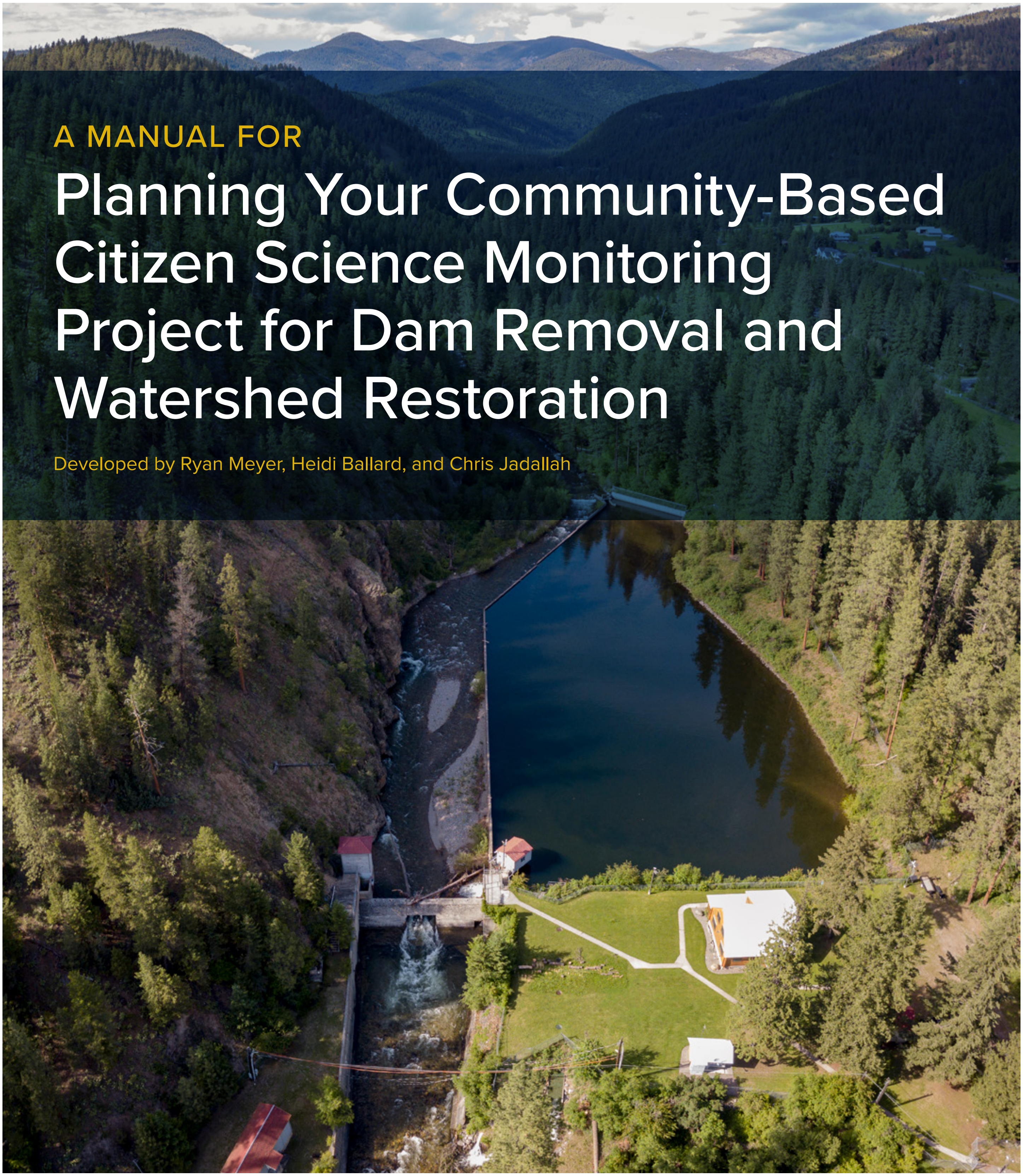
A MANUAL FOR

Planning Your Community-Based Citizen Science Monitoring Project for Dam Removal and Watershed Restoration

Developed by Ryan Meyer, Heidi Ballard, and Chris Jadallah



CENTER FOR COMMUNITY AND CITIZEN SCIENCE

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About this Document

This manual was developed by Ryan Meyer, Heidi Ballard, and Chris Jadallah at the UC Davis Center for Community and Citizen Science for the Open Rivers Fund, a program of the Resources Legacy Fund, which is supported by the William and Flora Hewlett Foundation.

