Environmental Protection Belongs to the Public

A Vision for Citizen Science at EPA

National Advisory Council for Environmental Policy
and Technology (NACEPT)

December 2016

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Transmittal Letter to the Administrator From the National Advisory Council for Environmental Policy and Technology

For each EPA Administrator, the assigned mission is short and sweet—to protect human health and the environment—but how to accomplish it is dauntingly difficult. What priorities will do the most good? What is the best approach to balance the traditional core work of implementing EPA's statutory program with the need to push the Agency's work in new directions? What kinds of policy approaches should be used—from standards, permits and enforcement to market forces, information, partnership programs and other tools? How can EPA build public support for its mission?

Two pieces of advice have been articulated by previous EPA Administrators that may be cornerstones of EPA's future success. First, continue to invest in and use sound science to guide EPA actions and decisions. Second, stay connected to the American public, whom EPA serves.

These two ideas about how EPA best operates—science and citizens—come together in citizen science. Citizen science is science that actively and genuinely encourages public participation.

The National Advisory Council for Environmental Policy and Technology (NACEPT or Council) has assessed EPA's approach to citizen science in the context of current activities and recommends that the Agency proactively and fully integrate citizen science into the work of EPA. The members believe that doing so will be complex and difficult, yet transformational.

EPA has a grand opportunity to integrate the Agency's current set of small and valuable efforts and the burgeoning network of outside work into an organized structure that can accelerate virtually every activity being undertaken within EPA offices, programs and regions. The scope and power of the citizen science approach has been evident in some ways for many years, but currently it is evolving and emerging as a much greater force. Now is the time for EPA to take advantage of that force by working in concert with the thriving community of citizen science organizations and embracing a diversity of efforts toward environmental protection. Moving quickly to appoint a high-level and trusted individual to lead the Agency's collaborative efforts will be a vital first step.

In addition to that first step, the report contains other recommendations that NACEPT has attempted to craft as bold but practical and that can improve the next 4 years of environmental protection. The Council is grateful for the opportunity to present this report and its recommendations to you and the Agency and looks forward to your consideration of them.

EPA is poised to lead a national effort to mainstream citizen science that engages all parts of American society in learning about science and contributing to EPA's mission of protecting human health and the environment. It is an exciting prospect!

Respectfully,

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

Photo credit: *Nate Dappen/The Cloud & The Crowd.*

Executive Summary

Citizen science is much more than collecting data. It provides a way to engage all parts of society in gaining a deeper understanding of human environments, build an informed population that can advocate successfully for environmental protection, and more effectively protect human health and the environment. Citizen science broadens environmental protection by working across boundaries that can separate policy makers, scientists and members of the public, harnessing the shared commitment of grassroots efforts, formal research and federal protection to create a safer and healthier Nation. Increasingly during the last decade, rapid technical advances have opened opportunities for broader and deeper interaction and participation among individuals, communities and governments, allowing all levels of government to engage previously uninvolved people in issues affecting their communities and local environments. This movement—already encompassing thousands of projects and the energy of millions—is an opportunity for EPA to work together with the public on a more holistic approach to protecting the environment and public health.

The National Advisory Council for Environmental Policy and Technology (NACEPT or Council) developed this report, which is informed by a broader network of experts. The Council's 28 members—representatives of academia, business and industry, nongovernmental organizations, as well as state, local and tribal governments—have spent the last year researching, interviewing individuals and drafting this document, which identifies citizen science not only as an invaluable opportunity for the Agency to strengthen public support for EPA's mission but also as the best approach for the Agency to connect with the public. Below, the Council highlights recommendations that are explored in-depth within this report. In summary, NACEPT recommends that EPA:

- Embrace citizen science as a core tenet of environmental protection.
- Invest in citizen science for communities, partners and the Agency.
- Enable the use of citizen science data at the Agency.
- Integrate citizen science into the full range of work of EPA.

Fully integrating citizen science into the work of EPA is complex, yet transformational. The Council understands that Agency staff and external partners are excited and ready to engage; the limiting factors are leadership, coordination and resources. A concerted leadership effort is needed to achieve this transformation.

The new EPA Administrator should move quickly to appoint a high-level and trusted individual to lead the Agency's citizen science efforts. The new leader, working with EPA regions and programs, should develop a strategy, including funding needs, for the Administrator within the first 6 months. This strategy should include both policy development and new resources.

Some of the Council's recommendations may be implemented immediately using current resource levels; others will require long-term investment. This report provides specific steps toward achieving these recommendations.

Embrace citizen science as a core tenet of environmental protection

Citizen science is here and thriving; EPA should recognize the opportunity and build a proactive, collaborative agenda to engage the public in environmental science. Citizen science has created a global paradigm shift in environmental protection and public health, and it is imperative that EPA create a strategic vision for supporting and leveraging this movement.

The Agency should identify opportunities to meet people where they are—in their own backyards and communities, museums, and public schools—and emphasize a place-based approach to integrating citizen science into EPA's core mission. EPA should reach out to communities and stakeholders throughout the country to actively understand ways that citizen science already has had beneficial effects on local and national environmental issues. The Agency should engage in dialogue with those communities to understand both how citizen scientists could benefit from EPA support and involvement and how citizen science initiatives could enhance EPA environmental priorities. As part of this approach, EPA should integrate a specific effort for inclusiveness and outreach to marginal and excluded groups and embrace qualitative ways of knowing, such as stories, traditional ecological knowledge, and lay and local knowledge.

Because fully integrating these approaches will be challenging, citizen science must be an Agency priority for this approach to reach its full potential. EPA should engage with citizen science efforts to create an Agency-wide strategic approach and develop an operational plan for near-term actions.

Key recommendations under this theme include:

- Articulate and implement a vision for citizen science at EPA.
- Take a collaborative approach to citizen science.
- Define and communicate EPA's role in citizen science.
- Emphasize place-based approaches to citizen science.

Invest in citizen science for communities, partners and the Agency

Citizen science is becoming widely recognized across federal agencies, as exemplified by recent directives from the White House Science Advisor and the growth in federal projects and programs. The needs, interests and energy of a diversity of communities and organizations have already changed environmental protection; additional investments in these efforts can multiply and scale impacts. EPA should consider ways to enhance ongoing work through funding and capacity building and also should leverage intermediary organizations to reach broader audiences. Technology in support of citizen science, in particular, is growing rapidly; the ability to share data, information and stories has been amplified by the ability to create new tools that support data collection, literacy, management and dissemination. EPA should work to be responsive and supportive of technological innovation through providing funding for, documentation of or training on tools. Moreover, EPA should co-design core technologies, policies and toolkits with users and communities.

Key recommendations under this theme include:

- Dedicate funding for citizen science.
- Improve technology and tools and build technical capacity.

Enable the use of citizen science data

EPA should promote a positive, proactive agenda toward the use of citizen science data in support of the Agency's mission. EPA should support culture change throughout the Agency toward the acceptance of citizen science data. Rather than being deterred by challenges, EPA should develop policies and practices that support institutionalization of these approaches. For example, EPA will increase data utility by investing in data standard setting and providing clear guidelines for producing data fit for purpose and communicating the data quality needed for a range of data uses. Engaging or leveraging talent in existing Agency forums or councils will be appropriate to accomplish some of these tasks. Throughout, EPA should co-design with citizen scientists,

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

respect the goals and objectives of those collecting and disseminating information, and build in feedback loops—essential for setting expectations and ensuring positive relationships—for responding to citizen science groups and intermediary organizations.

Key recommendations under this theme include:

- Adopt a positive, cooperative agenda that increases the utility of citizen science data.
- Adopt standards for citizen science data.
- Provide guidance and communicate data quality needs for different data uses.

Integrate citizen science into the full range of EPA's work

Citizen science is more than just community engagement or a method for targeting issues for enforcement; activities such as long-term baseline data collection and rapid response around environmental crises have significant value. In the short term, EPA should identify opportunity spaces where citizen science can fill an important role, such as where regulations already allow for public participation and where the Agency lacks regulatory or enforcement tools. In addition, EPA should consider the full spectrum of ways that citizen science can support the Agency's mission of protecting human health and the environment. Citizen science will have significant effects on public perception and involvement in environmental protection through community engagement and education. Many opportunities exist for strengthening environmental research and management by using citizen science efforts as condition indicators. Citizen science can play a role in complementing EPA's ongoing policy, regulatory and enforcement work through careful design and open partnerships between external groups and EPA. Ultimately, citizen science can improve the Agency's enforcement processes by helping to identify issues proactively.

Key recommendations under this theme include:

- Support citizen science for environmental protection beyond regulations.
- Support community citizen science.
- Integrate citizen science into EPA science.
- Expand EPA's regulatory mission to include citizen science.

Proactive actions by the Agency in this space will contribute to a world in which members of the public understand and value science and environmental protection, where local and emerging issues are identified proactively and solutions are developed quickly and collaboratively, and where open communication allows people to help define government and research priorities.

Photo credit: *Pacific Rivers.*

CHAPTER ONE: Introduction

What is citizen science?

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.[1] 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.[2]

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.

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.

Citizen science is a transformational approach to environmental protection

Citizen science represents a huge opportunity to advance EPA's mission to protect human health and the environment. Successfully confronting current environmental challenges calls for engagement with all parts of society—the people affected by climate change or pollution in air, water and land need to be included in the solutions. Citizen science produces a direct connection between our government, the communities we serve, and our environment and health that can provide another way to support and invigorate EPA program and regional activities. Successful citizen science programs and partnerships that harness the public's energy and creativity exist across the country and the world and provide real benefits, including increased public understanding of environmental science, direct connections with individuals and communities, and new contributions to environmental and health research.

Citizen science is happening with or without EPA. Citizen science is changing how communities are engaging with their own environment and health and also attracts new groups of people who were previously not active in environmental issues. If EPA embraces citizen science, it will open up new opportunities for the Agency—in partnership with other entities and stakeholders—to connect with the public about science, human health and environmental protection while improving environmental and health outcomes (**Table 1**).

The value of citizen science for governmental processes

Citizen science transcends individual projects, engaging people directly in issues of personal interest, improving public understanding of science and the environment, and connecting the public with environmental issues. Citizen science goes beyond data collection by including and valuing other ways of knowing, such as traditional ecological knowledge, lay and local knowledge, and stories. A scientifically informed and engaged public is vitally important for effective governmental policy making, and citizen science can enhance EPA's approach to connecting its mission to the American people.

Table 1. Benefits of EPA Support for Citizen Science

Benefits of Citizen Science
Engaged Communities. An educated and engaged public that can support EPA in solving environmental and health problems.
Collaborative Governance. Energized and improved environmental governance created through generating deep public involvement in EPA priorities and monitoring practices.
Common Vision. A public connected to and invested in the missions of federal agencies by promotion of open government, civic participation and volunteerism.
Actionable Information. 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 information on problems not adequately covered by monitoring networks.
Shared Knowledge. The advancement and acceleration of scientific research through collaborative practices bounded in group discovery, learning and the co-creation of knowledge.
Accessible Technology. Technology that is open sourced to promote rapid iterations and advancements in support of environmental priorities.
Environmental Literacy. The advancement of national priorities around science, technology, engineering, arts and mathematics (commonly known as STEAM) education through citizen science activities.

Engaging the public will give EPA the ability to tap into divergent expertise and increase the affordability of data, technology and supporting processes while meeting its national priorities. Civic participation also makes government and institutional work transparent, allowing the public to effect change. Citizen science could benefit the Agency in the same way that the open data movement has changed the landscape of institutional data sharing and transparency. Civic engagement in technology, science and data produces better products, makes science more accessible and affordable, and delivers better data and information. Public involvement builds trust and supports innovation of better information management practices. Priorities developed with the public allow the public, private and civil sectors to work collaboratively to meet shared goals.

Citizen science in the context of global sustainability

Citizen science is part of a global trend of sustainability that is built on empowerment and community engagement. From community gardens and renewable energy to community pollution monitoring, communities and cities are building greater resilience and transitioning to greater self-sufficiency. Scientists are finding new, cost-effective approaches to work with members of the public to expand and increase scientific knowledge. Citizen science—and greater citizen involvement in all aspects of government—will play an important part in working toward a more sustainable future. EPA should create conditions that support this transformation to advance the protection of human health and the environment.

The diversity of citizen science approaches

Citizen science encompasses an enormous range of efforts that span different environmental media, engagement and responsibility levels, and roles. Citizen science has a wide range of active organizations, uses, outcomes and effects. It is important that these be recognized and incorporated into citizen science planning.

Although citizen science is diverse, identifying the *purpose* is a useful way for EPA to begin conceptualizing, integrating and implementing citizen science efforts. This generally will dictate the structure of the effort. For example, the purpose will determine the level of data quality needed, including what quality controls should be put in place, as well as how much training volunteers and community researchers may need. Some citizen science projects are designed for educational or engagement purposes only, whereas others are designed to affect science or policy. The diversity of citizen science is a strength; if designed well for its purpose, a citizen science effort can contribute to any number of goals, such as educating students on the water quality of a local stream, helping scientists develop better management plans for a species, or contributing to regulatory enforcement.

Citizen science can be driven by individuals, communities and/or institutions

Community citizen science can be initiated and implemented almost entirely by nonprofessional scientists in community groups. Although these groups may approach the Agency for advice, EPA researchers have limited or no involvement in project design and implementation. These efforts are conceived organically and reflect areas of interest and concern among

Center in the Park's Senior Environment Corps (CIPSEC)

CIPSEC, a local Philadelphia group established in 1997, provides opportunities for older adults to play a role in environmental protection, education and advocacy. Specific projects include monthly water quality monitoring, habitat assessments and watershed tours.

Composting Food Waste with Fermentation

Three Episcopal Korean churches in the greater Washington, D.C., region organized Greenwave, a grassroots environmental group that has been developing a program, using the Bokashi composting method individually and at church functions to deal with food waste. This hands-on citizen science initiative contributes to food waste management and community engagement.

Southeast Alaska Tribal Toxins Partnership

The Southeast Alaska Tribal Ocean Research (SEATOR) program supports tribes working together on climate change effects on the marine environment in Southeast Alaska. SEATOR created the Southeast Alaska Tribal Toxins partnership using EPA funds to create an early warning system for harmful algal blooms, which affect human health. Tribal citizens collect reliable data that allow state agencies to make informed decisions. This regional program contributes to condition indicators, community engagement and research.

individuals and groups of community members who are motivated to document local existing conditions and encourage local, state, tribal and/or federal action toward greater environmental protection. EPA often becomes aware of these projects when members of the public approach the Agency with data and information indicating an environmental concern.

Institutions also may design studies that involve citizen scientists in activities such as data collection or processing. Some institution-driven projects are initiated and implemented within EPA, whereas others are designed and managed by professional researchers and scientists.

Citizen science has a range of purposes and data uses that benefit communities and institutions

Effective citizen science work has a genuine purpose for science, research and policy. Citizen science can be used to accomplish a wide range of outcomes and purposes related to science and policy, including community engagement, education, condition indication, research, management, regulatory decision making, regulatory standard setting and enforcement (**Figure 1**). Well-designed citizen science supports environmental and science, technology, engineering, arts and mathematics (STEAM) education, outreach and/or civic engagement in addition to science and policy goals.

Citizen science efforts can include objectives at the community level, institutional level or both. Community purposes may include local decision making, such as natural resources management, whereas institutional purposes at EPA may include the entire range listed above.

Citizen science is incredibly diverse. Because of this, categorizing it can be a difficult task. **Figure 2**, which identifies some key characteristics of any given citizen science project, and the case studies that are described in detail throughout the report illustrate the wide range of citizen science projects. The selected case studies also highlight the geographic diversity of past and current citizen science projects throughout the United States (**Figure 3**).

Citizen science: the current context

Citizen science has a long history, from 17th century weather and natural history observations to the last 50 years of volunteer water quality monitoring. A variety of approaches, such as volunteer monitoring and community-based participatory research, have emphasized the contributions of volunteers and community researchers and provided a foundation of practice, allowing many disciplines to experience the enormous value of engaging members of the public in both science and government.

On September 30, 2015, Dr. John Holdren, Assistant to the President for Science and Technology, issued a policy memorandum, *Addressing Societal and Scientific Issues through Citizen Science and Crowdsourcing* (obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/holdren_citizen_science_memo_092915_0.pdf), highlighting the current benefits of citizen science for the work of the federal government. This memorandum also directed all federal agencies to take specific steps to build capacity for citizen science, including identifying a coordinator and cataloging federally supported citizen science and crowdsourcing

Tonawanda Coke Air Monitoring

The Clean Air Coalition of Western New York, later joined by EPA and the New York State Department of Environmental Conservation, built a citizen science effort that used air quality data and direct action methods to address concerns about the industrial plant Tonawanda Coke. Residents of Tonawanda collected air samples for this local effort. Their data collection and communication efforts resulted in an EPA enforcement action and criminal trial.

