPA in the gathering of data and in the implementation of environmental laws, such as the Clean Water Act. Federal law, however, frequently is blind to differences and circumstances that may hinder a community's ability to collaborate. For example, the implementation of the Safe Drinking Water Act requires dealing with 149,000 small systems that serve fewer than 3,000 people (usually 25 to 400 households). These systems serve people with different ethnicities, levels of education and economic status and often

District of Columbia Citizen Science Activities

The government of Washington, D.C. and surrounding local communities have led efforts to preserve the local environment with citizen science efforts.

Lead Environmental Agency: D.C. Department of Energy & Environment

Other Relevant Groups: Maryland-National Capital Park and Planning Commission[57], Prince George's County Parks and Recreation Department, Metropolitan Washington Council of Governments

Water Projects: The D.C. Department of Energy & Environment and the Metropolitan Washington Council of Governments are working with local organizations to coordinate citizen science efforts to protect the Anacostia River.[58]

Other Activities: The Metropolitan Washington Council of Governments created an Environmental Justice Toolkit guiding policymakers on how to use citizen science as a tool to increase engagement with disadvantaged communities.[59]

have different burdens because they are in different watersheds or have a different climate. Generally, each system individually collects data needed by EPA to reach congressional objectives. These small systems often are unable to aggregate their power to collaborate with EPA in the search for data and information.

Citizen science groups can provide information that local governments and communities can use to protect public health and the environment. For example, the Senior Environmental Corps in Philadelphia discovered untreated sewage in a creek that threatened to contaminate the city's water supply, resulting in a $1 million dollar emergency intervention by the Philadelphia Water department.

Action Item

EPA should explore how to best build capacity in local government for citizen science. This includes both projects organized by local government and those coordinated by other local organizations (libraries, garden clubs, youth organizations, schools, etc.). EPA should work with local governments to define opportunities for citizen science to support local priorities and recognize the different needs of local governments and organizations when creating national priorities and plans.

A volunteer trains other volunteers how to carry out data collection in their communities. ***Photo credit:*** *Courtesy The Crowd & the Cloud, supported by the National Science Foundation.*

Jose Barros (left), President of Tropical Audubon, and Paul Bithorn participating in the Audobon Christmas Bird Count in the Florida Everglades. The Bird Count began in 1900 and is one of America's longest running citizen science projects. Instead of killing birds for bragging rights, founder Frank Chapman suggested counting, eventually generating data that can show environmental change over time. **Photo credit:** Nathan Dappen/Courtesy The Crowd & the Cloud, supported by the National Science Foundation.

Opposite Page: *Participating in the Colorado River Watch program.* **Photo credit:** Colorado River Watch.

CHAPTER FOUR: Leverage External Organizations for Expertise and Project Level Support

During NACEPT's interview process, many interviewees expressed the view that EPA lacks an understanding of other organizations, especially in terms of limits in the resources of nongovernmental organizations. Limited resources may result in the inability of representatives of small external organizations to travel, attend conferences or devote resources to project management. For meaningful engagement, EPA must meet organizations "where they are" to facilitate partnerships and collaboration. To pursue partnerships with external organizations, the Agency should think strategically about how partnerships can address limitations in Agency work and the strategic benefits other organizations can provide toward EPA priorities (**Table 4**).

Recommendation 6. Co-create EPA citizen science priorities through consultation with external organizations.

External organizations have access to and relationships with citizen science groups and projects. These networks can be utilized for direct access to people who are implementing citizen science in their work and can help EPA assess data gaps, advise on citizen science needs and best management practices, and educate on principles for equitable partnerships. They also can provide a conduit for EPA and tribal, state, territorial and local governments to disseminate helpful information to the citizen science community. Partnerships and collaboration with these groups can help the Agency consistently and systematically integrate citizen science into its mission. These groups also can provide relevant information, training and resources to the citizen science communities and assist with cultivating relationships, developing capacity and managing expectations. Organizations that could act as intermediaries include the Citizen Science Association and the River Network, as well as place-based organizations, such as Air Alliance Houston. EPA should develop a strong working relationship with these and other key external organizations and rely on them to co-create EPA citizen science priorities through a consultation process.

Stakeholders expressed a need for a variety of resources and assistance from EPA, including the following:

Capital Investment

- Funding to support citizen science projects, including direct funding and guidance for obtaining other funding.
- Monitoring equipment, apps and other technical tools that citizen science groups can use to collect data.