The **Center for Community and Citizen Science**, based at the UC Davis School of Education, uses research, teaching, and service to help scientists, communities, and citizens collaborate on science to address environmental problems as a part of civic life. More at **education.ucdavis.edu/ccs**.

Resources Legacy Fund (RLF) works with philanthropists to conserve land, water, and ocean resources while advancing healthy communities and social equity. The Open Rivers Fund (ORF) is a ten-year program of RLF that was launched in November 2016 and capitalized by the William and Flora Hewlett Foundation. ORF supports local community efforts to remove obsolete dams, modernize infrastructure, and restore rivers across the western United States. ORF focuses on removing barriers that impair river function and pose challenges, costs, or risks to communities. ORF aims to create significant economic and environmental benefits, but also to build technical knowledge, organizational wherewithal, and public awareness in order to advance the field of dam removal. More at **resourceslegacyfund.org/our-approach/open-rivers-fund**.

This manual aims to support ORF projects and the broader field by building capacity in local communities for monitoring the impacts of dam removal and river restoration, while also supporting ongoing stewardship and learning. As we learn from communities, we will adapt and update this resource.

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Acknowledgments

This document draws extensively on the experiences and knowledge of the authors, as well as published articles[1] and other resources (referenced throughout) from the growing field of community and citizen science. We acknowledge in particular a handbook that one of the co-authors, Heidi Ballard, developed with colleagues David Pilz and Eric T. Jones, which has been both a valuable source of insights, and influential in structuring our approach to this manual: Pilz. D., Ballard, H. L., & Jones, E. T. (2006). *Broadening participation in biological monitoring: Handbook for scientists and managers* (Gen. Tech. Rep. PNW-GTR-680). US Department of Agriculture, Forest Service, Pacific Northwest Research Station. **fs.fed.us/pnw/pubs/pnw_gtr680.pdf**

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[1] We have focused on resources that are freely available; however, some of the references are unfortunately behind journal paywalls, or in books requiring purchase.

Cover photo: Jason Jaacks. **Design:** Mark Briggs.

Contents

Jason Jaacks

1. Introduction

THE OPEN RIVERS FUND (ORF) has a unique opportunity to support, learn about, and build capacity for dam removal across the Western United States. An important element of that process is tracking what happens after dam removal and during river restoration at individual project sites. One way to meet the need for environmental monitoring and support local capacity to steward these sites into the future is to involve local communities and organizations in that monitoring through citizen science. A citizen science approach offers project funders and partners the opportunity to gather important data about target environmental parameters and build and sustain community engagement in watershed restoration. We have developed this manual to guide groups in their planning and implementation of citizen science activities at ORF sites specifically and for dam removal and river restoration more generally.

What Is Citizen Science?

There is no single agreed-upon definition of "citizen science." It is one of many terms used to describe the general approach of involving members of the public in scientific research (which may refer to experimental science or monitoring). Citizen science projects are extremely varied in terms of the nature and extent of volunteer participation, the degree of investment in volunteers (e.g., training, oversight), and the variety of beneficial outcomes that might result from the effort. An effective program is a balance of aspirational goals and on-the-ground realities. Typically, not all data needs can be met through a citizen science approach, and not all projects will be appropriate places in which to develop and implement a citizen science project. In light of these opportunities and limitations, this document can serve as a resource for ORF partners and the broader field to support decision-making about citizen science, and the development and implementation of citizen science programs.

Key Terms

Throughout this document, we refer to various groups of people who have roles to play in the development and implementation of citizen science monitoring for dam removal and river restoration projects.

- **Participants** have an active role in the citizen science project, and those roles may vary widely, even within a single project (e.g., collecting data, training volunteers).
- **Collaborators** are actively involved in the management or administration of a project, and, unlike most participants, hold coordinating or decision-making authority, either collectively or as individuals.
- **Sponsors** are individuals or organizations who provide financial or in-kind support to a project, regardless of active participation.
- **Stakeholders** are individuals and organizations that have an interest in the project, its outcomes, and its products, regardless of whether they are directly involved. By our definitions, *all groups outlined above qualify as stakeholders*.

Any individual might wear multiple hats within a project. For example, a sponsoring individual may also be a collaborator helping to run the program, or a participant.