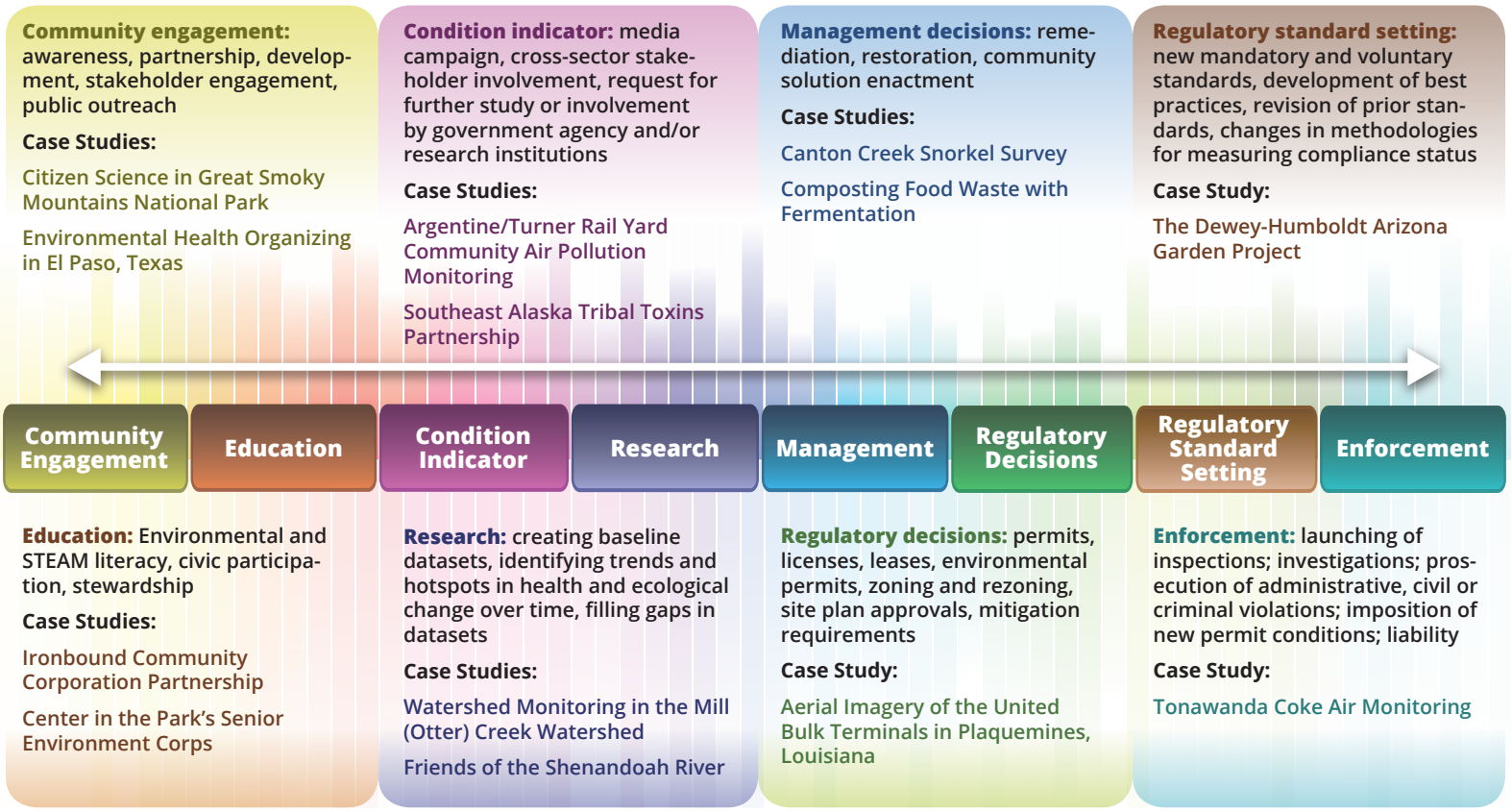


Figure 1. The spectrum of citizen science data use.

Case studies illustrate the range of ways that EPA can integrate citizen science into EPA's work, from engaging communities in environmental protection to using citizen science data for enforcement action. These examples address community engagement, education, condition indicators, research, management, regulatory decisions, regulatory standard setting and enforcement across the spectrum of data uses.

projects. The memorandum encourages agencies to build and support citizen science by developing federal policy to engage and aid citizen science, allow for resources and staffing, support the development of technology, fund a diversity of projects, and invest in evaluating the effectiveness of citizen science to improve practice.

This memorandum has initiated a period of growth for citizen science in the federal government, beginning with the release of a variety of resources designed to support the use of citizen science approaches. CitizenScience.gov provides a portal to a catalog of federally supported citizen science projects, a toolkit to assist federal practitioners with designing and maintaining their projects, and a gateway to a community of citizen science practitioners across the government.

Citizen Science at EPA: Past and Present

The public's interest in addressing environmental concerns through monitoring and observations predates EPA. The foundation of citizen science at EPA begins with volunteer water quality monitoring programs formalized in the early 1970s; EPA's Office of Water has supported those efforts since the 1980s with grants, data quality and assurance plans, and workshops. Currently, projects and programs support citizen science and crowdsourcing approaches throughout the regions and program offices, including the Office of Water, Office of Research and Development (ORD), and Office of Air and Radiation. The following projects and programs comprise some of EPA's efforts and partnerships in this area but is not comprehensive.

Characteristic	Examples	
What is the topic?	Citizen science covers a wide range topics, including: air, water, biodiversity, ecosystems, land use, toxic substances, **human health**, **climate change**, etc.	*The Southeast Alaska Tribal Toxins partnership works on climate change-related impacts on the marine environment and associated health impacts.*
What is the scale?	Citizen science occurs at various scales, including: local, **regional**, state-wide, national, global, etc.	*The Canton Creek Snorkel Survey is implemented at a regional level within the North Umpqua Watershed.*
Who are the participants?	Citizen science engages different groups of participants, including: students at all levels, local community, special-interest, stakeholders, **seniors**, etc.	*The Center in the Park's Senior Environment Corps provides opportunities for older adults to contribute to environmental protection, education and advocacy.*
What is the purpose?	Citizen science can serve multiple purposes, including: education, community engagement, condition indicator, research, **enforcement**, regulation, etc.	*In the Tonawanda Coke Air Monitoring project, air quality data collected by citizen scientists led to EPA enforcement action and criminal trial.*
What part of the scientific process?	Citizen science contributes to different aspects of the scientific process, including: **formulating research questions**, conducting scientific experiments, collecting and analyzing data, interpreting results, making new discoveries, developing technologies and applications, solving complex problems, etc.	*The Expert and Citizen Assessment of Science and Technology (ECAST) engages the public in formulating research questions and defining environmental priorities.*
Who is implementing?	Many entities can and do implement citizen science projects, including: community organizations, **faith groups**, nonprofits, academic institutions, state governments, federal government agencies, etc.	*A program for composting food waste with fermentation has been developed by Greenwave, a grassroots environmental group organized by three Episcopal Korean Churches.*

Figure 2. Diversity of citizen science projects.

This figure characterizes the diversity of citizen science projects, which may differ by topic, scale, participants, purpose, to which part of the process participants are engaged in, and who implements a project. The examples given are meant to be representative of the diversity of projects rather than a comprehensive list of all potential characteristics.

EPA has previously (www.epa.gov/nps/nonpoint-source-volunteer-monitoring) and continues to support volunteer water quality monitoring throughout the United States through conferences, a listserv, Agency representatives, and resources on planning and implementing volunteer programs. For example, the Equipment Loan Program for Citizen Science Water Monitoring provides organizations in Regions 1 and 2 with equipment and technical support. The National Estuary Program provides a *Volunteer Estuary Monitoring Manual* (epa.gov/polluted-runoff-nonpoint-source-pollution/nonpoint-source-volunteer-monitoring) that explains how to establish and maintain a volunteer monitoring program.

Support for citizen science air quality monitoring has focused on training and communication regarding the use of air sensors by community groups. For example, EPA provided Newark's Ironbound Community Corporation (youtube.com/watch?v=lL5tPNn5X48&feature=youtube) with air monitoring equipment and training that supported the community members in collecting air quality data. This effort resulted in information about air quality in Newark as well as best practices for communities' use of air monitoring equipment and training. ORD's Air Sensor Toolbox for Citizen Scientists (epa.gov/air-sensor-toolbox) provides information and guidance on advanced monitoring equipment for measuring air quality. In July 2015, EPA hosted a Community Air Monitoring Training Workshop (epa.gov/air-sensor-toolbox/air-sensor-toolbox-resources-and-funding#training_videos) to bring the Air Sensor Toolbox to community groups, including sharing information on air quality tools, best practices and resources for those wanting to begin collecting data on air quality.

EPA's regional offices have direct connections with members of the public and community groups and are supporting citizen science efforts across the country. Region 2 is a leader in citizen science at EPA and has

Figure 3. Geographic diversity of U.S. citizen science projects highlighted in the case studies throughout this report.

provided a number of resources to community groups, including a generic Quality Assurance Project Plan (QAPP) (epa.gov/citizen-science/interested-collecting-data-about-environmental-concern-your-community) and the design and maintenance of a citizen science website (epa.gov/citizenscience). Region 10 has worked extensively with community groups, especially in using EPA tools such as the Environmental Justice Screening and Mapping Tool (epa.gov/ejscreen; commonly known as EJSCREEN), Community-Focused Exposure and Risk Screening Tool (epa.gov/healthresearch/introduction-community-focused-exposure-and-risk-screening-tool-c-ferst; commonly known as C-FERST), Community-LINE Source Model (https://www.epa.gov/healthresearch/community-line-source-model-c-line-estimate-roadway-emissions; commonly known as C-LINE), and EnviroAtlas (epa.gov/enviroatlas).

EPA grant programs support citizen science efforts. The Office of Environmental Education and Urban Waters (epa.gov/urbanwaters) grant programs have supported citizen science projects that align with the mission of each organization. Until recently, EPA's Community Action for a Renewed Environment (CARE) program supported communities in projects that use collaborative, local problem-solving that advance environmental health and quality, including many citizen science efforts. Recently, the National Environmental Justice Advisory Council commended the CARE program on its success and recommended that EPA fully fund and expand the CARE program.

Jointly funded through an Indian Environmental General Assistance Program grant from Region 10 and science and technology funds from ORD, the Alaska Native Tribal Health Consortium developed the Local Environmental Observer (LEO) Network (leonetwork.org/en), which uses Google Maps to share information about observations of unusual environmental events with LEO members in Alaska, the Circumpolar Arctic and Mexico. The goal of the LEO Network is to increase awareness about vulnerabilities and impacts from climate change.

In recent years, EPA has been working to provide organizational support to EPA staff in implementing citizen science projects. In the spring of 2016, the Office of Management and Budget approved EPA's *Generic Clearance for Citizen Science and Crowdsourcing*, which allows for a streamlined approval process for the Paperwork Reduction Act of 1995; this approval process will expedite citizen science and crowdsourcing projects. EPA has supported small seed funding opportunities for internal projects to use citizen science and crowdsourcing; these initiatives have resulted in five new citizen science projects being developed and implemented.

In June 2016, Region 1 sponsored an innovative Open Space meeting for EPA and state employees, nongovernmental organizations, and community groups to explore the potential of citizen science for environmental and human health. EPA co-chairs the

Expert and Citizen Assessment of Science and Technology (ECAST)

The ECAST network brings together academic research, informal science education, citizen science programs and nonpartisan policy analysis to engage the public. ECAST creates peer-to-peer deliberations to inform members of the public about and solicit their input on science and technology policy issues in an effort to more fully inform decision making. Formally launched in April 2010, ECAST has conducted large-scale public deliberations in the United States on policy issues related to biodiversity, space missions, and climate and energy.

Monitoring the Gowanus Canal, Brooklyn, New York. ***Photo credit:*** *Mike Weiss.*

Canton Creek Snorkel Survey

Pacific Rivers, the Phoenix School, the Bureau of Land Management, the North Umpqua Foundation, Steamboaters and the Cow Creek Tribe worked in partnership to recruit and train high school students to collect data for this baseline watershed monitoring program. With adequate funding, this regional citizen science initiative will continue indefinitely, contributing to management, research and community engagement.

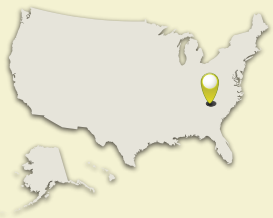
Federal Community of Practice for Crowdsourcing and Citizen Science (citizenscience.gov/community), a grassroots community open to all federal practitioners working on, funding or interested in learning about citizen science and crowdsourcing. Through this interagency effort and partnership with the White House Office of Science and Technology Policy, EPA participated in the development of a toolkit (crowdsourcing-toolkit.sites.usa.gov) that includes best practices, training, policies and guidance for citizen science and crowdsourcing and a catalog (ccsinventory.wilsoncenter.org) of federally supported projects at CitizenScience.gov. EPA also hosts a monthly Agency-wide EPA Citizen Science Community of Practice that includes participants from throughout the national programs and regions. Meetings typically involve an internal or external speaker to discuss relevant citizen science issues at EPA. The EPA Citizen Science Community of Practice works to coordinate related citizen science projects and connect those across EPA programs and regions that use citizen science approaches or are involved in citizen science-related work.

About this report

For this report, NACEPT has identified 13 recommendations, which are described in four chapters and arranged by theme. The recommendations are ordered sequentially across the entire report, regardless of chapter (Recommendation 1 through Recommendation 13). Chapter Two provides four recommendations that would allow EPA to *enable citizen science as a core tenet of environmental protection*. Chapter Three provides two recommendations for *investing in citizen science for communities, partners and the Agency*. Chapter Four provides three recommendations for *enabling the use of citizen science data*. Chapter Five provides four recommendations for *integrating citizen science into the work of EPA*. Throughout the report, the Council provides overarching as well as specific recommendations and both long- and short-term recommendations. Some recommendations can be accomplished within current funding levels, whereas others would require redistribution of funds.

Citizen Science in Great Smoky Mountains National Park

Location and Dates:
Great Smoky Mountains, early 1980s to present



Groups Involved:
Great Smoky Mountains Institute at Tremont (Tremont Institute), Discover Life in America, Inc. (DLIA), National Park Service (NPS)

Also an Example of: Education, research

Budget: At Great Smoky Mountains National Park (GSMNP), limited funding is devoted specifically to citizen science. Two NPS educators incorporate citizen science into their program, although they do not hold formal roles as citizen science educators. Tremont Institute funds a citizen scientist coordinator, summer interns and some field equipment. DLIA does not have a specific budget devoted to citizen science, but its employees engage in coordinating citizen science activities as part of their responsibilities. The DLIA budget is funded by some grants, donors, sponsorships and special events. The NPS provides in-kind support to both Tremont Institute and DLIA, including facilities.

IN BRIEF

Topic: Biodiversity, ecology
Scale: Regional
Participants: Community members and park visitors
Data uses: Community engagement, education, research

Summary: GSMNP has been mobilizing citizen scientists to collect data and weaving citizen science into educational programs since the early 1980s. The citizen science projects in GSMNP are a team effort between the NPS, Tremont Institute and DLIA. DLIA is responsible for the All Taxa Biodiversity Inventory (ATBI), which "seeks to inventory the estimated 100,000 species of living organisms in GSMNP." The ATBI is the "largest sustained natural history inventory in the United States and one of the largest in the world."[1] DLIA was founded at the request of the NPS to recruit, coordinate and organize scientists and volunteers to undertake the ATBI. Given the magnitude of the scope of work, scientists relied on the contributions of citizen scientists when they created the initial work plan. DLIA has trained almost 3,000 citizen scientists in 16 years and currently has an active core of 150 to 200 volunteers who participate in various projects. To date, the ATBI has almost doubled the number of species known to be in GSMNP. At the beginning of the project, there were about 9,150 species documented in the park, and the ATBI has documented an additional 9,140 species. Furthermore, the ATBI has generated more than 600,000 data records for the biodiversity database. Citizen scientists with all levels of expertise and local knowledge can participate in the project in myriad ways, from field work (e.g., science assistant, citizen science project coordinator, field photographer, local guide) to computer and technical work (e.g., managing websites, entering data, laboratory photographer) to education and outreach.

At any given time, a wide variety of ongoing citizen science projects are available to local community members, participants in residential education programs, and visitors to the park. At the lower end of time commitment and difficulty, projects exist in which individuals can use a smartphone app (iNaturalist) to note the location of various species. Other projects are more complicated and involve significant training and in-depth protocols. More recently, Tremont Institute and the NPS began a plot-based phenology study that relies on the contributions of citizen science volunteers. In this study, phenology plots are visited weekly during spring and fall to observe seasonal changes such as leaf emergence, flower blooming, and migratory bird arrival and departure. A total of 28 plots exist across the national park, representing different elevations, aspects and forest types. As a result of the study, subtle shifts can be tracked over time.