Technical Assistance

- Easily accessible contacts in each EPA region or program for assistance with QAPP development and approval or as a resource for citizen science collaborations.
- EPA employees with expertise in communicating with the public on technical questions.
- Training and support for data management, especially for contributing to the National Water Quality Portal and the Water Quality Exchange.

Table 4. Partnership Opportunities: Connecting Organizations to Work With One Another and With EPA

Type of Potential Partner	Examples of Organizations	
Government	• Federal • Tribal • State	• Regional • Local
Educational institutions	• K–16 (public, private, home school) • Colleges and universities • Museums • Libraries	• Science centers • Cooperative extensions • Makerspaces
Nongovernmental organizations	• Environmental organizations (conservation groups, environmental health organizations) • Environmental justice organizations	• Volunteer organizations • Hobbyists (outdoor and sportsmen's groups, boaters and outfitters associations) • Land trusts and watershed associations
Private Sector	• Water users • Water, air and land managers • Water planners • Sampling and analysis equipment developers and providers	• Software, application and systems developers • Agricultural associations • Professional organizations

- Assistance with study design, including identifying monitoring questions and data objectives, as well as targeting specific decision makers and their data and information needs.
- Assistance with data analysis protocols and procedures.

Policy/Guidance

- Creation of standards for providing data of known quality for known decision processes.
- Support for increasing the value and use of the data collected in citizen science projects.
- Outreach materials about citizen science.
- Information on citizen science projects and success stories.
- Technology recommendations, including monitors and other tools for data collection.

Action Item

EPA should create a strategic partnership with key external citizen science organizations. These partnerships should identify specific roles for each organization in order to help the Agency consistently integrate citizen science to meet its mission of protecting human health and the environment.

Recommendation 7. Create EPA policies, incentives, and guidance that encourage engagement with stakeholders in citizen science projects.

EPA does not consistently engage in citizen science across EPA's programs and regions. For example, interviews suggest that EPA regions tend to be more conservative

Collecting saliva samples in Puerto Rico to perform an immuno-assay to determine exposure to waterborne pathogens. ***Photo credit:*** *Center for Environmental Education, Conservation and Research, Inter-American University of Puerto Rico.*

in their interactions with the public than EPA program staff. A cooperative model that embraces citizen science is especially important in EPA's regional offices because these offices often administer partnerships with local nongovernmental organizations.

EPA should establish clear policy, incentives and guidance about when and how to use citizen science to create a systematic path and Agency norms around these approaches. This guidance should include a common lexicon for citizen science implementation that would help standardize documentation, communication and progress nationwide. EPA should empower and incentivize regional employees to interact with local organizations. For example, the Agency should empower regional employees to create methods to allocate Supplemental Environmental Projects (SEPs) (part of the enforcement tools after a finding) as a source of funding citizen science. To support that effort, EPA should prepare an inventory of research needs at the local level to negotiate SEPs. Alternatively, EPA could consider redesigning SEP funding processes to be more inclusive of citizen science efforts, such as by embracing a more cooperative model or a pooled approach.

A cross-section of EPA personnel at different levels and roles at the Agency have varied ideas and perceptions about the meaning and use of citizen science. At regional offices, many described citizen science as a tool that facilitates collection of data by local residents that would be difficult or too expensive to obtain with limited human resources or government funding. At the local level, many described citizen science as a tool for working with members of the public with scientific knowledge or skills,

"*Familias Unidas del Chamizal* wants to work with citizens to monitor air quality in the Chamizal neighborhood in El Paso, Texas. Multiple air quality detectors will be distributed to trained citizens who can set up equipment in their own backyard. Data can be collected together as a community to understand the quality of air in this neighborhood. The group also wants to work with students at the local Bowie High School to help execute a public health survey for a general community health assessment. As a part of the Chamizal community, these students will develop a connection and consciousness of what is happening in their community and how it affects them."

–Hilda Villegas, Familias Unidas del Chamizal[60]

EPA and Inter-American University of Puerto Rico staff and members of seven Puerto Rican communities discuss data and information sharing for an epidemiological study aimed to help the communities. ***Photo credit:*** *Center for Environmental Education, Conservation and Research, Inter-American University of Puerto Rico.*

including working with these skilled members of the public to gather needed data for decisions and learn data collection techniques. Scientists within EPA Headquarters programs described citizen science as any information received by the Agency from outside sources. All of these are useful definitions and complement the overall goal of partnership, cooperation and collaboration between EPA and states and territories, local jurisdictions, external organizations and tribal nations. This diverse set of ideas, however, speaks to the need for consistent policies and guidance for citizen science among EPA staff, especially those who already work with communities.