This document is based on the experience of the authors and a wealth of academic publications and other literature, including resources from many other citizen science programs that have tackled challenges related to volunteer monitoring in watersheds. In each section, we offer examples where appropriate and references for further reading. We expect lessons from early years of citizen science monitoring at ORF projects to inform the manual over time, and thus welcome feedback that can help us improve this resource.[2]

[2] Contact us through the Center for Community and Citizen Science website: education.ucdavis.edu/ccs

Ryan Meyer

2. Using this Manual

WE HOPE THIS MANUAL will be useful to any stakeholders considering or developing a community-based citizen science monitoring program. The major sections of this manual focus on:

Building a Team

Building a Process

On-the-Ground Implementation

Follow-through and Sustainability of the Monitoring Project

This structure suggests a linear, chronological account of a monitoring program, but decision-making and planning processes will not necessarily proceed in precisely this order. For example, there may be issues related to project sustainability (See **Section 7**) that coordinators want to consider as a first order concern, and use those issues to inform how other aspects of a new project should be designed. We have endeavored to lay out the structure of the manual clearly, so that any user can draw from the various sections in whatever order feels the most appropriate.

All sections of this manual are worth considering *before* monitoring begins, and in an ongoing way as a project or program evolves. But **manual users will likely skip around to priority sections, as appropriate**. Our intent for this document is to help collaborators quickly make decisions about where to focus based on needs, gaps, existing capacities, or other aspects of their particular context. We have also provided a basic overview of each section in a "Quick Guide," available at **education.ucdavis.edu/ccs-manual**, along with a digital copy of this manual and other resources.

In some cases, citizen science may be the sole source of monitoring data, thus requiring a comprehensive ground-up planning process. In other situations, citizen science may form one piece of a broader monitoring effort that includes professional scientists. In such cases, some of the more fundamental questions about monitoring may be answered outside the citizen science planning process, and some sections of the manual may be more relevant than others.

Avery Maxwell, WEN

3. Should We Do Citizen Science?

DECIDING IF A CITIZEN SCIENCE APPROACH is appropriate involves thinking about the different forms that it could take, the goals that collaborators want to pursue, and a wide variety of other considerations. This section offers some important first steps in deciding whether citizen science is right for your project, but sections throughout this manual also raise important points that could be helpful.

Are incentives and goals for collaboration well-aligned? Community-based citizen science monitoring is inherently collaborative. Successful collaboration depends on understanding how collaborators' goals overlap, and determining whether it is worth their while to work together. Incentives for collaborating differ widely. Which people or organizations might collaborate to undertake a citizen science monitoring effort, and why? Discussing these questions can help inform whether to pursue a citizen science approach at all, in addition to helping with the planning process.

We recommend developing a thorough understanding of both individual and shared goals among collaborators, and using that to guide in both the assessment of whether citizen science is a viable option and in the project planning process. In the remainder of this section, we discuss some forms of collaboration; advantages, disadvantages, and barriers to collaborating; and potential means to make collaborations work. Many of the essential elements of making collaborations work are also covered in other parts of this manual.

3.1 Goals of Citizen Science

An important goal of most scientific monitoring is to produce data with a level of rigor and quality that will serve one or more needs. This is also an important goal with citizen science, but there may be a variety of other reasons to develop a citizen science approach to monitoring. Some common goals of citizen science monitoring, beyond collection of useful and rigorous data, include:

1. Fostering community development and public support for a project
2. Improving interaction and trust among stakeholder groups
3. Maintaining local/community ownership of the scientific process
4. Addressing public priorities and concerns
5. Accessing and using local or traditional knowledge
6. Providing formal and informal learning opportunities
7. Sharing costs, and improving cost-effectiveness
8. Reducing conflict and litigation

Stakeholders may bring a wide variety of personal interests and motivations that, depending on their role, might impact the broad goals of a citizen science effort. These are explored further in **Section 4.1**. **We recommend creating opportunities for stakeholders to discuss and clearly express their personal motivations and goals for involvement in a citizen science effort.**

When citizen science projects involve diverse stakeholders, **consider beginning with broad vision statements or mission statements as a means of finding common ground**. This can be a useful step before tackling more detailed and sometimes difficult tasks, such as identifying goals (See **Section 4.5**), and agreeing on processes (See **Section 4.3** and **Section 4.4**).