More information: gsmit.org/CitizenScience.html; dlia.org/citizen-science-smokies; dlia.org/volunteer-job-descriptions

1. White, P. 2008. *Discover Life in America, Inc., and the All Taxa Biodiversity Inventory in the Great Smoky Mountains National Park: A Statement for the Subcommittee on National Parks of the Senate Committee on Energy and Natural Resources.* Asheville, NC: Discover Life in America, Inc.

Photo credit: *Bronwen Densmore.*

CHAPTER TWO: Embrace Citizen Science as a Core Tenet of Environmental Protection

Recommendation 1: Articulate and implement a vision for citizen science at EPA

EPA should elevate citizen science as a top-tier critical strategy for EPA's success in the next administration, including a compelling vision, framework and operational actions. A committed, unified strategy and a place in EPA's national agenda would demonstrate the power of citizen science approaches and is the foundation needed to work effectively with other organizations that operate citizen science programs.

EPA should think bigger and bolder about the future role of citizen science in the protection of public health and the environment. One useful approach that stimulates strategic ideas for the future is to learn explicitly from different scenarios for citizen science, as described in this report, and contrast current scenarios with possible future scenarios (**Table 2**). EPA's strategy for citizen science should build on the potential for leveraging all parts of society and should incorporate human-centered design thinking. The design for the strategy and operational plan should incorporate the recent and relevant advice and recommendations of the National Environmental Justice Advisory Council (epa.gov/environmentaljustice/national-environmental-justice-advisory-council) Advice Letter on Environmental Monitoring (currently in draft form) as well as the recent report, *Advanced Monitoring Technology: Critical Next Steps for EPA and States. A Report to the E-Enterprise Leadership Council*.[4]

The Agency must:

- **Co-design a strategy.** EPA must collaborate with citizen science groups to create an Agency-wide strategic approach, common framework and language that defines how citizen science can best support mission-critical environmental protection. The Agency should strategically implement citizen science, working to connect top-down and bottom-up approaches to

New Approaches in EPA's History

EPA's history includes examples of successful introduction of new approaches to Agency work, and these may be helpful in developing tools that the next Administrator can use to advance citizen science.

Examples of such actions include pollution prevention under Administrator William Reilly, environmental justice initiatives and the EPA/Department of Housing and Urban Development/Department of Transportation Partnership for Sustainable Communities under Administrator Lisa Jackson, Making a Visible Difference in Communities under Administrator Gina McCarthy, and the use of risk assessment tools for decision making under Administrator Lee Thomas.

Table 2. Future Scenarios: Examples of Potential Impacts From EPA's Support of Citizen Science

Use Case	Concern	Current Situation	Future Scenario
Community member	Rebecca and her neighbors are concerned about the air quality in their urban neighborhood, and they learn through inquiries to their city councilman that no recent, local air quality data currently exist.	Rebecca purchases an air quality sensor she finds online and recruits neighbors to archive data from the sensor for 6 weeks, which appear inconsistent. She and her concerned neighbors share these data with their regional EPA contact, who informs them that the data cannot be used because of quality assurance issues. They are frustrated and left wondering why EPA will not help them.	Through an online search, Rebecca finds information from EPA on how to design an air monitoring study. She and her neighbors regularly meet for training and to share their concerns with the local EPA office. They also share their data through an open repository and receive feedback to help contextualize their data. The residents and EPA develop mutual respect for each other and work together to discover and address community concerns.
Teacher	Ronnie is a middle school science teacher who is excited to learn about a soil moisture citizen science project to confirm National Aeronautics and Space Administration satellite data. This project aligns nicely with his curriculum.	Immediately on registering his class for the project, Ronnie learns that he will need a heat lamp, digital scale and other instruments that he does not have and cannot afford. He abandons this project and reverts to teaching his class what already is known rather than engaging the students in the process of producing new knowledge.	On registering his class for the project, Ronnie is given the option to borrow the required materials, including a heat lamp and digital scale, an infrared thermometer to measure soil surface temperature, and a rain gauge to measure precipitation. His students now report data to three projects, advancing important research on soil moisture, documenting weather trends, and calibrating the accuracy of satellite instruments. In the process, they learn a great deal about their school's soil conditions, which enables the school's groundskeeper to efficiently hydrate the property.
EPA scientist	Will is a scientist at EPA's Region 3, and he is eager to collaborate with local residents willing to be trained to collect water quality data regularly from local streams.	Will is unaware that similar projects are already taking place in his region, and he inadvertently sets up a duplicate effort. Residents have already identified an appropriate sensor, adhered to data quality assurance regulations, and compiled a spreadsheet. They want to see how their data compare to EPA Region 5's stream data. Unfortunately, without a data repository, their data lacks context, and the community researchers lose interest.	Will references a database linked to thousands of citizen science projects and quickly identifies three similar, local projects. Will, the local residents, and the leaders and participants of the local projects join forces to accelerate data collection and interpretation. They share their data with the most appropriate data repository, export local data as needed, and even expand their efforts to include biodiversity monitoring.

environmental research and protection. The Agency should support a full range of efforts, including community engagement, education (particularly environmental and STEAM education), management, research, regulations, regulatory standard setting and enforcement (**Figure 1, Table 5**) Such a strategy will guide operational plans for near-term actions (**Table 3**).

- **Develop an operational plan.** EPA should assign a top-level official with the responsibility of integrating citizen science into Agency work. EPA has a variety of citizen science projects underway through some of its regional and program offices, and these projects have been exploratory and innovative and have set the stage for an integrated strategy. EPA should strive for internal alignment within and across programs, connecting them while recognizing that environmental issues cross multiple organizational boundaries. EPA should identify and remove internal barriers to citizen science, empowering employees in program offices, regional offices and research laboratories to use citizen science to complement and advance program goals and to work with partner organizations.

Recommendation 2: Take a collaborative approach to citizen science

Citizen science provides a new foundation for EPA to leverage limited resources to collect and assess

Table 3. Actions to Organize Citizen Science at EPA

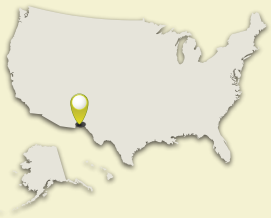
Headquarters	• Develop an action plan for steps the new Administrator can take in his or her first 100 days. • Designate a Citizen Science Director—the individual the Administrator will hold directly accountable for transforming EPA into a leader and partner in citizen science. • Define citizen science as a cross-Agency strategy. • Establish the Administrator's Award for Leadership in Citizen Science (one national award; 10 regional awards). • Establish an internal task force/working group with representatives from the Office of Public Engagement, Office of Environmental Education, Office of Environmental Information, Office of Environmental Justice, and regional and program offices. • Identify additional intramural resources and staffing for strategy implementation. • Establish a national advisory board with broad representation from academia, practitioners and institutional partners. • Establish citizen science performance measures to evaluate internal Agency progress.
Regions	• Charge the Office of Research and Development with creating guidance for developing citizen science action plans for the regional offices (e.g., partnerships, "inventory" assessment, data collection and quality assurance programs, training programs for local organizations, technical assistance, regional advisory boards). • Direct each Regional Administrator to develop a citizen science action plan. • Identify additional intramural resources and staffing for communicating with intermediary organizations and community groups. • Designate one or two staff to provide support to regional scientists and/or offices for development and support of regional efforts. • Direct each region to convene a citizen science workshop to highlight and recognize the activities underway. (Note: Region 1 convened a successful workshop in June 2016 with valuable results.)[5]

CASE STUDY

Community Engagement | Education | Condition Indicator | Research | Management | Regulatory Decisions | Regulatory Standard Setting | Enforcement

Environmental Health Organizing in El Paso, Texas

Location and Dates:
El Paso, Texas, 2005 to present



Groups Involved:
Westway's Imaculado Corazón de María (Immaculate Heart of Mary) Catholic Church, Border Interfaith, Texas Industrial Areas Foundation

Also an Example of: Research, condition indicator

Budget: Unknown

IN BRIEF

Topic: Human health, air quality
Scale: Local
Participants: Community members
Data uses: Community engagement, research, condition indicator

Summary: Members and organizers of the Westway community in Texas used community-based participatory research to document evidence of a cancer cluster for dissemination and action. Westway is a predominantly Mexican-American *colonia*—an unplanned, unincorporated and unregulated housing development—northwest of El Paso, Texas. The colonia is 1.3 square miles in size and located next to a large steel recycling plant. *Per capita* income figures show severe inequality even within a low-income county. The nearby Border Steel plant has produced visible pollution—including soot, smoke and particles—for 50 years. Since 2005, residents have been noticing, complaining about and videotaping evidence concerning the pollution.[1]

Father Pablo Matta of Westway's Imaculado Corazón de María Catholic Church repeatedly voiced his concern that he had never buried so many people who had died from cancer. As a result, community leaders looked for evidence of cancer clusters.[2] Border Interfaith, a coalition that included the church, partnered with the statewide Texas Industrial Areas Foundation and researchers to document evidence.

More information: Additional information can be found in the following publications:

Minkler, M. and N. Wallerstein, eds. 2008. *Community-Based Participatory Resource for Health: From Process to Outcomes, 2nd edition*. San Francisco, CA: Jossey-Bass.

Marquez-Velarde, G. 2013. *Mental Health in a Colonia*. Ph.D. dissertation, University of Texas at El Paso.

1. Staudt, K., M. Dane-El, G. Marquez-Velarde. 2015. "In the Shadow of a Steel Recycling Plant in These Neoliberal Times: Health Disparities Among Hispanics in a Border Colonia." *Local Environment* 21 (5): 636–652. doi:10.1080/13549839.2015.1016902.

2. Crowder, D. 2010. "Communities Split Over Nearby Steel Plant." *El Paso Inc. Magazine*, July 11–17, 22A.

more comprehensive environmental information while building stronger relationships with current and potential stakeholders. EPA can become an increasingly active partner in a collaborative network.

2.1: Be an active partner and a leader of citizen science at the highest level

Although citizen science is not new, increased awareness exists about the many citizen science efforts underway in the United States and many parts of the world; many of these efforts are coordinated among numerous organizations. Because EPA is seen as the final arbiter of environmental and health science, the Agency can lend credence and encourage partners to pursue citizen science approaches by acting as a convener and coordinator. EPA should be an active partner and a leader of citizen science at the highest level, supporting other organizations' efforts and highlighting best practices.

As the federal government's main environmental regulatory body, EPA should take on the primary role of encouraging other government agencies to get involved and inspiring nongovernmental organizations to greatly expand their efforts. Through this strategy, EPA can empower groups already working on citizen science by supporting community-based initiatives; small businesses providing research, tools and services; and key partners. EPA should organize and invest in high-impact partnerships for citizen science and leverage existing networks that cross organizational boundaries.

2.2: Recognize the vital role of other organizations and embrace the Agency's unique role in citizen science

Citizen science is built on collaboration, and successful efforts often engage diverse organizations that contribute in different ways. Organizations across the United States are interested in contributing to citizen science at the local level, and EPA can benefit from the multiplicative power of these organizations' environmental networks. Rather than managing citizen science programs and projects independently, EPA is beginning to find ways to leverage its own expertise in networks of other organizations. Moving forward, the Agency should embrace this approach and collaboratively support other organizations that are engaged in and often better equipped to manage citizen science programs. EPA should not manage citizen science projects independently but rather design and conduct these projects in collaboration with other organizations.

Ultimately, EPA's key role is to be an enabler. The Agency can create synergy in some cases by being an equal partner and in others by playing a supporting role. EPA can help organizations with similar interests to collaborate and build networks, assist in capacity building through training and tools development, ensure scientific quality is designed into projects, communicate data quality needs, and improve data utility and access. EPA should use these collaborations to help gather needed data strategically and improve the Agency's ability to achieve its mission. Working across organizations multiplies resources and efforts and allows citizen science to achieve greater effect for every dollar spent, supporting a faster rate of return.

Role of Museums and Educational Institutions: Connection With Youth and Students

EPA has limited direct connection to members of the public. EPA needs to collaborate and utilize existing formal "K–16" educational and academic institutions, organizations and networks to encourage and invest in citizen science. EPA can leverage existing citizen science efforts and help direct and focus their applicability to meet the information and data needs of the Agency.

Informal educational organizations and institutions—including museums, science centers, and youth and outdoor education centers—offer great citizen science opportunities. These entities often have more flexibility in their offerings to maximize exposure and citizen science engagement with youth and adults.

2.3: Identify partners that can leverage citizen science to achieve common goals

Key partners

EPA should identify national, regional and local partner organizations that would create the greatest synergy for using citizen science and work collaboratively with these organizations (**Table 4**). Key organizations will advise EPA and provide leadership, resources and support for citizen science groups; working together will prevent duplicative efforts and increase capacity. Many of these organizations already host conferences and trainings and provide resources, technical support and best practices. These entities are a conduit to the needs of the citizen science groups and can be a strategic connection to communities and participants. One such organization is the Citizen Science Association (citizenscience.org).

In particular, many environmental and health organizations, including environmental justice groups, provide services to underserved populations and already have a mission and the capacity to implement citizen science. Many have been operating community-based environmental monitoring separate from governmental support because of barriers within local, state and federal agencies. Intermediary organizations aim to connect smaller organizations and scientists to members of the

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
Industry	• 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

public. Others have access to local group networks and can help connect EPA and local needs with citizen science projects. Examples of intermediary organizations include River Network (rivernetwork.org), Public Lab (publiclab.org), and Air Alliance Houston (airalliancehouston.org). By focusing partnerships on these organizations, EPA can expand the reach of its citizen science efforts.

Federal, tribal, state and local governments

EPA should align efforts and develop a clear plan for how to build on existing relationships with federal, tribal, state and local agencies. EPA should encourage these agencies to promote citizen science within their spheres of influence.

Nontraditional partners

EPA should build collaborative public-private partnerships to advance the goals of citizen science policies and as a means to accelerate citizen science acceptance as a ubiquitous component of environmental stewardship and leadership.

The private sector is an important but underutilized partner for expanding the scope and effect of citizen science. Industry and business have the capacity to develop technology for every step of the process (e.g., input, retrieval, analysis, display, integration), but citizen scientists often have no mechanism to connect with these innovations to meet their technology needs. The private sector's ability to create marketplaces and raise capital can complement academic and government resources and help citizen scientists access expensive and cutting-edge technologies. The creative efforts by companies committed to sustainability are a model for how the private sector can engage in citizen science, and EPA can help connect these companies with citizen scientist efforts. The Agency should support small businesses that create tools as long as the small businesses share a commitment to open data and tools.

The Citizen Science Association

"The Citizen Science Association actively works to—

- Establish a global community of practice for citizen science.
- Advance the field of citizen science through innovation and collaboration.
- Promote the value and impact of citizen science.
- Provide access to tools and resources that further best practices.
- Support communication and professional development services.
- Foster diversity and inclusion within the field."[6]

citizenscience.org

Oneida citizen scientists are ready to plant wild rice to help restore wetlands in the Coyote Run Natural Area, Oneida, Wisconsin. ***Photo credit:*** *Oneida Environmental Health and Safety Division.*

Recommendation 3: Define and communicate EPA's role in citizen science

Various legal, administrative and procedural issues may constrain or promote the use of citizen science data and information in EPA's specific environmental policy and regulatory decision making. An example of a barrier to the use of citizen science data and information is seen in the Paperwork Reduction Act of 1980,[7] which has resulted in limiting public involvement in federal agency projects. Questions also exist about privacy, access to monitoring sites, data quality, and volunteer liability issues. Laws and existing guidance affect EPA's ability to use data and information obtained from citizen science, including procedural limits on the timing of scientific inputs for regulatory decision making, peer review, human subject research, and evidentiary support for enforcement actions.

There will be situations and cases for which the risk, cost, rules and regulations either inhibit or prohibit the use of citizen science data and information by the Agency. EPA will be able to discern those situations and should develop a process and mechanism to articulate, communicate and be transparent regarding the limits and rationale.

Every entity, including EPA, has limitations. The Agency has an opportunity to be transparent and institute a consistent, accountable and systematic process for discerning and communicating these limitations. By acknowledging that these instances exist and having such a process, EPA can build trust, reduce miscommunication and strengthen Agency and citizen science efforts. To do so, EPA could:

- Make yearly commitments/goals towards addressing citizen science barriers.
- Clearly communicate the issue in a way that allows for constructive thinking in the broader citizen science community.
- Establish a working group to address each barrier.
- Request input from the public on how to address each barrier.