EPA programs such as Environmental Justice, Urban Waters and Community Action for a Renewed Environment have supported and promoted numerous projects in which grassroots organizations and/or communities overburdened by contamination have served as partners in the gathering of data and information to prevent or correct environmental issues that affect health and quality of life. Groups that participate in these programs have been readily recognized by EPA and know how to access the Agency and voice their concerns.

NestWatch is a citizen science project that monitors the status and trends in bird reproductive biology, including the timing and survival of eggs and hatchlings. Citizen scientists contribute to a database of breeding bird populations by finding a bird nest, visiting the nest every 3 to 4 days and then reporting their findings to the database. Results inform an understanding of breeding bird population numbers and the impact of climate change, habitat loss, landscape change, and non-native plants and animals.[61]

Action Item

EPA should develop clear policies for how to engage in citizen science work. This policy and guidance should be focused especially on EPA's regional offices to expand local collaborations.

Case Study. Applying Supplemental Environmental Project (SEP) Funds to Citizen Science Projects in Puerto Rico

EPA officials in charge of small potable water supplies in Puerto Rico had an idea: working together, they could help the region comply with congressional goals for safe drinking water by providing a mechanism to use SEP funds to apply fines from violators to citizen science projects. EPA employees believed that this type of negotiation could result in citizen science and collaborative projects that would have a positive effect on EPA's agenda and goals in the area. These projects could help the region meet its goals and improve health in the rural, underprivileged areas that it is charged to protect. Staff consulted with their supervisors and decided to perform a pilot project to determine the possible legal and administrative barriers for such application of the SEP process. In a recent enforcement case, a construction company and a quarry violated their National Pollutant Discharge Elimination System permit by discharging into a small stream that serves as the source for small potable water supplies. EPA negotiated a SEP to be offered to the violator and engaged the community and a local university to collect the preliminary water quality data needed for the design. In principle, the violator accepted the idea. After months of work, however, the violator decided to pay the fine. Moving forward, EPA officials are developing an inventory of SEPs that violators could choose to fund with their regulatory fines. The question remains, however: What amount and type of funding from SEPs should be allocated to citizen science work? Because it is a voluntary action, what will motivate violators to choose to support citizen science?

Opposite page photo: *Youth in the Bourj Al Shamali refugee camp in south Lebanon use a kite to map a refugee camp from the rooftop of one of their houses.* **Photo credit:** Claudia Martinez Mansell.

CHAPTER FIVE: Encourage Transparency Through Open Data and Advanced Technology Policies

"When EPA communicates data, they focus only on how it can inform individual choices. The overall message seems to be, if AQI is bad, stay indoors. Most people, especially the most vulnerable people, don't have those choices. EPA should look at the data in terms of how it reveals systemic issues, in order to improve environmental quality."[9]
–Dr. Gwen Ottinger, Drexel University

Recommendation 8. Expand public engagement in EPA work by prioritizing open licensing and making data and tools more transparent, accessible and usable.

EPA can empower citizen scientists and maximize opportunities for the public to engage in environmental research and protection by increasing the level of transparency in all aspects of the Agency's work. So far, EPA has focused on sensors and personal monitoring opportunities; however, EPA should open up and transparently engage the public in hardware and software use and development, data collection, model use, publishing, the development and implementation of grant programs (and development of subsequent publications), and peer review. This would provide additional avenues for engaged members of the public to participate in environmental protection, from education and community engagement to regulations and enforcement.[3]

Open data often are not easily accessed or interpreted by those who want to use them. EPA should make open datasets accessible, interpretable and useful for a variety of audiences by creating systems for data visualization and use in parallel to their open datasets. EPA should (1) develop a standard for open data sharing, (2) make

According to the National Environmental Justice Advisory Council (NEJAC), "Merely making data available on a website does not make it meaningful or useful to a community. Most people need training or help to be able to fully understand and gain useful knowledge from monitoring data. This training should help them understand and apply the data and information to their problems or concerns."[8] NEJAC provides specific suggestions for how to do so, including recommending that EPA provide data focused on community concerns, provide additional information with raw data, include explanations and comparative analysis to help people understand threats, report data within the context of the ambient conditions, and include simple, direct language when presenting cautionary information.[8] EPA can create analysis and interpretation tutorials, which will provide a place for organizations to interact with their data, draw conclusions, take action and tell their story.