3.2 Types of Citizen Science Monitoring

What type of citizen science monitoring are you envisioning? Citizen science can be as simple as cooperating with a single volunteer to count the numbers of fish swimming upstream from video camera footage or as complicated as a national, volunteer-based program (e.g., Nature's Notebook, run by the USA National Phenology Network[3]). Some projects will involve participants during all stages of the project; in others, participants might only assist with data collection. Managers or scientists often initiate projects, but others could develop when a community approaches a manager with monitoring needs. Some complex programs that coordinate many local projects can be tightly prescribed and centralized (e.g., California's Clean Water Team program, run by the State Water Resources Control Board[4]), whereas others are decentralized and open to innovation (e.g., Nature Groupie, run by University of New Hampshire Cooperative Extension[5]).

Citizen science can take different forms. Some of the important structural components are described in Table 1. **Consideration and assessment of possibilities for a potential citizen project will help expand the world of potential approaches.** Another common way to conceptualize citizen science is in terms of the roles played by volunteers in various stages of a scientific process. Table 2 summarizes one common framework. Note, however, that this framework is not the only way to conceptualize volunteer involvement; a single project may have a range of roles for participants.

Table 1. There are many structural possibilities with citizen science.[6]

Technology	Pencil & Clipboard	⟷	Mobile App
Volunteers	Single Volunteer	⟷	Thousands
Participant Age	Youth	⟷	Retirees
Audience	Restricted	⟷	Open
Spatial Coverage	Single Site	⟷	Global
Sampling Effort	Annual	⟷	Daily
Sampling Design	Opportunistic	⟷	Highly Structured
Impetus	Community	⟷	Scientists
Organization	Local Nonprofit	⟷	Global Organization/Network
Activity	Independent	⟷	Large Teams
Training	None	⟷	Extensive with Tiered Roles

[3] usanpn.org/natures_notebook
[4] waterboards.ca.gov/water_issues/programs/swamp/cwt_volunteer.html
[5] naturegroupie.org/about-nature-groupie
[6] Adapted from: *Citizen Science and Ocean Resource Management in California: Guidance for forming productive partnerships.* California Ocean Science Trust, CA, USA. August, 2014.

Table 2. Roles of participants in three idealized modes of citizen science.

Note that in reality, even in a single project, there may be variation in how individuals participate, and in the roles they fulfill.[7]

	Contributory Projects generally designed by scientists, for which members of the public primarily contribute data.	Collaborative Projects generally designed by scientists, for which members of the public contribute data but also help refine project design, analyze data, and/or disseminate findings.	Co-created Designs by scientists and members of the public working together and for which at least some of the public participants are actively involved in most or all aspects of the research process
Define a Question/Issue			●
Gather Information			●
Develop Explanations		●	●
Design Data Collection Methods		●	●
Collect Samples	●	●	●
Analyze Samples	●	●	●
Analyze Data		●	●
Interpret Data/Conclude			●
Disseminate Conclusions			●
Discuss Results/Inquire Further			●

Are there similar projects that can be imported and/or adapted? Many citizen science projects make program resources, such as training materials, methods, and protocols, available for review and adoption by others. Review “Drawing on Existing Citizen Science Resources and Projects” on page 36 for ideas that can help you avoid reinventing the wheel.

3.3 Advantages and Disadvantages of Citizen Science

There may be many different reasons for people to collaborate, such as mutual interest, job requirements, shared political concerns, or legal requirements. Collaborations may originate from government agencies, community groups, resource users, nonprofits, tribal governments, or other entities. Considerations presented in Figure 1 on page 10 are all influenced by the form of the citizen science monitoring project and many are a matter of perspective. **You can use lists of advantages, disadvantages, and barriers to explore the potential for using citizen science**, and to proactively identify goals to pursue and challenges to overcome. The framework in Figure 1 can also help with the question of whether to use a citizen science approach.[8] None of these factors is a deal-breaker. For example, small-scale sampling may still be quite amenable to a citizen science approach when there is high motivation and engagement is very important.

[7] Adapted from: Shirk, Jennifer L., Heidi L. Ballard, Candie C. Wilderman, Tina Phillips, Andrea Wiggins, Rebecca Jordan, Ellen McCallie, et al. 2012. “Public Participation in Scientific Research: A Framework for Deliberate Design.” *Ecology and Society 17*(2): 1–20.
[8] See also some lists of advantages and disadvantages for both organizations and individuals on page 20 of Pilz et al. (2006) at fs.fed.us/pnw/pubs/pnw_gtr680.pdf.

Figure 1. Should you consider a citizen science approach?

This simple framework shows six important considerations for thinking through the applicability of citizen science approaches.