Citizen Science in Tribal Nations

Tribal nations already use citizen science and are interested in expanding the types of applications. NACEPT conducted a survey of tribal citizen science projects and organized a discussion of tribal needs and interests during a session at the December 2015 National EPA-Tribal Science Council business meeting and at the April 2016 Tribal Environmental Program Management Conference. Tribes use citizen science in a variety of ways. For example, in the Great Lakes region, tribal members are interested in how citizen science can be applied to issues such as wild rice, water quality, invasive species, illegal dumping, wildlife harvests, frog and toad surveys, forest and prairie restoration, maple syrup, and phenology.

Ironbound Community Corporation Partnership

Location and Dates:
Newark, New Jersey,
2013 to 2015

Groups Involved:
Ironbound Community Corporation and EPA

Also an Example of:
Community engagement, condition indicator

Budget: $170,000

IN BRIEF

Topic: Human health, air quality
Scale: Local
Participants: Community members
Data uses: Education, community engagement, condition indicator

Summary: EPA has partnered with citizen groups, such as the Ironbound Community Corporation, to empower communities to collect their own environmental data, understand their local environmental conditions, and evaluate citizen science air monitoring sensors. EPA provided the air monitors, guidance on instrument siting and operation, data management software, and guidance on quality assurance. These EPA resources facilitate education, awareness and stewardship and also build community capacity for citizen science. The air monitors measure nitrogen dioxide and fine particulate matter, two air pollutants with significant health effects. This project successfully engaged citizens in data collection of air quality measurements, identified geospatial trends in fine particulate matter and nitrogen dioxide, and put the community air quality into context with that of other cities.

More information: epa.gov/sites/production/files/2015-03/documents/citizen_science_toolbox_ironbound_community_fact_sheet.pdf; cfpub.epa.gov/si/si_public_file_download.cfm?p_download_id=527976

Recommendation 4: Emphasize place-based approaches to citizen science

A place-based approach is central to citizen science for defining and solving problems at the local and community levels. By increasing engagement at the local level and promoting outcomes in local decision making, place-based citizen science can reduce the need for regulatory intervention and increase the capacity of EPA to support environmental protection. Citizen science has the potential to substantially contribute to EPA's core mission, especially when thoughtfully fused with EPA's existing top-down regulatory and enforcement approaches. This convergence must start with a place-based and thematic focus, however, to identify short-term outcomes that demonstrate environmental and human health benefits to a particular geographic area.

The "power of place" is the influence of emotional, cultural and material connections to the places where people live, which motivates action. In addition to science providing knowledge, the concept of place is central to other ways of knowing, such as traditional ecological knowledge. Not only does an emphasis on place enhance the experience for participants in citizen science, but also these efforts ultimately have more of an effect on decisions. Newman et al. (2016) recommend explicitly incorporating "place" into project design and implementation, using the power of place to co-identify issues, goals and objectives; tying citizen science to identified priority stressors, phenomena and baseline needs; increasing place-based collaboration in citizen science; and creating place-based networks for collective impact. While emphasizing the power of place, EPA's efforts also should recognize the value of networking smaller efforts and pooling citizen science information and resources.[8]

Center in the Park's Senior Environment Corps

Location and Dates: Philadelphia, Pennsylvania, 1997 to present

Groups Involved: Ironbound Community Corporation and EPA

Also an Example of: Community engagement, condition indicator

Budget: Unknown

IN BRIEF

Topic: Water quality, ecosystems, habitat assessment
Scale: Local
Participants: Older adults
Data uses: Education, community engagement, condition indicator

Summary: According to its website, Center in the Park's Senior Environment Corps (CIPSEC) is "a group of dedicated volunteers who value the area's natural resources and are working to conserve, preserve and improve the environment for future generations." Established in 1997, CIPSEC provides opportunities for older adults to play an active, visible role in environmental protection, education and advocacy. Volunteers participate in a variety of important projects, such as monthly water quality monitoring, habitat assessments, tree plantings, watershed tours, environmental events, advocacy projects, school programs, youth and community education and outreach programs, and trips. For example, they found *Escherichia coli* counts in the hundreds of millions on the Monoshone Creek, which alerted the Philadelphia Water Department, Pennsylvania Department of Environmental Protection and EPA to respond. As a result, the Philadelphia Water Department issued a multimillion dollar emergency contract to address suspected sewer cross connections.

More information: www.centerinthepark.org/programs-environment.html

For example, if attainment of EPA's goals for clean water (or improved soil or air quality) is challenged by the lack of adequate assessment of watersheds, an EPA strategy and unifying vision for citizen science should start with selecting a specific number of high-priority, stressed, geographically defined watersheds (e.g., the Shenandoah River watershed) and determining how a citizen science-led effort could aid in specific assessment efforts. The evaluation of prospective citizen science contributions to that assessment effort also would benefit from the consideration of:

- Clear relationships with existing EPA regulatory/enforcement efforts within that specific geographic area.
- Existing connections to EPA and existing and potential partnerships with local/geographically defined commercial, educational, research, civil society and governmental institutions.

Using electric current to stun fish during a stream survey. ***Photo credit:*** *U.S. Environmental Protection Agency.*

- Potential replication of any successes and lessons learned to other geographic areas of the United States.

Specifically, EPA could strengthen partnerships formed through watershed planning for Clean Water Act Section 319 grant projects and total maximum daily loads. Volunteer monitors could be engaged in additional monitoring to document success or needed refinements to the implementation of these plans.

Photo credit: *Michaela Taylor.*

CHAPTER THREE: Invest in Citizen Science for Communities, Partners and the Agency

To take advantage of the opportunities that citizen science presents, the Agency must invest in citizen science efforts. Although it requires resources, citizen science is cost-effective and a force multiplier for EPA even in strained fiscal times. There is a critical role for Agency receptivity to citizen science both with and without increased funding capacity. To build resources and capacity for citizen science, EPA must provide resources—including funding, technical support and training—and understand the technical capacity needed to fully engage with a field that has embraced innovative technology. EPA should review its internal capacity to support citizen science by investing in resources over the long term that will amplify current work and encourage innovation and the advancement of citizen science.

Recommendation 5: Dedicate funding for citizen science

The Agency should review current funding guidelines to ensure that citizen science efforts are supported across an entire project—from community engagement to data management and transfer—and should identify future funding initiatives that encourage the innovative expansion of citizen science practices.

EPA additionally should support community citizen science and other citizen science projects that approach timeframes and impacts differently, including the support of proactive data and information gathering, baseline monitoring network creation, and long-term monitoring projects. Data collection efforts not only should support direct outputs but also appropriately answer the question being asked in terms of the amount of data collected, resources spent, collection period duration and collection timeline. Funding should encourage long-term efforts through sustainable funding.

5.1: Provide more funding opportunities for community citizen science within all EPA program areas

Citizen science is cost effective, but it requires support. EPA should include the following as part of its funding strategy: seed grants for facilitating data transfer between community organizations and municipalities, direct citizen science grants to community organizations and tribal groups, multiyear funding for projects to monitor long-term trends, the integration of resources for funding community citizen science efforts across EPA program areas, and a favorable bias toward proposals that include community citizen science methods. Long-term funding is particularly important for monitoring long-term trends. EPA must provide funding that supports monitoring as a preventative measure rather than as solely a reactive measure.

As part of this effort, EPA should strive to adopt an integrated approach to support citizen science. Within EPA, many opportunities exist to support citizen science at the local level, and EPA should strive to create some integration of these efforts. Real environmental issues affect or are derived from multiple sources that different EPA programs address, and the Agency's response to and support of community citizen science initiatives should reflect these interconnections.

Comparing results for Colorado River Watch. ***Photo credit:*** *Michaela Taylor.*

In addition to broad funding support for citizen science programming, EPA could sponsor citizen science awards and recognitions for innovation in citizen science. EPA could work with citizen science organizations to identify strong ideas that support citizen science-driven partnership development, education and innovation in addressing Agency and community priority areas.

5.2: Allow and encourage citizen science in Agency-wide grant-making practices

Increased monetary and public support for citizen science should be distributed across Agency grant-making programs and used as a metric to measure public involvement in funded projects. Citizen science signals strong partnership development and community engagement and should be rewarded in grant-making programs.

EPA could modify the conditions of grants so that they are more amenable to funding citizen science work. Specifically, EPA can use its grant-making authority to push the limits of its programs by:

1. Encouraging and funding innovative projects that use citizen science methods in the understanding of, or solution to, emerging issues.
2. Developing proposal assessment criteria that foster the incorporation of citizen science in funded projects.
3. Encouraging pilot partnerships and demonstration projects to understand the boundaries of current statutes, regulations and guidelines in relation to data generated through citizen science processes.

Recommendation 6: Improve technology and tools and build technical capacity

As citizen science increasingly incorporates open technology and media developed outside of EPA, the Agency should nurture the development of the field and extend efforts to get the most out of citizen science as it grows and progresses rather than trying to reactively manage the resulting issues.

6.1: Build citizen science capacity by providing technical support, training and guidance through intermediary organizations rather than investing in new tools

The Agency should carefully consider its own role in capacity building and how to collaborate with other organizations that have expertise and credibility at the local level, especially intermediary organizations. The public has increased its contribution to creating environmental monitoring technology—software and hardware—and EPA should respond to this trend by providing co-design and co-location opportunities for testing hardware or facilitating these requests with states.

Citizen science has built infrastructure around data collection, storage and management. The Agency should take advantage of this existing infrastructure and focus on how and where it can best increase the capacity of citizen science efforts, whether through support for infrastructure maintenance or leading the drive around data accessibility for communities and the public. EPA also should assess the current resources that it provides to community citizen science efforts and invest in technical training on EPA documentation through intermediary organizations. Supporting current citizen science efforts rather than attempting to build independent EPA citizen science programming will net greater effects.

EPA should collaborate with intermediary organizations to help communities design and implement projects. This would include support at strategic points in citizen science processes, such as providing input on study design during project planning phases; providing resources, materials and participant training prior to the start of a project; and providing assistance on

Argentine/Turner Rail Yard Community Air Pollution Monitoring

Location and Dates:
Kansas City, Kansas,
2013 to 2015

Groups Involved:
Argentine/Turner Good Neighbor Committee,
Diesel Health Project,
Global Community Monitor, Kansas Sierra Club,
Kresge Foundation

Also an Example of: Community engagement, research

Budget: Unknown

IN BRIEF

Topic: Air quality
Scale: Local
Participants: Community residents
Data uses: Condition indicator, community engagement, research

Summary: The Good Neighbor Committee and its partners conducted a community-based air-monitoring project in the Argentine and Turner neighborhoods of Kansas City, Kansas, from late 2013 through early 2015. The project sought to characterize the potential impacts of emissions from diesel switch yard locomotives on the health of low-income residents, a significant percentage of whom are Hispanic and African American and live adjacent to the facility. Monitoring results showed that high levels of elemental carbon (EC)—a constituent of diesel exhaust—were present in neighborhoods near the switching yard. A report of the study[1] provided to Global Community Monitor characterized the risks as follows:

Seven of 16 EC levels in filtered air samples were above a level associated with a short-term health risk. These are generally closer (within 200 meters) to the BNSF Railway facility; samples with lower EC levels were generally further (more than 1,000 meters) from the facility.

EC levels exceeded normal to the point that persons spending time outdoors at this location would be subject to an elevated risk of cardiovascular and respiratory hospitalizations on the day of exposure on 21 of 47 days.

On seven of these days, EC levels also were high enough that persons spending time outdoors at this location on these dates also would be subject to an elevated risk of cardiovascular mortality 2 and 3 days postexposure.

Publication of the report generated significant local television and newspaper coverage. The *Kansas City Star* published an editorial calling for the BNSF Railway to work with EPA to reduce emissions from the facility. Since the project report was published, the Good Neighbor Committee and BNSF Railway have had an ongoing dialogue about emissions reduction strategies and the needs of the community.

More Information:

drive.google.com/file/d/0ByaDcI-8M5aXY3U4amc5aDJNbDg/view?pref=2&pli=1

mokanair.com/2015/07/kansas-city-star-calls-for-bnsf-and-epa-to-take-action-regarding-air-pollution-from-the-argentine-rail-yard

www.kansascity.com/living/health-fitness/article25735729.html

kansascity.com/opinion/editorials/article25924828.html

1. Chernaik, M. 2014. *Letter to Global Community Monitor Regarding Argentine Turner Diesel Project. Science for Citizens. July 8.*

resource-intensive topics, such as equipment calibration. EPA can effectively provide technical support and training via intermediary organizations, which can receive technical support and training and distribute the information within their networks.

The Agency should respond to requests for information and support community citizen science efforts by providing technical assistance and training related to study design (e.g., quality assurance/quality control [QA/QC] requirements, QAPPs). EPA also should collaborate with intermediary organizations to offer training opportunities for activities that are highly resource-intensive for community groups, such as tool calibration and data interpretation. EPA can help build capacity in communities and citizen science efforts by creating documents that will enhance project accessibility, such as training materials and easily replicable workshop structures; these documents can be distributed through intermediary organizations as well. EPA could support community citizen science and citizen science projects through activities such as the following:

- To ensure sensing projects are being structured appropriately, EPA should publish example experimental frameworks for individuals and communities to follow. These example projects would be able to be duplicated by other communities.
- Photographic evidence is relatively easy to obtain and can support project types across the spectrum of citizen science data uses. To encourage and inspire through partnering with organizations, EPA could provide solid guidance for reporting environmental issues with photography and host reports on public sites outside of the Agency that are widely used for environmental documentation, such as Public Lab and iNaturalist.org (www.inaturalist.org). Through partnerships, EPA could annotate and comment on reports with such feedback as the following: "Place this on a map," "Provide more contextual photos," or "Add photos from another day to establish a pattern."
- Because videos are more accessible than written materials, EPA should provide a series of YouTube videos about different types of monitoring and testing. Videos could be produced by EPA or through a competition sponsored by EPA; the Agency also could highlight videos others already have made. Videos would allow people to see—in concrete, visual terms—the processes that EPA expects when monitoring.
- EPA should be responsive to the fact that many community citizen science efforts employ commonly available technological tools, such as Microsoft Office or Google Earth. The Agency needs to make data and information available to communities in formats that are compatible with these tools.

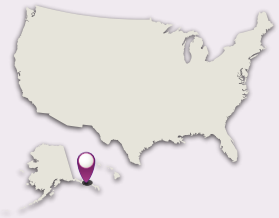
"iNaturalist is a place where you can record what you see in nature, meet other nature lovers, and learn about the natural world."[9]
–SciStarter.com

6.2 Provide clear guidance on advanced monitoring technology

A recent rapid evolution in environmental monitoring has opened up opportunities for citizen scientists to collect more and better data about their environments using smaller, portable and less expensive sensors. The performance of new monitoring technology, however, often is unknown, and the quality of the resulting data is not trusted. A recent report by the E-Enterprise Leadership Council provides several recommendations to address these concerns, which are in line with the other recommendations in this report. The E-Enterprise Leadership Council recommends that EPA perform a detailed options and feasibility analysis on the creation of an independent third-party evaluation/certification program to ensure that clear and objective information on the quality of new technologies is available and develop and start executing technology scanning and screening

EPA Administrator Gina McCarthy (in red) meets with community members in Newark, New Jersey. ***Photo credit:*** *Marie O'Shea, U.S. Environmental Protection Agency Region 2.*

Southeast Alaska Tribal Toxins Partnership



Location and Dates: Sitka, Alaska, 2013 to present

Groups Involved: Southeast Alaska Tribal Ocean Research (SEATOR), Southeast Alaska Tribal Toxins (SEATT) partnership, Sitka Tribe of Alaska Environmental Regulatory Laboratory, Sitka Tribe of Alaska

Also an Example of: Community engagement, research, management

Budget: $1.5 million as of 2016. Although it is a challenge to maintain funding for citizen science, many small communities in Southeast Alaska are interested in engaging in citizen science. Mr. Chris Whitehead (SEATOR founder) is working with partners, including the National Oceanic and Atmospheric Administration (NOAA), University of Alaska Fairbanks, the commercial geoduck industry, and the Alaska Department of Environmental Conservation to obtain funding for equipment and supplies for these interested communities.

IN BRIEF

Topic: Toxic substances, human health

Scale: Regional

Participants: Members of Alaska Native villages and tribes

Data uses: Condition indicator, community engagement, research, management

Summary: The SEATOR program is involved in a variety of projects in Southeast Alaska, including the SEATT partnership. SEATOR supports partnered tribes working together on climate change-related impacts on the marine environment in Southeast Alaska; this unprecedented unification of Alaska tribes provides credibility. Despite the common concern about subsistence clam resources and the increased prevalence of harmful algal blooms (HABs), Alaska state agencies have not provided needed assistance regarding these issues, so SEATOR created the SEATT partnership in late 2013 using EPA Indian General Assistance Program funds to develop an early warning system. Paralytic shellfish poisoning (PSP) from HABs is caused by a toxin more lethal than sarin nerve gas, with coastal Alaskan Native populations being 12 times more likely to be affected by PSP than non-Native communities.