Arizona State University and SciStarter hosted the Citizen Science Maker Summit at the ASU Chandler Innovation Center in Chandler, Arizona. The day-and-a-half event brought together academics, practitioners, educators, citizen scientists and makers to catalyze and strengthen collaborations between the communities. Objectives included the following: develop a framework for a public-facing database of common citizen science tools to complement SciStarter's database of citizen science projects and events; identify real-world case studies including efforts to identify, build or improve low-cost tools for citizen science; address issues of access: how to better reach and support underrepresented communities and educators around citizen science and making; and explore plans for future citizen science and making collaborations.[62]

the case for data publishing and treating data as an asset by publishing data for others to use and providing all necessary metadata and supporting resources, and (3) integrate that standard as a practice in all programs, grants and peer reviews.

Open data and tools need to improve the quality of the environmental and health science EPA uses for its work, and the Agency should remove barriers that prevent citizen scientists from accessing these tools. EPA should support and incentivize open-source licensing in EPA funding for citizen science tools, which would allow for results, tools, equipment and techniques to be sharable and not patentable. Funding applications should emphasize open-source licensing and, when open-source licensing is unavoidable, require applicants to justify why proprietary licensing is necessary. EPA should partner with nongovernmental organizations that can provide support on technology design processes, iterations, piloting, verification and workflows related to citizen science projects; these groups can identify technology needs along the pathway from data and information to action and help with the design of these tools to meet community needs.

As an important part of this effort, EPA should recognize the value of nondigital sensors and recognize that do-it-yourself (DIY) methods and analog tools, such as odor logs, can provide data appropriate for some uses and actions. EPA should value the development of nondigital technology based on which tools are appropriate along the spectrum of citizen science data use.[3]

To ensure broader accessibility of open technology tools, EPA should encourage the use of lending library models and support lending libraries through partnerships and collaborations with external organizations. Lending libraries can provide means for people to access otherwise high-cost technology. EPA should both facilitate successful lending programs, such as developed by EPA's Regions 1 and 2,[63] and through resources such as training modules, documentation and funding, support other lending programs developed by citizen science projects.

Action Item

EPA should increase its efforts in open hardware, software, data, models, publishing and peer review. EPA should work to make data more accessible, prioritize open licensing, value DIY and nondigital sensors, and encourage lending libraries.

Recommendation 9. Encourage EPA collaboration with the private sector and other stakeholders on big data initiatives with careful consideration for transparency and EPA's governmental role.

Private companies, associations, nongovernmental organizations, app developers and other stakeholders have a growing interest in the field of citizen science. Industry interest ranges from that of Fortune 500 companies to small startups, as well as products from sensors to apps to forecasting capabilities to data repositories. The growing technology sector is an important but underutilized partner for expanding the scope and beneficial effects of citizen science. Companies and other stakeholders have the capacity to develop technology for citizen science efforts, including team-building, product design, data collection and analysis, and information dissemination. EPA should facilitate collaborative research and development with companies

and other stakeholders that are testing new approaches to big data system development, open-access data platforms and innovative security approaches. Doing so would benefit the production and use of citizen science data and information. The Agency could provide a connection to citizen science community needs and concerns while also promoting knowledge sharing and training for small businesses engaged in open data and tools.

As this interest grows and partnerships between the private sector, other stakeholders and government agencies expand into new areas, EPA can develop standards to facilitate positive stakeholder involvement in environmental protection. EPA should look to related models to help define its inherently governmental activities, promote mutually beneficial outcomes, and develop communications tools for these kinds of collaborative efforts. For example, EPA should require that all partners document and be transparent about data licensing, sharing and use. These efforts will help provide context to an expanding array of citizen science-related products that may use data and information from EPA or other environmental agencies.

Action Item

EPA should develop standards and practices for partnership with the private sector and implement these standards in new collaborations with the private sector to expand and enhance citizen science.

Recommendation 10. Build EPA expertise in advanced technology to facilitate collaboration and strategically engage in citizen science at national and international levels.