Currently, no subsistence or recreational regulatory safety testing is performed by Alaska state agencies; only commercial shellfish are tested. This created a niche for SEATT, which monitors species abundance, cyst beds, HABs and other conditions. As part of an approved Quality Assurance Project Plan, SEATT provides training to citizen scientists via workshops, videos and a sampling manual. Citizen scientists also receive equipment that allows them to communicate their findings directly to Mr. Whitehead, who is able to identify species remotely from his computer desktop. Data collected by SEATT are provided to NOAA's SoundToxin Database and Phytoplankton Monitoring Network. The citizen science data collected by SEATT are reliable and allow state agencies to make informed decisions. This real-time citizen monitoring has allowed the development of an early warning system and forecasting tools.

SEATT provides outreach to tribal and nontribal citizens about the health risk potential related to the subsistence clam harvest and coordinates with state and local health departments about this issue. The group also is developing an interactive online mapping tool to help fisherman and clammers make informed decisions. The Sitka Tribe of Alaska Environmental Regulatory Laboratory was established to support SEATT with real-time shellfish toxin analysis and provide regulatory data to tribes and communities to assess their vulnerability to risks associated with marine biotoxins. Tribes can use the laboratory to develop subsistence shellfish management plans.

More Information: www.seator.org; seator.org/seatt

procedures within EPA and the states. The Agency also should provide support to help users make decisions on which equipment they should purchase and pilot for a particular use. Both of these steps would provide useful guidance to groups as they identify which technologies to use and identify project goals.[10]

6.3: Provide clear EPA policy preference on open licensing

Because EPA is a publicly funded agency, any products (e.g., results, tools, equipment, techniques) developed using Agency funding should have open licensing and not be patentable. Examples of licensing options include Creative Commons (creativecommons.org),[11] the GNU General Public License,[12] the CERN Open Hardware License[13] and the MIT license.[14] The Free Software Foundation also provides a detailed list of licenses.[15]

6.4: Provide co-design opportunities, including documentation, data and toolkits

EPA documentation should include broad support for processes being used by community citizen science efforts and provide support through intermediary organizations. EPA should incorporate equipment performance rather than specific instruments in Federal Reference Methods (FRMs) and Federal Equivalent Methods (FEMs) and make the guidance accessible so that people can produce and use equipment more suitable to their situation (e.g., lower cost, more portable). EPA should provide support for developing QA/QC and Quality Management Plan documentation that is reflective of the open design and development processes that many citizen science efforts are using. EPA should disseminate calibration standards so that communities, as well as open hardware groups and companies, can test their equipment against them to determine fitness for a specific type of monitoring. Being able to pass a double-blind "EPA test" potentially would prompt further involvement from EPA's ORD.[10] This recommendation is in line with the recommendation of the E-Enterprise Leadership Council to "lean the current technology approval process to ensure that regulatory, permitting and compliance programs operate as efficiently as possible."

Generally, EPA should support community citizen science projects in developing documentation—in collaboration with intermediary organizations—that can facilitate project replicability, such as curricula, workshops and training materials.

Federal Reference Methods and Federal Equivalent Methods

EPA, along with state, local and tribal governments, operates regulatory monitors to assess compliance with National Ambient Air Quality Standards (NAAQS) established under the Clean Air Act.[16] Section 103 of the Clean Air Act[17] requires that EPA "shall conduct a program of research, testing, and development of methods for sampling, measurement, monitoring, analysis, and modeling of air pollutants" through the "[e]stablishment of a national network to monitor, collect, and compile data" and "[d]evelopment of improved methods and technologies for sampling, measurement, monitoring, analysis, and modeling." With this direction, EPA has established Federal Reference Methods and Federal Equivalent Methods for instruments and manual methods (e.g., monitors, analyzers and samplers) used in monitoring for the NAAQS.

6.5: Make data and information available and accessible

EPA should focus on identifying what EPA data sets are available and support the use of these data sets by enhancing data clarity, promoting data literacy and facilitating data interpretation. EPA can obtain input on what communities need to visualize and interpret data and co-design systems. The Agency also should work to make data from settlement agreements or permits available and accessible.

6.6: Provide citizen science tool developers with specific examples of the Federal Equivalent Method designation process

The example of rigorous validation for FRMs and, in turn, development of equivalent requirements for new technologies in the form of FEMs, may provide an effective model for making data and information useful for multiple purposes in citizen science projects. For example, a number of personal air sensors have been introduced into the market in recent years, but only one, the Personal Ozone Monitor™ by 2B Technologies, has

Watershed Monitoring in the Mill (Otter) Creek Watershed

Location and Dates: Bucks County, Pennsylvania, 2012 to present

Groups Involved: Silver Lake Nature Center, Friends of Silver Lake Nature Center, independent community members

Also an Example of: Community engagement, condition indicators

Budget: $10,000 grant. After the initial funding, the staff time required to support the program has been funded by the Friends of Silver Lake Nature Center. The initial cost of a water monitoring kit is approximately $500, and the annual upkeep costs range from $50 to $150. Grants sometimes are available to cover the initial cost.

IN BRIEF

Topic: Water quality
Scale: Regional
Participants: Residents of local municipalities
Data uses: Research, community engagement, condition indicators

Summary: The Mill/Otter Creek watershed is part of the Delaware Estuary Coastal Zone, beginning at Mill Creek, running through Magnolia and Silver Lakes, and ending at Otter Creek, which flows into the Delaware River. In 2011, the Friends of Silver Lake Nature Center received a $10,000 grant to develop a watershed monitoring and education program and to provide outreach to local municipalities. There are two main components to the watershed monitoring program: data collection and stormwater drain mapping. Once a month, a core group of about 12 volunteers works in pairs to test different sites in the watershed for pH, dissolved oxygen, nutrients such as phosphates and nitrates, and the presence of aquatic organisms. In addition, volunteers locate and map stormwater drainage outfalls. These data are available to local municipalities and the state and are used to help determine the sources of any pollutants found in the watershed.

The data are kept in Excel format and mapped in Google Earth to provide access to anyone who is interested. It is reported internally at the Silver Lake Nature Center and also shared with local, state and private organizations such as the Delaware Riverkeeper, Pennsylvania Department of Environmental Protection, Pennsylvania Fish and Boat Commission, health departments, and Stroud Water Research Center. The Silver Lake Nature Center hired an outside organization to assess its quality assurance and quality control criteria (test the testers and the equipment) and passed with flying colors. A retired chemist calibrates the equipment. Data are recorded monthly on spreadsheets, which keep track of who monitors each site and allows pictures to be uploaded.

With additional funding, the Silver Lake Nature Center would like to collect data before and after stream remediation projects to tie in with the current high school curriculum and also develop an additional high school curriculum involving field work, teacher training, student involvement, equipment purchases and lesson plans.

More Information: silverlakenaturecenter.org, silverlakenaturecenter.org/things-to-do/watershed-monitoring/

been designated as a FEM,[18] with the caveat that a user must ensure that the instrument is used according to FEM protocol, including appropriate ambient conditions and calibration. A full listing of FRMs and FEMs as of June 17, 2016, is provided by EPA's Ambient Monitoring Technology Information Center.[19]

Public Lab

Public Lab is a community of scientists, organizers, educators and researchers, supported by a 501(c)3 nonprofit, that develops and applies open-source tools to environmental exploration and investigation. Public Lab seeks to change the way people obtain, understand and share information and equips communities with the tools they need to collect and share good, communicable research on local environmental issues. By doing so, people concerned about the wellbeing of their environment and communities are able to be active participants in the research process, contribute their considerable but often overlooked expertise, and advocate for the changes they need. The PublicLab.org research portal provides people with the ability to contribute and share questions and environmental research.

publiclab.org

6.7: Improve access to the best tools for data management from the public and private sector and promote EPA data accessibility, not ownership

EPA should collaborate on data management tools that benefit and are supported by EPA but which have shared costs and are developed through partnerships. Currently, the number of new platforms, apps and tools for citizen science efforts is expanding rapidly. EPA should support the public's ability to access, analyze and interpret data by building in and supporting the use of tools for data aggregation, storage and interpretation outside of tools created by the Agency. EPA needs to help promote and make data management sites widely available, transparent and easily accessible in a format that meets all the recommendations of this report.

Because of the diversity of organizations, disciplines and environmental media encountered in citizen science

Examining bacterial cultures at the annual Public Lab conference in Cocodrie, Louisiana. ***Photo credit:*** *Public Lab/Jeffrey Warren.*

projects, EPA's technology capability and funding would be inadequate for the Agency to be the repository for citizen science data and information. Recent trends in information management indicate a stronger public trust in shared, open-source systems, as well as a diminishing role for government agencies as the sole repositories of scientific data and information. Consistent with this trend, citizen science data and information should be collected and managed in nonproprietary, unencrypted, uncompressed, open-standard formats.

"CitSci.org supports your research by providing tools and resources that allow you to customize your scientific procedure—all in one location on the Internet. As your partner in research, CitSci.org provides tools for the entire research process, including: creating new projects, managing project members, building custom data sheets, analyzing collected data, and gathering participant feedback."[20]
–CitSci.org

Nevertheless, EPA can create systems to help communities understand the data products, results and insights generated from citizen science projects. EPA should identify which entities are equipped to manage the data, identify elements to include so that EPA can

use the data, and collaborate with external organizations from the beginning so that EPA can benefit from the data collected. Any data management sites supported by EPA should follow the guidelines outlined in this report, including transparency and the inclusion of metadata.

Citizen science projects originate from a variety of sources, and that grassroots nature will continue. Rather than focusing on one particular site or portal, EPA should work to ensure that sites can communicate and work to make those data accessible and usable at EPA. When possible, EPA should funnel relevant citizen science projects to the most extensively used sites.

EPA should inventory what data warehouses and platforms exist that the Agency could leverage to funnel data to citizen science projects and ensure accessibility of citizen science data to the Agency. Examples of sites include CitSci.org (citsci.org), SciStarter.com (scistarter.com) and the Water Quality Portal (waterqualitydata.us).

> "SciStarter is the place to find, join, and contribute to science through more than 1,600 formal and informal research projects and events. Our database of citizen science projects enables discovery, organization, and greater participation in citizen science."[21]
> **–SciStarter.com**

The Water Quality Portal and the Water Quality Exchange, (epa.gov/waterdata/storage-and-retrieval-and-water-quality-exchange), a means for publishing data to the portal, provide mechanisms to document and communicate data quality, evaluate data quality, support metadata inclusion, communicate data standards and establish credibility. The portal also already provides data integration with the U.S. Geological Survey's National Water Information System and other federal agencies, states, tribes and volunteer monitoring groups.

A model that EPA should review is that of the California Monitoring Council. Implementing a similar model would not require EPA to engage in managing data—the users determine the use and validity for their own purposes—but such portals still could provide a "go-to place" to display results. The cost-sharing model provides resources, transparency and shared responsibility for each portal.

Approximately 60,000 participants helped researchers to classify plant, rock and bone fragments embedded in more than 1 ton of mastodon matrix. ***Photo credit:*** *SciStarter.*

The **California Monitoring Council was** charged with using all available data for its Clean Water Act and California Environmental Protection Agency decisions. Rather than create a "one-stop shop," the California Monitoring Council opted to provide portals to share and disseminate information based on such questions from the public as "Is my water safe to drink?" This unfunded legislative mandate is supported by the data providers and users, including entities that have regulatory mandates and citizen science groups. Data are not judged but are displayed and available based on the question and mission. Each portal contains data with varying degrees of data quality that are available for review and download. The California Monitoring Council determines data guidelines, norms and portal goals.

Photo credit: *Center in the Park Senior Environment Corps.*

CHAPTER FOUR: Enable the Use of Citizen Science Data

Data and information are critical to EPA's mission. Citizen science communities are a rich source of information for public policy makers as well as the scientific and environmental communities.

By identifying major citizen science data issues and solutions, EPA can encourage citizen science projects and ensure that these efforts ultimately positively benefit human health and the environment.

EPA needs to revisit and change its approach to data and information, particularly data collected outside of the Agency. Delaying a strategy toward the integration and communication of data from the public will cause misunderstandings and conflicts that undermine the capacity and ability of EPA to achieve its mission.

Recommendation 7: Adopt a positive, cooperative agenda that increases the utility of citizen science data

There is a perception that EPA has an implicit bias against citizen-generated data and information and that EPA and state organizations minimize the value of community citizen science, having not embraced an approach to improve the quality and quantity of these efforts. Community citizen science groups are frustrated that state and federal agencies generally do not accept data collected through citizen science efforts and often are uncertain about how local, state and federal agencies will recognize and use the data that they collect. The Agency can promote community trust by embracing community needs and issues, developing outreach to build relationships, supporting a collaborative mentality, and recognizing that shared data and information can lead to shared understanding.

Environmental Justice 2020 Framework: EPA's Response to Public Comments

"Commenters suggest that EPA encourages community-based participatory research and citizen science but has not provided a clear path for consideration of citizen-gathered data. EPA should create a policy on the use of citizen science."[22]

The scientific value of citizen science often is underestimated, and citizen science data often are assumed to have lower quality than data collected entirely by professionals. This assumption affects the usability of data for different purposes at EPA. The topic of citizen science data quality is being extensively explored in academic literature, and no evidence exists that citizen science data are inherently less reliable than professionally collected data; one recent meta-analysis found that citizen science data sets and those produced by professionals were similarly reliable and that most types of bias in citizen science data sets also are in professionally produced data sets.[23] Citizen science projects often adhere to high standards of data quality to combat this perception, and most citizen science studies employ at least two validation methods to ensure data quality.[24,25] Moreover, in some cases, "quantity becomes quality." Low-quality data from 5,000 distributed sensors actually may provide a better synoptic picture of the spatial variation of problems than high-quality data from a few monitors. EPA can employ a number of strategies to ensure that citizen science data quality is

Members of the public learn about and inform NASA's Asteroid Initiative during a public deliberation organized by The Expert and Citizen Assessment of Science and Technology (ECAST). ***Photo credit:*** *Arizona State University.*

suitable for the intended use; these strategies all involve the establishment of clear guidance and transparent procedures.

The Agency needs an active agenda to dictate how these new approaches get managed and used to increase the utility of citizen science data, address internal and external obstacles in receiving and using data collected through citizen science processes, and guide future citizen science data generation. EPA has the opportunity to adopt a positive, cooperative agenda that allows the Agency to accept data collected through citizen science efforts. EPA must recognize that citizen science data sets come in all forms, from quantitative data from sensors to qualitative approaches such as traditional ecological knowledge and stories. EPA must embrace them all and work to extract useful information. The Agency should shift thinking from "How can EPA get the data it wants?" to "How can EPA want the data it gets?" In a shift to EPA wanting the data it receives, the Agency can focus on mining useful information out of the data and information that becomes available. The Agency should study means to extract all information from citizen science-generated data regardless of the standard used to collect the data. EPA must be careful that efforts to improve data quality do not alienate potential citizen scientists by adding too much complexity.

EPA currently addresses data and information needs by generating its own data through EPA staff efforts, contracts, collaborations and interagency memoranda, among other mechanisms; legislation (e.g., Clean Water Act,[26] Clean Air Act,[27] Safe Drinking Water Act[28]), regulations, partnerships and grants; and indirect or third-party collaborations and technologies. EPA already utilizes data and information from external sources, including states, tribes, other federal agencies, water utilities and stakeholder groups. For example, embedded in the Clean Water Act, dischargers collect their own samples for monthly permit discharge reports. The data quality, protocols and study design all are provided. Citizen science is another data provider—another source of data of a known quality. Citizen science is a significant source of scientifically valuable data that must be utilized strategically by EPA in the future to fulfill its mission.

Excellent examples of using citizen science data and information can be found in New Jersey,[29,30] Oregon,[31] California,[32] Montana,[33] Missouri,[34] Iowa,[35] New York, [36] Maryland,[37] Georgia and the Yukon Tribe.[38] The River Watch Program provides regulatory data (see case study). EPA can provide information, guidance, incentives, tools and resources to foster the continuation of these successful programs and initiation of additional programs.

Recommendation 8: Adopt standards for citizen science data

The role of EPA should be to help share and integrate data and information across citizen science efforts. EPA should work to establish and/or promote standards and should help make data more discoverable through improved metadata documentation.

EPA needs to be a leader in integrating and using a variety of data sources; efforts in this area will create comprehensive, geographically diverse data sets that can be used by the Agency and a wide range of partner organizations. EPA should participate in efforts around standardization to promote data accessibility by supporting the inclusion of metadata, standardized data collection, documentation and storage between organizations and projects involved in citizen science to promote accessibility and encourage reuse.

8.1: EPA should help to make data and information more discoverable through improved metadata documentation

Metadata describe and provide additional information about data; metadata are a means to document the quality of data sets so that the data's quality is known and transparent. In the context of citizen science, metadata can include time stamps, data collection locations, study purposes, monitoring questions, data quality objectives, field and laboratory methods, units, and QA/QC protocols.[1] Metadata also include data that describe measurements, such as temperature, wind speed and other environmental variables. Well-documented data with comprehensive metadata are an asset because they can be evaluated for fitness for use and therefore used repeatedly for other appropriate purposes and by other researchers outside the immediate context of data collection. When little is known about a data set, it cannot be used to make a decision, take a specific action, or be combined with other data sets.

8.2: EPA should work with partners to establish and promote data standards[39]

Data standards are rules establishing a consistent format for describing and recording data. Standards are relevant when data collection protocols are being designed and when data are documented through metadata, stored and made available for reuse. Implementing and employing the use of standards makes data usable to more than just the project or person that created the data. Standards are useful for integrating data from multiple resources; if the various sources initially agree on a standard, time will be saved in reconciling any differences. EPA's Office of Environmental Information already works closely with federal agencies, states, tribes and other partners to develop environmental data standards.

EPA can learn about relevant international data standards that exist or are in development, support and invest in existing international standardization efforts, and augment generic standards with standards specific to EPA when needed. EPA should determine and then accommodate practices and technology systems currently being used in the field. The Agency should work with key partners and states to develop valuable outputs from data standardization and integration and promote data sharing between states and territories.

Quality assurance testing for Colorado River Watch. ***Photo credit:*** *Michaela Taylor.*

Water Quality Portal

The Water Quality Portal is a cooperative service sponsored by EPA, the U.S. Geological Survey and the National Water Quality Monitoring Council.[40] It serves as a portal for water quality data collected by more than 400 state, federal, tribal and local agencies, including many citizen science organizations. The Water Quality Portal allows for degrees of standardization and data integration of water quality, physical habitat and biological data. The platform allows for documentation of metadata and communication of data quality and, therefore, can manage a range of data quality. The data platform puts the responsibility for the information and quality of the data on the data provider.

waterqualitydata.us

Water data currently can be integrated into EPA through the Water Quality Portal. EPA should continue its support of the portal and assist in the process of publishing data. Support should be focused on resources, tools and outreach staff to assist citizen science groups' capacities to publish data to the portal.

Friends of the Shenandoah River

Location and Dates: Shenandoah River Watershed in Virginia and West Virginia and other watersheds in Virginia, West Virginia, and Maryland, 1989 to present

Groups Involved: Shenandoah University, Friends of the Shenandoah River (FOSR) Clarke County Chapter, Friends of the Shenandoah River Three Rivers Chapter (North, Middle and South River), Friends of the Shenandoah River Page County Chapter, Friends of the Middle River, Friends of the North Fork of the Shenandoah River, Virginia Department of Environmental Quality (VA DEQ), Virginia Department of Game and Inland Fisheries, Soil and Water Conservation Districts, Blue Ridge Watershed Coalition, Shenandoah and Potomac Riverkeepers, Smith Creek Showcase Watershed Committee, C-Spout Run Project, Linville Creek Total Maximum Daily Load Project, Chesapeake Commons, James Madison University, George Mason University

Also an Example of: Management, regulatory decisions, education

Budget: Current annual operating budget is $145,000

IN BRIEF

Topic: Water quality
Scale: Regional
Participants: FOSR network
Data uses: Research, management, regulatory decisions, education

Summary: FOSR has a network of 800 members, including 80 volunteer citizen scientists collecting water quality samples at 150 designated sites throughout the 3,000 square miles of the watershed. FOSR operates a VA DEQ Level III accredited water quality analysis laboratory located on the campus of Shenandoah University. The laboratory is the only EPA-certified laboratory in the entire Chesapeake Bay region that is run by a volunteer citizen scientist nonprofit organization. The FOSR laboratory tests water samples for nutrients (total nitrogen, total phosphorous, ammonia, nitrate/nitrite, orthophosphate); water chemistry (dissolved oxygen, pH); water physical characteristics (water temperature, turbidity, conductivity); bacteria (total coliform, *Escherichia coli*); and benthic factors (macroinvertebrates, microinvertebrates). FOSR manages and houses the collected data with unrestricted access on its geospatially formatted "FOSR Water Window."

The data collected by FOSR's citizen scientist Level III monitoring program are used to interpret and resolve critical water quality issues. These data are used by the VA DEQ in the *National Water Quality Inventory Report to US Congress (305(b) Report*) and the *303(d) Impaired Waters Report* to EPA. VA DEQ and equivalent state and local agencies rely on FOSR's data for the development of their total maximum daily load programs and related restoration activities. This has included listing impaired streams and delisting nonimpaired stream segments. As a Level III accredited laboratory, FOSR's citizen-science collected data are relied on at face value without further testing. This saves time, human resources and money for VA DEQ and EPA. The data also are used to inform the community about potential health risk exposures at local water recreational areas and springs used by the public as a drinking water source.

More Information: fosr.org

Canton Creek Snorkel Survey

Location and Dates: North Umpqua Watershed, Oregon, 2011 to present

Groups Involved: Pacific Rivers, Phoenix School (Roseburg, Oregon), Bureau of Land Management, North Umpqua Foundation, Steamboaters, and Cow Creek Band of Umpqua Tribe of Indians

Also an Example of: Research, community engagement

Budget: Ongoing budget of $7,000 to $10,000 per year, which pays for Dr. Charlie Dewberry's time for survey setup, data analysis and report preparation, and equipment replacement.

IN BRIEF

Topic: Species monitoring
Scale: Regional
Participants: High school students
Data uses: Management, research, community engagement

Summary: Canton Creek is a major spawning and rearing stream for salmon and steelhead of the North Umpqua River in southwest Oregon. The ownership of the watershed is divided between two federal agencies (Bureau of Land Management and U.S. Forest Service) and private industrial timber companies. Federal public land was extensively logged in the 1960s without regard for stream protection. Local fishermen produced the film *Pass Creek* to document the destruction. This helped shift federal land management to a more ecologically sensitive paradigm. Today, the stream still is considered degraded, the forests are growing back, the private timber is nearing harvest, and the Bureau of Land Management is finalizing new management plans, which include increased logging and smaller riparian buffers. The U.S. Forest Service soon will be updating its management plans as well.

Management changes were being implemented, but no one had been monitoring the stream health or fish populations to guide restoration or document the effects. In 2011, Pacific Rivers, a regional watershed conservation group, established a long-term baseline monitoring program. The group raised enough money to hire Dr. Dewberry to design a snorkel survey of the abundance and distribution of salmonids in the Canton Creek Watershed. High school students were recruited and trained from the Phoenix School. The Cow Creek Band of Umpqua Tribe of Indians and other foundations provided wet suits and equipment. The surveys, which are in their 5th year in 2016, will continue indefinitely with adequate funding. Involved students help to recruit new volunteers each year and now are strong advocates for their local watershed; several students are pursuing careers in natural resource management. The heightened awareness of the importance of this watershed positively affects both public and private restoration and management plans.

More Information: pacificrivers.org/our-work/what-were-doing/monitoring/; vimeo.com/50181875

Recommendation 9: Provide guidance and communicate data quality needs for different data uses

There is a clear desire within the Agency for a system to report data and information from citizen science in a way that is transparent and accessible, communicates the quality of data needed for specific decisions, and conveys a clear sense of how the data are being used.

The establishment of clear, easy-to-understand data collection and reporting protocols would benefit the Agency and its community partners by increasing the quality, reliability and utility of the data that citizen scientists collect and ensure that data are suitable for their intended use. These guidelines should cover a broad spectrum of projects, from monitoring activities initiated and implemented by individuals and community groups to research projects designed and managed by professional scientists.[41]

EPA's Criteria for Data Evaluation

EPA's criteria for data to be useful and actionable varies across program areas, operating units and divisions. In some cases, well-documented performance standards are broadly understood by citizen scientists, whereas in other cases, performance standards are more ambiguous.

EPA has a variety of quality assurance, data quality and communication guidance documents, including standards set forth in EPA Information Quality Guidelines,[42] *Guidance for Quality Assurance Project Plans*,[43] *Guidance on Environmental Data Verification and Data Validation*,[44] *EPA Quality Manual for Environmental Programs*,[45] EPA's Quality System-Related Regulations,[46] and Good Laboratory Practice Standards Compliance Monitoring Program,[47] as well as in EPA guidance documents on risk assessment,[48] communication[49] and management.[50] EPA should communicate the variety of QA/QC needs that are set forth in these documents and help citizen science groups understand them and strategize to meet them, including providing training and outreach through partner organizations.

EPA uses a four-tiered, graded approach to communicate data quality and provide consistency to quality assurance programs implemented across all program and regional offices. This approach is based on the principle that the quality requirements for any Agency activity must be commensurate with its importance to EPA's mission. Regulatory, enforcement and policy contexts set the highest bar for data quality. Four project categories are defined for establishing the stringency of QA/QC requirements:

- **Category I** projects require the most detailed and rigorous QA/QC for legal and scientific defensibility. Category I projects typically stand alone. In other words, the results from such projects are sufficient to make the needed decision without input from other projects.
- **Category II** projects complement other projects in support of regulatory or policy decisions. Such projects are of sufficient scope and substance that their results could be combined with those from other projects of similar scope to provide necessary information for decisions.
- **Category III** projects are performed as interim steps in a larger group of operations. Such projects include those producing results that are used to evaluate and select options for interim decisions or to perform feasibility studies or preliminary assessments of unexplored areas for possible future work.
- **Category IV** projects involve studies of basic phenomena or issues, such as proof of concept and screening for particular analytical species. Such projects generally do not require extensive, detailed QA/QC activities and documentation.

9.1: Develop and communicate data quality needs through Data Quality Indices

EPA needs to integrate and adopt a framework and language to communicate data quality needs and criteria. For example, EPA could create Data Quality Indices that cover the spectrum of uses of citizen science data (**Table 5**). Categorizing data would help EPA, tribes, states and territories be transparent about data quality needs and provide a mechanism to communicate and share the known quality of generated data and would serve as a heuristic tool for identifying or developing new projects and for evaluating data quality and data management methods.

Following the establishment of Data Quality Indices, EPA should develop a strategy to communicate, educate and train the citizen science community through intermediary organizations and key partnerships. EPA should identify projects that meet the Agency's criteria and suggest general ways that these models can be applied. This recommendation is consistent with the recommendations of the E-Enterprise Leadership Council, who recommend that EPA and states should "develop data use types (tiers) and data standards for advanced monitoring technologies to allow numerous and diverse entities to distribute, share and integrate data."

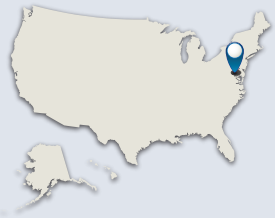
One possible approach to Data Quality Indices[52] identifies the applications of citizen science work in three categories: increasing public understanding, scientific studies and research, and supporting legal and policy action (**Table 5**). "Increasing public understanding" projects support community engagement and education, "scientific studies and research" projects are aimed at research and decision making, and "supporting legal and policy action" projects produce legally defensible evidence for enforcement and policy. These Data Quality Indices can be mapped to EPA's QAPP project categories and to the spectrum of uses of citizen science data.

Table 5. Example of How EPA Can Define Data Quality Needs for the Spectrum of Citizen Science Data Uses[3]

Activity	Data Use	Data Quality Categorization	EPA QAPP Project Category
An engaged public can provide opportunities for individual and collective actions designed to identify and address issues of public concern.[51]	Community engagement	Increasing public understanding	Category IV
Empowered citizen scientists can learn about their environments, scientific processes, and science, technology, engineering, arts and mathematics (commonly known as STEAM).	Education	Increasing public understanding	Category IV
Programs can generate data and information that support planning and goal setting for future decision making.	Condition indicators	Scientific studies and research	Category III
Volunteers collecting data and information can add to the efforts of government science agencies to advance knowledge.	Research	Scientific studies and research	Category III
Focused projects can help government agencies specify how public resources under their control are managed.	Management	Scientific studies and research	Category III
Public decision makers use data and information to make decisions about land development permits, licenses, leases and environmental permits.	Regulatory decisions	Supporting legal and policy action	Categories I and II
Public participation in science can support adoption of new mandatory and voluntary standards, development of best practices, revision of prior standards, and changes in methodologies for measuring compliance status.	Regulatory standard setting	Supporting legal and policy action	Categories I and II
Certain agencies may take a variety of actions, including launching inspections or investigations; prosecuting administrative, civil or criminal violations; and imposing new permit conditions.	Enforcement	Supporting legal and policy action	Categories I and II

Composting Food Waste With Fermentation

Location and Dates: Greater Washington, D.C., 2016 to present



Groups Involved: Greenwave, Episcopal churches

Also an Example of: Community Engagement

Budget: Unknown

IN BRIEF

Topic: Food waste
Scale: Regional
Participants: Members of an environmental group and local Episcopal Korean churches
Data uses: Management, community engagement

Summary: Kitchen scraps dumped into landfills cause methane emissions, which have effects 24 times more than those of carbon dioxide. Greenwave, a grassroots environmental group organized by three Episcopal Korean churches in Maryland and Virginia, has been developing a program for dealing with kitchen scraps mostly dumped into landfills. Utilizing a fermentation composting method also known as Bokashi composting, the group has been practicing the method individually every day and at church functions.

The members of this program collect their kitchen waste and sprinkle them with Bokashi bran with efficient microorganisms in a bin. The fermentation process begins within approximately 2 weeks of the bin becoming full. The bin is moved outside, and the content is buried under the ground with about 6 to 8 inches of soil on top to cover. In about 2 to 4 weeks, depending on outside temperature, the fermentation process is complete. Composters know this because there is no sour or pickle smell.

Greenwave plans to extend the composting program to local restaurants in the greater Washington, D.C., area, with the inclusion of collection services and redistribution of the soil from the compost to the community. The organization's goal is to develop a procedure that maximizes the effect of making a good soil that can be sold commercially. The monetary benefit of making Bokashi fermentation soil for commercial sale is the primary incentive to encourage people to see the values of food waste composting and change people's behavior and perspective of understanding environmental impact.

Greenwave plans to work with experts who will design appropriate data-collecting procedures. These will include techniques for making the best soil while keeping the process commercially effective, as well as techniques for determining the effectiveness of Bokashi composting in reducing methane release to the atmosphere. Greenwave would like to look at the entire cycle from food waste, fermentation, making soil and commercialization of the food-waste soil.

More Information: planetnatural.com/composter-connection/indoor-composting/bokashi-composting; compostguy.com/bokashi-resource-page; bokashi.com.au; davesgarden.com/guides/articles/view/109/; provinos.nl/images/Fermentation_versus_composting.pdf; the-compost-gardener.com/bokashicomposting.html

Oneida students engage in wetland restoration by planting wild rice. ***Photo credit:*** *Oneida Environmental Health and Safety Division.*

9.2: Streamline and support the Quality Assurance Project Plan process

EPA should simplify and streamline the QAPP process. Internal EPA projects and EPA-funded external projects must be implemented under approved, project-specific QAPPs developed in accordance with EPA's *Guidance for Quality Assurance Project Plans*.[43] The QAPP applies EPA's graded approach to data quality. EPA's guidance for QAPPs should provide the tools to facilitate the use of the Data Quality Indices based on the finality of the data or information collected. The purpose of the study should drive the QAPP process. The QAPP plays a significant role in the utility of data and information collected by citizen scientists and the communication of that quality. A checklist for project planning and implementation should include the data requirements as well as clear messaging about potential outcomes and related EPA responses and decision making.

EPA Quality Assurance Officers should be involved in the development of data plans for citizen science projects from the beginning of project design. To promote effective communication, the Agency should emphasize feedback loops between project planners and EPA staff. To support purposeful, appropriate data collection, the Agency should be engaged early in the process (rather than raising concerns about data quality in the mid-stages of a project) and be a part of community data dissemination. EPA should be careful not to create barriers to entry for communities interested in asking questions about places they care about. This is especially important for the collaborative process and the capability of EPA to accept citizen science data. EPA also should include qualitative data, semi-empirical data, and other ways of knowing, such as traditional ecological knowledge, in the review criteria.