Rapid advancement in advanced technologies such as artificial intelligence, machine learning, blockchain, virtual reality and the Internet of Things have the potential to radically alter the way that environmental governance structures work and how the public participates in data collection and use. Effective technology partnerships are possible when EPA employees recognize and understand new technologies and can participate in national conversations about emerging, open and advanced technologies. EPA should provide internal training sessions on these advanced technologies and encourage and incentivize expertise in these areas for the following four reasons. First, this would allow the Agency to be aware of trends and advancements in these rapidly developing areas. Second, EPA could facilitate collaborations with the private sector. Third, EPA could strategically engage in bringing technology to citizen science groups. Finally, the Agency can help to develop opportunities and challenges to move citizen science data and information to action.

Action Item

EPA should increase the expertise of Agency employees on emerging and advanced technologies through training, encouragement and incentives and create systematic funnels to share new resources with citizen science groups.

When speaking at the 2017 Air Quality Sensor Conference about back-end applications for sensor networks, Dean Bethke, Business Development Lead for Internet of Things (Azure IoT) at Microsoft, emphasized how industries are using Internet of Things and cloud-based solutions for scaling data storage and analysis to improve data access:

> **"Now we have this around the world in 40 different regions, over a 100 different data centers… there are only a couple of companies in the world that are doing things at this scale. Sometimes you don't need this type of scale, but oftentimes you do, in particular around regulatory compliance because data sovereignty is a challenge."[64]**

Conclusion

Citizen science is an approach for action. Citizen science provides a valuable opportunity for encouraging the public to work together with EPA toward more effective protection of human health and the environment. By embracing and integrating citizen science as a core tenet of its mission, EPA can lead the transformation of environmental and human health protection into a paradigm that engages the very population that the Agency seeks to protect. By prioritizing citizen science, the Administrator has the opportunity to increase the efficiency and effectiveness of EPA programs and empower stronger partnerships and collaborations for environmental protection. Continuing to articulate and implement a vision for citizen science at EPA will provide Agency staff with leadership and support to guide their enthusiasm and desire to connect with the American public. The recommendations transmitted in the 2016 NACEPT report provided the foundation for EPA to identify citizen science as a cross-Agency strategy for devoting necessary resources so that EPA staff can approach citizen science and open communication with the public without hesitancy. Strengthening Agency partnerships with states, territories, tribes nongovernmental organizations and emerging technology sectors is an essential next step to build on the current momentum surrounding this movement. By defining and communicating EPA's role within each of these relationships, the Agency can strategically support citizen science in a unique and powerful way that benefits both EPA and the public.

Stakeholders need more support from EPA

To more fully leverage the power of citizen science for environmental protection, EPA needs to strengthen the support for communities, partners and the Agency in using citizen science for actions and decisions. By understanding and acting on the diversity of concerns and resource needs of partners, EPA can build equity into citizen science programming. Leveraging partnerships and collaboration across the spectrum of citizen science activities can build trust and support local groups moving data and information to action. Prioritizing the needs of the user-community will not only increase civic engagement in environmental protection, it also will promote positive relationships between EPA and members of the public.

EPA needs to work more closely with other government partners

There is a high level of interest from local, state, territorial and tribal stakeholders in using citizen science to improve environmental protection. Recognizing the unique role that EPA has with states, territories, and tribes will allow the Agency to tailor support for citizen science that considers the diverse regional and cultural needs of stakeholders and help to support local governmental partners in addressing and solving environmental problems.

EPA can help build a cooperative partnership model that networks the many organizations outside of government

To help local, state, territorial and tribal communities integrate citizen science into their decision making, EPA should engage more closely with nongovernmental organizations. These groups often have deep-rooted connections at a local level and are able to serve as a conduit for EPA and community partners, streamlining efforts in assessing data gaps, identifying capacity needs and developing equitable relationships. Through thoughtful design and work with these organizations, EPA can empower its employees to move from a government-legal model, based on EPA's role as regulator, to a more cooperative model that allows the Agency to embrace citizen science.

EPA can expand efforts to make Agency data and technology open and accessible and build technological expertise

EPA must be able to leverage technology to build an efficient and effective infrastructure for citizen science to thrive. Recognizing the contributions of information and technology industries outside of the Agency will allow new avenues for collaboration and innovation to develop citizen science tools that better meet the needs of local communities. By engaging with leading and emerging industry sectors in citizen science in hardware, software and data sharing, EPA can enhance the power of information by delivering on-demand data to the right people at the right time. Through robust training programs for staff and managers, EPA can increase competencies in open data management tools and data sharing to further accelerate data interpretation and use.