9.3: Ensure feedback loops are in place

Project planners interested in enhancing the utility of their data products for informing EPA policy, science and regulatory programs should coordinate their data plans with EPA program office staff prior to and during the projects. This initial coordination can help set expectations for EPA staff and community groups as to how the data and information may be used and what timeline to expect. Following data use, EPA should record how the data and information were used and provide feedback to the citizen science groups and community organizations. The feedback loop is the most critical part of the process because too often, communities that have participated in or have been the subject of scientific studies have received little or no information—and consequently little or no benefit—after a project has concluded. Without feedback loops in place, it is hard to know whether data and information are used without expenditure of extensive community resources. Collecting data and contributing information to EPA must be a value proposition for communities outside of other goals of these projects. To enact this recommendation, EPA will need to devote additional staff time toward communication and feedback. Clarity around ownership of data should be provided during partnership development so that people and organizations have a choice as to whether or not to share information and data with EPA as part of their project scope. EPA should recognize that some citizen science projects begin because of a lack of funding or methods to coordinate studies through EPA's standard processes. Some communities that perform citizen science need support to coordinate with the Agency, even at the local level. EPA should develop strategies to deal with this limitation and set criteria that allow Agency programs to approach project planners in addition to project planners approaching EPA.

Aerial Imagery of the United Bulk Terminals in Plaquemines, Louisiana

Location and Dates: Plaquemines Parish, Louisiana, 2012 to 2015 (and ongoing monitoring)

Groups Involved: Communities of Davant, Wood Park and Myrtle Grove, Louisiana; Clean Gulf Commerce Coalition; Tulane University Environmental Law Clinic; Louisiana Department of Environmental Quality

Also an Example of: Community engagement, condition indicators, management

Budget: Unknown

IN BRIEF

Topic: Air pollution
Scale: Regional
Participants: Nonprofit organization and community members
Data uses: Regulatory decisions, community engagement, condition indicators, management

Summary: The Clean Gulf Commerce Coalition—a partnership between community groups, local nonprofits and branches of national green organizations—used aerial imagery to demonstrate systematic problems in a polluting facility. This effort ultimately led to stricter pollution prevention terms by the polluting facility, further containment and cleanup activities, and additional fines.

Initially, neighboring communities had demonstrated the United Bulk Terminals to be an ongoing problem. Through data collected during nuisance litigation, they showed that coal dust was covering their homes. Seeking to enforce the environmental laws, advocates from the Gulf Restoration Network and the Sierra Club collected aerial imagery through plane trips over the facility and by flying a 9-foot kite. Through direct observations via aerial imagery, they observed systemic issues resulting from problematic equipment.

The partnership efforts resulted in a consent decree from the Louisiana Department of Environmental Quality, including fines of $16,000.[1] Following that decree, the Coalition worked with the Tulane University Environmental Law Clinic to sue United Bulk under the citizen suit provision of the Clean Water Act; this suit resulted in stricter pollution prevention terms and additional fines of $75,000 for wetland restoration. In addition, United Bulk Terminals made necessary corrections to its operations and processes. It also has ensured interaction with the Clean Gulf Commerce Coalition moving forward so that if future violations occur, there will be documented conversation on cause, steps for remediation and potential additional fines.

More Information: drive.google.com/file/d/0B9TzfQJ7Qw4GcHdFMkVzM1NXbkxJV1p5bXo0aHp6RnIzS2p3/view

1. U.S. District Court for the Eastern District of Louisiana. 2015. Consent Decree: Gulf Restoration Network et al. *v.* United Bulk Terminals Davant, LLC: Case 14-cv-00608.

Chapter 5: Integrate Citizen Science Into the Work of EPA

Citizen science is a transformative vehicle for engaging various aspects of science, government, business, and society and the public. A recent report from the Wilson Center, *Clearing the Path: Citizen Science and Public Decision Making in the United States,* describes multiple ways that citizen scientists can support and augment science at EPA and many other organizations.[3] All of these data uses point to ways that citizen science can increase the ability of EPA and other organizations to gather information using approaches that would otherwise exceed available resources (**Table 5**).[53]

Recommendation 10: Support citizen science for environmental protection beyond regulations

10.1: Empower environmental and science, technology, engineering, arts and mathematics educators to use citizen science

Citizen science has a direct connection with informal and formal education, service learning, and environmental and STEAM education.[54] The opportunity is larger than involving youth in science as it provides an avenue to involve students in more than just data collection by encouraging critical thinking and decision making.

Citizen Science Creates Meaningful Connections to the Environment

"Surveys indicate Americans who have made a personal connection to climate impact are most likely to care about climate and seek climate literacy. Citizen science and place-based formal and informal education can provide learners with meaningful and relevant connections to climate and the environment. The increased science understanding afforded by direct, personal involvement with data collection and research, and learning about causes, consequences and opportunities for individual action in climate mitigation and adaptation can catalyze learning and action. Through such experiences, people learn with minds, hands and heart—a formula steeped in learning theory and practice."[55]

Many existing citizen science projects involve environmental and STEAM education for both youth and adults. EPA can build on these models and expand into new areas and issues. EPA could partner with groups such as EarthForce and encourage others to partner or emulate this model in other areas of the country.

Gardenroots: The Dewey-Humboldt Arizona Garden Project

Location and Dates: Dewey-Humboldt, Arizona, 2008 to 2012

Groups Involved: Community of Dewey-Humboldt, Arizona; University of Arizona (UA) Department of Soil, Water and Environmental Science; Dewey-Humboldt Town Council; UA Yavapai Cooperative Extension

Also an Example of: Community engagement, enforcement, regulatory decision, research

Budget: $15,000 grant from EPA's Office of Research and Development, which paid for supplies, analytical costs, travel, and communication materials; Dr. Monica Ramirez-Andreotta's time was covered by fellowships (UA Diversity, UA Water Sustainability Program, and a National Aeronautics and Space Administration Space Grant) and a National Action Council for Minorities in Engineering Scholarship.

IN BRIEF

Topic: Toxic substances, pollution

Scale: Local

Participants: Community residents

Data uses: Regulatory standard setting, community engagement, enforcement, regulatory decision, research

Summary: In March of 2008, the Iron King Mine and Humboldt Smelter Superfund site in Dewey-Humboldt, Arizona, was added to the EPA National Priorities List. In 2008, community members expressed concerns to EPA about the site's effects on their land (elevated levels of arsenic and lead prone to wind and water erosion). Specifically, they wanted to know whether it was safe to consume vegetables from their home gardens, and if so, how much they could eat. In response, a UA researcher and residents worked together throughout most stages of the study 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.

Three training sessions were organized and provided the community with information on how to properly collect soil, water and vegetable samples from their home gardens for laboratory analysis and with a tool kit that included all required supplies. Of the 40 people who attended training, 25 returned their kits. Throughout the project, various informal science education experiences were offered to discuss the Superfund site's contaminants of concern, other community inquiries and project data. The results showed that in general, arsenic concentrations were higher in Gardenroots vegetables than store-bought vegetables, as compared with the 2010 U.S. Food and Drug Administration Market Basket nationwide study. Calculations of estimated average arsenic daily dose from the three potential exposure routes measured suggested that arsenic exposure was greatest from drinking water (when assuming the primary source of water for irrigation also is used for drinking), followed by incidental soil ingestion and then a relatively small contribution from homegrown vegetable ingestion.

Efforts to communicate results included an aggregate overview of the community and greenhouse results, a set of recommended best practices, and personalized reports, which translated the raw risk data into specific quantities of vegetables one could consume at various target risks and also that compared all three potential exposure routes (vegetable, soil, water). This allowed participants to make educated choices. Participants increased their community networking, participated in other environmental projects, and leveraged the results to encourage government officials to take action and be more stringent in their cleanup efforts. For example, the Gardenroots project revealed that the local public water system was serving water that exceeded the arsenic drinking water standard, prompting participants to work together to notify other households that were connected to the public water supply. The project leaders also reported the results to federal and state environmental agencies. As a result, the municipal water supplier was issued a notice of violation for exceeding the federal arsenic drinking water standard. Arsenic concentrations in private well water also exceeded the drinking water standard for several participants. Gardenroots worked closely with those households to provide information regarding water treatment technologies that could be implemented to reduce their arsenic concentrations. Local, state and federal decision makers are using Gardenroots products and study results to inform their work and use in community outreach materials.

More Information: superfund.arizona.edu/projects/community-engaged-research/gardenroots/home; gardenroots.arizona.edu

Recommendation 11: Support community citizen science

Community citizen science is a vastly underutilized resource that has enormous benefits for both EPA and people using citizen science activities in their work. Community citizen science supports communities in inquiries about the places they care about. The benefits to EPA are wide-ranging, as community citizen science directly supports the mission of the Agency by supporting the ability of EPA staff members to perform their jobs more effectively and efficiently and serving as a strong public relations tool for the Agency.

In its most popular understanding, the global phenomena of citizen science involves the public in scientific activities and supports communities, scientists and agencies through the collection of data and information, but community citizen science is much more. It encompasses long-term and crisis-centered monitoring programs, projects that seek to act proactively by developing baseline data, and projects that reactively collect information because of a community concern. The effects of community citizen science are not just on regulatory action or enforcement but range across a spectrum of data uses that includes collecting different types of appropriate data for engaging community stakeholders, identifying condition indicators, researching, managing and regulating the environment, supporting changes in regulatory standard setting, and taking enforcement action against environmental and public health misconduct. At the heart of community citizen science, people are able to ask, "What does it take to make you [your community, the people you care about] whole again?"[56]

Community citizen science and environmental health and justice concerns are intricately linked. There are different types of citizen science models, but those driven by communities often center on immediate environmental health issues or long-term pervasive concerns, such as polluting facilities in close proximity to neighborhoods. The use of community citizen science to address environmental health and justice concerns is not new, but during the last decade, barriers have been lowered as tools are developed with community use as a central premise. In the 1970s, the Love Canal neighborhood in Niagara Falls, New York, became a

Building Trust With Communities

EPA's National Environmental Justice Advisory Council (NEJAC) currently is developing recommendations on community monitoring. One of the key ideas is that building trust must be a first step and primary emphasis of any citizen science program.

To accomplish this goal, the NEJAC is discussing several proposed EPA actions:

- **Educate the technical experts and government staff on how to build a genuinely trustful relationship with the community and the people who live there.** This will require a shift in thinking and attitudes, where the technical experts and government officials listen and respond to the issues, concerns and ideas from the community rather than imposing government-generated projects.
- **Train government technical experts in how to help community residents understand scientific matters.** This should include figuring out how to manage and present data collected by citizen scientists so that the information is meaningful and understandable to nonexperts. Note that this also requires education and a shift in thinking and attitude about the significant potential value of citizen-collected data.
- **Engage in joint learning activities and joint training in which technical experts and community-level citizen scientists can interact and discuss different perspectives and mutual concerns.** The goal is to build trust and understanding that reduces polarization between the two groups. This can help avoid government staff opposing efforts considered important and valuable by communities and can help communities understand issues like the level of data quality needed for decision making.

Trust about community generated citizen science is vital to EPA's mission. The Agency needs to find new, better ways to work with communities on citizen science, with the common goal of safe, healthy communities.

Observing plants at the Chicago Botanic Garden. ***Photo credit:*** *Dennis Ward.*

EarthForce, a Youth Action Project

EarthForce provides a model of civic engagement for youth. It is a youth-based action model that engages young people in exploring a problem, gathering data and developing a solution. The framework uses data gathering as a catalyst to build critical thinking and leadership skills. The model places youth in real decision-making roles and processes. EarthForce also partners with industry. For example, EarthForce serves the communities near where its partner, General Motors, is located, which often are underserved communities. More than 80 percent of the projects EarthForce youth engage in involve the environment and water.

earthforce.org

hotbed of political action as residents organized and used scientific data to call attention to the detrimental health effects that members of the neighborhood were experiencing because of chemical waste. In the 1980s, the environmental justice movement recognized the distinct pressures and health consequences resulting from environmental racism and discrimination that communities of color and those from lower socioeconomic backgrounds were experiencing in rates disproportionate to others. From early examples of environmental justice organizing in Warren County, North Carolina, to crisis-oriented community citizen science scenarios in Flint, Michigan, and long-term community monitoring, such as is being conducted by the Canton Creek (Oregon) Snorkel Survey (see case study), using community environmental monitoring techniques, people increasingly have found the ability to be environmental and public health stewards and stakeholders in environmental decision making by engaging in scientific processes to achieve actionable goals.

In a 2012 letter to EPA Administrator Lisa Jackson, NACEPT called for better access to monitoring, detection, assessment, communications and solution technologies to address the issue of environmental justice and the needs of vulnerable underserved populations as these communities sought answers to environmental health questions. With the rapid increase of technological development during the last half-decade, sensors and smartphone applications, as well as data aggregation, storage, communications and interpretation platforms, have provided the means for people to monitor more robustly.

Community citizen science is a valuable framework for projects that comes primarily from within non-professional scientific contexts. Its tools and methods work to create equity in the use of science and data by giving anyone—including farm workers, urban and rural populations, and environmental justice communities—the ability to ask questions and answer them through appropriate study design and monitoring methods. Unfortunately, without EPA support for community citizen science—from basic recognition of communities performing their own monitoring to identifying obstacles

Colorado River Watch

Location and Dates: Statewide (all groups have same equipment, protocols and training), 1989 to present

Groups Involved: Annually serves 140 groups (85% schools and 15% adult citizen)

Also an Example of: Community engagement, education, management, regulatory decisions

Budget: $250,000 but saves an estimated $1.3 million per year

IN BRIEF

Topic: Water quality, habitat assessment, biodiversity
Scale: Statewide
Participants: Anyone
Data uses: Regulatory standard setting, community engagement, education, management, regulatory decisions

Summary: Colorado River Watch—a partnership between Colorado Parks and Wildlife, citizens and a nonprofit organization—annually provides equipment, training, support and sample analyses for 140 groups, which in turn monitor more than 650 locations monthly for chemical (e.g., metals and nutrients) and annual macroinvertebrate and physical habitat assessment. The program directly reaches 2,000 individuals and indirectly reaches 15,000 individuals every year. In comparison, the Colorado Clean Water Act Agency has the ability to fund 40 annual stations to cover more than 700,000 miles of Colorado streams. Colorado River Watch uses the same field and laboratory methods as the Colorado Clean Water Act Agency. Primary uses of the data collected include decision processes, such as standard development and setting, use assessment, impaired stream listing/delisting, development and monitoring of total maximum daily loads, and nonpoint source project monitoring.

The Colorado Clean Water Act Agency conducts an annual data call to evaluate use attainment and update designated uses assigned to specific water bodies. Colorado River Watch data have more temporal and geographic coverage than any other data provider—often being the only data available for a water body—that can be used in these regulatory standard setting hearings. Colorado River Watch macroinvertebrate data are used to calibrate multimetric indexes used for aquatic life use impairment and to determine use attainment. Colorado River Watch has a 27-year history of providing data for these regulatory standard hearings.

Colorado River Watch also provides baseline and postmonitoring data for regulatory and nonregulatory standard and goal setting for remediation projects, fish kills, environmental spills and Superfund efforts. For example, Colorado River Watch data have been used since 1990 on the Animas River in six standard setting hearings, evaluating attainment and then directing remediation efforts in the basin. Colorado Parks and Wildlife uses the data for fishery management, native species introduction, stream restoration and invasive species efforts. Others use the data, network and program for watershed management activities, education, community engagement, nonregulatory decisions and data acquisition. Colorado Parks and Wildlife uses the program to protect fisheries, leverage resources, strategically collaborate to achieve mission goals, provide outdoor experiences, educate, and enhance public relations. Baseline data are essential to determine baseline conditions and goals for reclamation projects and after floods, fires and environmental spills. This program collects more data than any other entity in Colorado and has the most volunteer monitoring data in EPA's national water quality database, STORET, and in the Water Quality Portal. The state of Colorado and others depend on this program for statewide baseline data coverage for rivers. As such, the Colorado Clean Water Act Agency is working on a plan to utilize this program for ambient water quality monitoring and focusing scarce resources on targeted monitoring.

More information: cpw.state.co.us/aboutus/Pages/RiverWatch.aspx

Making careful observations of a linden tree in Boulder, Colorado. ***Photo credit:*** *Carlye Calvin.*

within the Agency for accepting community citizen science data—there are limitations to the effects that citizen science can have in supporting community goals and EPA's role in environmental regulation and enforcement. EPA should address community citizen science not just because of the benefit that Agency support will add to efforts but also because community citizen science has provided and will continue to provide an added benefit to EPA. Community citizen science adds a new layer of material—originating from scientific data and local experience and knowledge—that has the potential to add to or fill in gaps in existing information sets.

The increase in the availability of technology—from practices of documentation, such as maintaining odor logs, to the development of the bucket-brigade monitoring tool (modeled after an EPA SUMMA® canister) to low-cost sensors and smartphone apps—has meant that it is easier than ever to obtain, store and interpret data. Adding environmental health monitoring to community organizing techniques, which is what community citizen science aims to do, supports a move away from technological enthusiasm for its own sake and toward technology as a means to inspire and support community-identified questions and goals. A major overhaul is needed, however, in the way that EPA interfaces with community citizen science efforts. EPA currently does not interface effectively with communities that collect their own information and performing their own monitoring. Some community citizen scientists and organizations are making their own environmental monitoring technology, but the Agency has not yet identified a strategy for integrating these tools, which often are more resource-accessible, into its own data collection and analysis activities or provided opportunities for co-location. Open principles and collaborative science design are being embraced as spaces open up for environmental organizers, scientists, technologists and others to work together, but EPA has not yet broadly accepted this new culture of problem solving. More and more people are feeling inspired to collect and use data and information, but they are doing so in "silos" outside of EPA because of a lack of understanding of the Agency's working processes among groups with limited resources. Environmental protection belongs to the public, and the movement from closed laboratory spaces into community hands represents a huge opportunity for EPA.

11.1: Expand the availability of EPA resources to support community citizen science in all project stages

EPA currently lacks policies and procedures to guide how Agency programs support community citizen science efforts (i.e., financial, material and technical resources). Although an understanding about how to best support communities is growing, more top-down direction is needed within EPA to make these efforts coherent and effective. The EPA Administrator should provide a statement of support about the value and utility of citizen science in supporting Agency programmatic goals. EPA's policy statement should emphasize the Agency's key leadership role in fostering citizen science partnerships between civil-sector and community organizations. EPA can use this statement of support for citizen science efforts to reach the Agency as a whole regarding the benefits of using citizen science data and information.

11.2: Ensure that communities are equal and equitable partners

EPA should support collaboration between intermediary citizen science organizations and community partners by providing or facilitating the development of memoranda of understanding governing the allocation of funding, data sharing, privacy concerns, and ownership and allocation of material resources. Intermediary citizen science organizations are institutions (nonprofit or academic) that receive resources from EPA to perform community citizen science work but partner with communities as a core part of their model.

CASE STUDY

Community Engagement | Education | Condition Indicator | Research | Management | Regulatory Decisions | Regulatory Standard Setting | **Enforcement**

Tonawanda Coke Air Monitoring

Location and Dates: Tonawanda, New York, mid-2000s to present

Groups Involved: Clean Air Coalition of Western New York, EPA, New York State Department of Environmental Conservation

Also an Example of: Community engagement, condition indicator, regulatory decisions

Budget: Unknown

IN BRIEF

Topic: Air quality
Scale: Local
Participants: Community residents
Data uses: Enforcement, community engagement, condition indicator, regulatory decisions

Summary: The Clean Air Coalition of Western New York built a community citizen science effort using air quality data and direct action methods to address concerns about Tonawanda Coke. The outcomes of this work resulted in a rare prosecution under the Clean Air Act. The group collected air samples using "homemade monitors" with parts from a local Home Depot to detect high levels of potentially carcinogenic chemicals. The group members pressured the New York State Department of Environmental Conservation to fund an air quality study that showed benzene levels "were 75 times higher than the EPA guideline."

According to the website (www.cacwny.org), Clean Air's campaign resulted in an EPA enforcement action and criminal trial. In March 2013, Tonawanda Coke was found guilty of breaking 14 federal laws under the Clean Air Act and the Resource Conservation and Recovery Act. The environmental control manager was found guilty on the same counts and an additional count of obstruction of justice. Since EPA's enforcement action, 86 percent and 68 percent reductions in benzene have been reported from two area air monitors.

More Information: www.cacwny.org/about/our-history/; publicintegrity.org/2013/06/18/12839/clean-air-case-yields-rare-criminal-convictions-new-york; epa.gov/enforcement/2014-major-criminal-cases

11.3: Work with organizations that are well equipped to support community-level citizen science

EPA could benefit greatly from existing relationships that states and territories, nongovernmental organizations, colleges and universities, extension programs, and other organizations have with communities engaged in citizen science projects. These groups can serve as intermediaries between experts in the science world and practitioners who operate citizen science projects. EPA should recognize, however, that the Agency should not force partnerships between groups that want to be uniquely represented, such as the 567 federally recognized tribal entities that are many times required to partner to receive federal resources.

Currently, community citizen science efforts to fill data gaps frequently stem from unfunded, in-community initiatives rather than partnerships with EPA. The Agency should understand its role in leveraging and improving communications between community citizen science efforts and local environmental governance agencies. By working with local communities to identify and understand monitoring needs, EPA can build trust with citizen science groups and position itself as an ally in, and advocate of, the work.

"The whole reason the Animas River Stakeholders group has a long record of water quality data is because of Colorado River Watch. They have collected monthly data at four sites around Silverton and around six sites in Durango for over 20 years. There have been 60 mine remediation projects in the upper Animas Basin, and with that baseline data we've been able to demonstrate water quality improvements. We've also shown the water quality degradation caused by issues around Gladstone, which led to EPA opening up the Gold King Mine."

–Peter Butler, Ph.D., Co-Coordinator of the Animas River Stakeholders Group speaking at the Annual Southwestern Water Conservation District Conference in Durango, Colorado, on April 1, 2016.

Recommendation 12: Integrate citizen science into EPA science

EPA should work to integrate citizen science into EPA science by identifying *opportunity spaces* or areas in which there is no alternative; no other research method could obtain a particular data set without using citizen science approaches. Examples of areas where no alternatives exist are using citizen science approaches to identify emerging issues and risks and to fill data gaps, such as the investigation of spatial variability in pollutants or unregulated issues such as indoor air quality.

12.1: Use citizen science to identify emerging issues and risks

EPA should consider how citizen science might support current Agency priorities *and* how it can provide insights into new issues. For example, EPA could invest in projects similar to the study performed by Virginia Tech scientists to examine the monitoring of lead in drinking water in Flint, Michigan.[57] Citizen science creates a new capability to focus on environmental issues that are not currently part of EPA, state and tribal priorities.

Citizen science can be a powerful tool for identifying early warning signals of environmental issues. With systems in place to transmit this information to agencies, EPA can better predict emerging environmental issues and disasters and be more prepared to act.[58] Examples of this approach include the LEO Network described in Chapter 1, which shares citizen scientists' observations of unusual or unique environmental events with experts, and the IVAN (Identifying Violations Affecting Networks) network (ivanonline.org), which allows community members to report local environmental issues or violations. Baseline monitoring also is especially useful when environmental disasters occur. Examples exist of citizen science data being the only baseline data available, and these data help to determine the impact of the disaster and the effectiveness of remediation efforts.

12.2: Use citizen science data to fill data gaps, including topics that are not regulated

Citizen science is valuable in addressing data and information priorities that are not currently being addressed because of time, resource and other constraints. EPA should consider the limitations of its ability to collect data and information and identify specific locations where citizen science data and information could be used to fill gaps, strengthen monitoring models and provide new sets of information that could enrich EPA's efforts. There should be increased transparency about existing data limitations and support for alternative studies or analyses outside of EPA to address these limitations. The Agency should explore how to interpret new data and information in the context of how EPA, tribes, states, territories and local entities currently operate their programs.

Citizen science data and information also may be useful to EPA in areas in which the Agency lacks regulatory or enforcement tools, such as indoor air quality.

12.3: Integrate citizen science into EPA's work on major environmental and public health issues

Citizen science has potential to change EPA science. Consistent with the Presidential Science Advisor's citizen science directive, EPA should lead agencies to use citizen science in areas of greatest impact.[1] EPA should identify the program areas in which the greatest need exists for core and supplemental data from the citizen science community. At the national level, EPA's interactive online

resource, *Report on the Environment* (cfpub.epa.gov/roe), has identified important environmental issues and indicators for which insufficient data exist.[59] EPA should assess how citizen science efforts could begin to amass data sets and start initiating pilots at a local or regional level. Obtaining additional spatial and temporal data may allow EPA to identify patterns that can contribute to solutions. Many potential EPA applications for new citizen science programs exist, from global issues such as climate change to regional and local issues such as drinking water. Citizen science could support EPA in several different priority areas, including:

- EPA's three water quality priorities—nitrogen, phosphorus and sediment—and regional issues such as legacy mining effects in the West, drinking water systems in underserved communities, dissolved oxygen in the East, and outbreaks of cyanobacteria.
- Regional air pollution issues, such as methane hot spots, winter urban temperature inversions, and areas affected by large fires.
- Effects resulting from climate change, such as temperature changes in drought areas, changes in runoff, and changes in air patterns.

Before beginning new projects, EPA should take advantage of all of the existing citizen science projects underway. The review should look into citizen science projects in other organizations that currently are working in the area of EPA priorities, allowing the Agency to take advantage of the data and information already being collected.

EPA could build on the current public comment system to elicit requests for information in specific regions, topic areas or research needs.

12.4: Expand successful projects

Examples exist of successful integration of citizen science into EPA research. EPA should identify these projects and expand them into national, highly visible, Agency-wide research projects that demonstrate best practices for EPA-driven citizen science. For example, EPA employees in Region 1 and ORD are working with the New England Cyanobacteria Monitoring Workgroup to engage members of the public in cyanobacteria and harmful algal bloom research through the projects BloomWatch (cyanos.org/bloomwatch) and CyanoScope (cyanos.org/cyanoscope). Expansion of these efforts could streamline project implementation and demonstrate the value of investing in these approaches in partnership with other organizations.

Recommendation 13: Expand EPA's regulatory mission to include citizen science

13.1: Support ways for the public to define environmental priorities

In addition to bringing the public into data collection and processing efforts, citizen science also can engage the public in asking research questions and defining environmental priorities. Through citizen science projects, EPA should engage with the American populace to identify Agency priorities aligned with the public and construct an action plan for addressing these priorities. Working with the public on defining priorities for EPA would create channels for citizen science to additionally support research and decision making within the Agency. Citizen science can complement professional expertise by providing new perspectives; it also can provide awareness to Agency staff about the social implications of their work.[60] Citizen science includes public deliberations that request input from participants, volunteers and co-researchers throughout project processes. EPA should engage organizations such as the Expert and Citizen Assessment of Science and Technology (ecastnetwork.org) to implement these valuable discussions effectively and advance the involvement of the public in EPA priority and agenda setting.

13.2: Provide opportunities for citizen science to impact regulatory and enforcement decisions

Citizen science should complement—rather than replace—current regulatory and enforcement processes. EPA, however, should work in partnership with individuals and community groups toward more transparent, efficient and comprehensive regulatory processes, including regulatory decisions, regulatory

standard setting and enforcement. Citizen science data and information should not automatically be considered suspect. Currently available low-cost sensors sometimes do not individually provide data of sufficient quality for regulatory or enforcement decisions. While advancing the capacity of low-cost sensors (see Chapter Three) and exploring ways to use networks of sensors, EPA also should support other methods for integrating citizen science into regulatory processes, such as through partnerships, other kinds of evidence, opportunity spaces, and by recognizing the value in low-cost sensing devices for providing data and information for research or pointing at condition indicators. To be able to engage effectively and explore these new approaches, EPA needs to invest human resources into this work through new or reassigned staffing.

Successful examples of citizen science efforts resulting in action typically have extensive communication or collaboration with representatives within government. EPA needs to engage with environmental justice communities and other grassroots groups by recognizing and validating their problem-solving goals and enabling connections between Agency and group representatives. These relationships could provide information on what can be accomplished, help design a project that could result in actionable data, and and promote Agency buy-in for the project and the community's ability to carry it out. Community groups need advocates within the Agency to understand the quality of the data and deliver the information to where it is most useful.

Focusing on other kinds of evidence beyond quantitative data from individual sensors may help demonstrate how citizen science can support regulatory decisions, regulatory standard setting and enforcement. For example, photographic evidence can be used to support regulatory decisions and enforcement, and networks of sensors—in combination with modern statistical approaches—can provide a more accurate picture of pollution by providing a large quantity of data with high spatial resolution.

Moving data into the regulatory decision process may be facilitated by opportunity spaces, including laws that actually invite citizen science into decision processes. Moving actionable data across this gap may be facilitated if citizen scientists use sensors or monitoring equipment that meet federal equivalency standards provided by such specific statutes as the Clean Air Act. EPA should build on existing mechanisms by which it currently uses citizen science in the decision-making process, such as *Federal Register* notices and the rule revision process. The Clean Water Act contains provisions that specifically provide for citizen-submitted information (e.g., to list impaired waters, "all existing and readily available water quality-related data and information" must be used and states must provide a written "rationale for any decision to not use any existing and readily available data and information[3]).

Conclusion

Citizen science engages the public to work together with EPA toward more effective protection of human health and the environment. By embracing citizen science as a core tenet of environmental protection, EPA will enhance Agency leadership in the transformation of environmental and human health protection. By prioritizing citizen science, the next Administrator has the opportunity to define what citizen science means for EPA and environmental protection. Articulating and implementing 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. A concrete and comprehensive implementation plan will allow EPA staff to work together for common goals. By identifying citizen science as a cross-Agency strategy and devoting the necessary resources, EPA staff can approach citizen science and open communication with the public without hesitancy. A collaborative approach to citizen science will allow the Agency to both support and benefit from the current momentum surrounding this movement, and by defining and communicating EPA's role, the Agency can strategically support citizen science in a unique and powerful way.

To more fully leverage the power of citizen science for environmental protection, EPA needs to invest in citizen science for communities, partners and the Agency. Dedicating funding to citizen science will allow citizen scientists to create invaluable long-term data sets and enable citizen science efforts to build capacity. Improving technology and tools and building capacity will open up technology development to skilled and creative people outside government and provide the necessary infrastructure to increase impact. Shared databases will be more accessible, allowing individual efforts to share data among themselves and with EPA and accelerate data interpretation and use.

Creating the conditions to use the data generated through citizen science is challenging, but a positive, proactive agenda toward citizen science will have significant impacts for environmental protection. An agenda that recognizes the contributions of those outside the Agency will allow community groups, citizen scientists, researchers and policy makers to develop mutual respect and work together to solve environmental problems. Adopting standards for citizen science data and providing guidance for data quality needs are key actions that will provide opportunities for data to be used at EPA.

Integrating citizen science into the full range of work that EPA does will allow EPA to leverage citizen science for environmental protection in a variety of ways. Citizen science will strengthen EPA science, especially by allowing for spatial and temporal resolution that would otherwise at times be challenging. Opportunities for citizen science exist that will benefit EPA's policy, regulatory and enforcement work through thoughtful design and partnerships. Importantly, citizen science work across the spectrum will have significant effects for civic engagement in environmental protection and will enhance understanding of science and the environment. It also may promote positive relationships between EPA and members of the public.

NACEPT envisions an Agency that values the participation of everyone: by developing shared agendas with the public, by respecting and responding to data collected by community groups, and by working to assess and build on the strengths that different organizations bring to citizen science. The Council envisions an Agency that harnesses the energy and passions of individuals for a shared, expanded understanding of the environment and that considers all available data and information to make informed decisions.

Citizen science is not a choice for EPA—it is the reality of how the Agency must operate in the future. Rather than slowly and incrementally engaging in citizen science projects, EPA has the opportunity to think and act strategically in a proactive rather than reactive way.

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

CARE Community Action for a Renewed Environment

ECAST Expert and Citizen Assessment of Science and Technology

EPA U.S. Environmental Protection Agency

FEM Federal Equivalent Method

FRM Federal Reference Method

LEO Local Environmental Observer (Network)

NAAQS National Ambient Air Quality Standards

NACEPT National Advisory Council for Environmental Policy and Technology

NEJAC National Environmental Justice Advisory Council

ORD Office of Research and Development

QA/QC quality assurance/quality control

QAPP Quality Assurance Project Plan

STEAM science, technology, engineering, arts and mathematics

Glossary of Terms

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 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.

EJ2020 Action Agenda: A plan developed by EPA that will help the Agency integrate environmental justice into all of its efforts while cultivating strong partnerships and moving forward to achieve better environmental outcomes and reduce disparities in the country's most overburdened communities.

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.

EPA SUMMA® canister: Evacuated stainless steel canisters with electro-polished inner surfaces widely used for sampling volatile organic compounds in the environment.

Human-centered design thinking: A three-phase approach to problem-solving that involves using empathy to deeply understand the needs of the people being served. This empathy ensures that the resulting innovative, creative solutions suit the needs of those people.

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

Integrated monitoring: The simultaneous collection of physical, chemical and biological measurements over time of different environmental variables at the same location. The collected data ultimately can be used to estimate responses to actual or predicted environmental changes.

K–16 education: Education beginning in kindergarten and continuing through postsecondary, often culminating in a college or university degree.

Metadata: Data that provide information about other data.

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 licensing: Also called open-source 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.

Seed grant: An early investment providing support to a company or program until it can generate its own financial support.

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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