NACEPT envisions an Agency that recognizes that the advent of disruptive innovations and technology is inevitable, but equitable outcomes are not. EPA must take the lead to ensure that trust, inclusion and collaboration are built into effective citizen science partnerships: by understanding the concerns of communities in comparison to the goals of local governments, by respecting and building on the strengths of external organizations and community groups, and by embracing and advancing the use of open technology.

Citizen science is transforming how government can support action. The Agency is poised to leverage the capacity of partnerships in citizen science to protect human health and the environment. By embracing the strength and creativity of open collaboration, EPA can answer the call to help the public move data and information to action.

Appendices

Charge to the Council

The benefits of citizen science to EPA's mission include: better environmental science and more data that can be used in decisions and policies; an informed citizenry that leads to civic engagement on environmental problems; and increased transparency and credibility in the scientific process.

To realize the full benefits of citizen science and to use EPA resources efficiently, we need to evaluate the current and potential roles for citizen science in environmental protection and prioritize our efforts. The charge to NACEPT is to assess EPA's approach to citizen science in the context of current activities and to recommend a coordinated framework for the Agency to embrace citizen science as a tool in protecting public health and the environment. We ask NACEPT to provide advice and recommendations on specific actions the Agency may consider to resolve issues that hinder the effective production and use of knowledge and data generated through citizen science.

Three overarching questions frame the NACEPT review:

1. How can we sustain and improve current EPA projects and programs?

EPA does not have a formal strategy on citizen science but considerable work is underway in EPA programs and regions. These projects and activities on citizen science support four areas of emphasis that help EPA accomplish its mission. In each area of emphasis, we ask NACEPT to evaluate current work and provide advice on how EPA can optimize its existing citizen science projects and activities to increase the impact and value of this work, including through possible collaboration with states, tribes, communities, citizen science associations, museums, universities, colleges, schools and other organizations.

- **Empower communities.** Citizen science advances environmental protection by helping communities understand local problems and collect quality data that can be used to advocate for or solve environmental and health issues. Citizen science provides effective methods to respond to a community's questions about their environment and health. EPA provides tools, technical expertise and funding for citizen science led by community groups to better understand local problems and advocate for improved environmental health.
- **Monitor the environment and human health.** Citizen science advances environmental protection by creating useful monitoring data. Citizen science programs can increase the temporal and geographic coverage of environmental monitoring to support EPA programs and environmental protection. EPA continues to support and enable a small number of citizen science monitoring programs and projects.
- **Conduct environmental research.** Citizen science advances environmental protection by supporting environmental and health research. Citizen science approaches are diverse, ranging from national data collection, to online crowdsourcing to community-based participatory research. Although some federal agencies now create large, robust data sets through established research programs, EPA is just beginning to explore this approach.
- **Educate the public about environmental issues.** Citizen science advances environmental protection by educating the public about environmental issues. EPA, working with other agencies and organizations, can use citizen science as a STEM education tool, including involving young people in science and research. EPA strives to incorporate well-designed citizen science activities into environmental education while also creating high-quality data that may be utilized to advance science.

2. How can EPA invest in citizen science approaches for the greatest gain?

EPA can build capacity in citizen science approaches as a whole and broadly support effective projects and programs through strategic investments; progress in a few key areas could enhance all four areas of emphasis at the Agency.

What citizen science opportunities, directions and collaborations should EPA consider to assist the Agency in accomplishing its mission? Are there partnership approaches that would allow EPA to work with other organizations to more effectively support citizen science methods? Frameworks are needed to ensure data quality, proper data management, and to evaluate and validate instruments used in citizen science; what investments in these areas would facilitate the use of these approaches?

a. **Data quality.** Standards or guidelines for quality control of citizen science data at EPA would help ensure that these data are suitable for their intended purpose.

b. **Data management.** Data from citizen science projects can be more effectively used if EPA can build capacity for managing and maintaining these data.

c. **Instrument evaluation.** Low cost ($100–$2500) sensors for air and water is an emerging technology area that has potential to increase the effectiveness and impact of citizen science projects. However, current versions of these sensors and instruments vary widely in the quality of data that they collect, including data accuracy, precision and bias. By providing guidance to citizen science organizations on low cost sensor technologies, EPA can facilitate the collection of high quality, actionable data.

3. How can EPA help increase the impact of knowledge and data generated via citizen science?

There is a need to have policies and guidelines in place that address citizen science approaches. How can EPA best leverage citizen science to protect human health and the environment?

a. **How can EPA support the use of citizen science knowledge and data for environmental protection at the local and state levels?** Citizen science can strengthen EPA's work, resulting in outcomes for individual participants, for communities and for environmental protection. **Participants** increasingly value the integrity, transparency and caliber of EPA science, increased understanding of environmental research, improved sense of place and stewardship, and a deeper relationship with the natural world. **Communities** better understand their environmental health issues, which will lead to improved solutions to problems and a better public understanding of the scientific process.

   How can EPA facilitate the role of citizen science in outcomes for individuals and communities, including governance and decision making by local, tribal and state governments?

b. **How can EPA support the use of citizen science knowledge and data for environmental protection at the federal level?** Quality data from well-designed citizen science projects can provide valuable information to supplement EPA research on standards and regulations; for example, these data can act as a screening tool to determine when more research is needed. With policies and guidance on the importance and purpose of citizen science data at the Agency, individuals and communities will be motivated to target their efforts towards an outcome that is mutually beneficial.

   How can the Agency leverage data collected via citizen science to better protect human health and the environment? What standards of data quality are needed to use citizen science data for its intended purpose (e.g., research, as a screening tool, for background monitoring, etc.)?

c. **How can EPA work with the public to interpret data from citizen science efforts?** Citizen science is an effective tool to foster public engagement and communicate environmental science. When communities who collect data around an environmental concern approach EPA, the Agency has the opportunity to engage communities and support a common understanding of data collection and the scientific process.

   How can EPA provide an appropriate response to community groups who collect data indicating an environmental concern? How can EPA communicate with individuals and community groups to promote an understanding of the data they collect, how the results relate to regulations or standards, and what the results mean in terms of health or risk?

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List of Acronyms

CEnR Community-Engaged Research

DIY do-it-yourself

EPA U.S. Environmental Protection Agency

EPD (Georgia) Environmental Protection Division

DEQ (Michigan or Virginia) Department of Environmental Quality

HABs harmful algal blooms

NACEPT National Advisory Council for Environmental Policy and Technology

NEJAC National Environmental Justice Advisory Council

PERC perchloroethylene

QAPP Quality Assurance Project Plan

SEP Supplemental Environmental Project

Glossary of Terms

Big data: Large sets of data and information that can be analyzed either by computers or humans to show correlations and make predictions. Crowdsourcing has been a key form of citizen science used in the development of big datasets.

Citizen science: In citizen science, the public participates voluntarily in the scientific process, addressing real-world problems in ways that may include formulating research questions, conducting scientific experiments, collecting and analyzing data, interpreting results, making new discoveries, developing technologies and applications, and solving complex problems. Related approaches include crowd science, crowd-sourced science, crowdmapping, civic science, street science, do-it-yourself (DIY) science, volunteer or community-based monitoring, or networked science.

Co-design: The collaborative design of research projects by scientists and the public. In the context of this report, co-design refers to research projects designed as a partnership between EPA scientists and communities.

Community citizen science: Community citizen science is collaboratively led scientific investigation and exploration to address community-defined questions, allowing for engagement in the entirety of the scientific process. Unique in comparison to citizen science, community science may or may not include partnerships with professional scientists, emphasizes the community's ownership of research and access to resulting data, and orients toward community goals and working together in scalable networks to encourage collaborative learning and civic engagement.

Data and information: Data are raw facts, numbers, values or unprocessed observations gathered in conducting research. Information consists of data that have been organized or processed to generate understanding by people. In this report, "data" and "information" are used interchangeably, unless otherwise indicated.

Environmental justice: A social movement that focuses on the fair distribution of environmental benefits and burdens regardless of race, color, national origin or income when developing, implementing or enforcing environmental laws, regulations and policies.

Equal: The quality of being the same in quantity or measure or value or status.

Equitable: Fair to all parties as dictated by reason and conscience.

Institution: (1) A society or organization founded for a religious, educational, social or similar purpose. (2) An established law, practice or custom.

National EPA-Tribal Science Council: A forum for interaction between tribal and EPA representatives to work collaboratively on environmental science issues to develop sound scientific approaches to meet the needs of tribes.

Open-source licensing: Also called open licensing, this type of licensing for computer software and other products allows the source code or design to be used, modified and/or shared under defined terms and conditions.

Total maximum daily load: Commonly known as TMDL, this is a Clean Water Act regulatory term describing a value of the maximum amount of a pollutant that a body of water can receive while still meeting water quality standards.

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