Increasing suitability for a citizen science approach ↑

Clarity of Aim/Question	Importance of Engagement	Resources Available	Scale of Sampling	Complexity of Protocol	Motivation of Participants
Clear aim/question	Engagement is important	Plenty of resources	Large-scale sampling	Simple protocol	Good reasons to participate
Vague aim/question	No engagement or only one-way communication	No resources	Small-scale sampling	Complex protocol	Reasons to participate are not clear

From Pocock, M. J. O., D. S. Chapman, L. J. Sheppard, and H. E. Roy. 2014. "Choosing and Using Citizen Science: A Guide to When and How to Use Citizen Science to Monitor Biodiversity and the Environment." Centre for Ecology and Hydrology.

To weigh the considerations above, you need to determine which of the advantages, disadvantages, and barriers apply to your particular circumstances, decide their relative importance, and estimate how difficult the disadvantages and barriers will be to surmount. **In weighing the advantages, disadvantages, and barriers of a citizen science approach, it is useful to ask: "Compared to what?"** Any approach to monitoring will entail a variety of challenges, with different potential benefits. These comparisons can help collaborators avoid becoming overly fixated on the challenges and barriers of a citizen science approach.

Professional Monitoring vs Citizen Science

The question of whether monitoring should be carried out by paid professionals or by citizen scientists is usually not a simple "either/or" proposition. Many citizen science efforts will bring professionals into the process in some capacity, at some point, such as planning, training, statistical analysis, or peer review. For many projects, the challenge is to develop a productive balance that takes advantage of varied capacities and knowledge of many different kinds of participants. The rest of this manual explores those issues in more depth.

However, citizen science is not a good idea in all cases. Some hypothetical examples are listed below. We also recommend using Figure 1 for a more thorough exploration of the decision-making process.

A citizen science approach to monitoring could be problematic for:

- **Safety and liability.** In some cases, it may not be possible for volunteers to get to a monitoring site and gather data safely and effectively. If highly specialized training and certification are required, citizen science is probably not advisable.[9]
- **Difficult methods at a small scale.** If protocols are complex and the scale of the effort is relatively small, it may not be worth the investment in relationships, training, equipment, and coordination that a citizen science effort would require.

[9] There are exceptions to this. For example, Reef Check California deploys volunteer divers to conduct elaborate surveys of rocky reef habitats, requiring advanced skills and knowledge.

- **Stakeholder fatigue or mismatched priorities.** In some cases, potential collaborators on a project may be consumed with issues that take priority over a new monitoring effort. These might be specific to the project itself, or other environmental issues in the community.
- **No local leadership.** Whether due to mismatched priorities (see previous point), or other factors, if no person, organization, or group of partners is available to lead a citizen science effort at the appropriate timeframe, then a professional person/organization may be a better option.
- **Lack of resources to sustain the effort.** Some projects may have very modest costs, but some level of time, money, and resources will likely be needed over the long-term of the project.

3.4 Integrating Citizen Science into Professional Monitoring

For many projects, it is not a question of citizen science *versus* professional monitoring, but rather coordinating both efforts. Citizen science commonly forms one piece of a broader monitoring effort that includes activities carried out by professional scientists. This has been the case with the Rattlesnake Creek Dam removal project in Missoula, Montana, where the Watershed Education Network is collaborating with Trout Unlimited and other partners to conduct monitoring (See Box 1). In that case, local partners worked together to develop a monitoring plan with many different participants. Part of that planning process involved identifying citizen science capacity, and iteratively exploring which aspects of the monitoring plan were amenable to citizen science. We describe this case in text boxes throughout this document to illustrate some of the important lessons learned from their experience. You can also review the project's monitoring plan (See **Appendix E**) to view which activities are taken on by citizen scientists, and which are assigned to professionals. This breakdown of responsibilities is not necessarily appropriate for other projects, but it does highlight how the team balanced issues such as safety, availability, and time commitment of volunteers, and the skills and knowledge of a pre-existing pool of volunteers.

Box 1. Collaborative Monitoring on Rattlesnake Creek: Goal Setting

Originally built in the early 1900s for municipal water supply purposes, the Lower Rattlesnake Creek Dam no longer served a functional purpose and impeded natural river processes. The dam's removal in August 2020 is expected to have wide-ranging impacts on Rattlesnake Creek and the broader Clark Fork watershed. Monitoring the impacts of removal is critical to adaptive site management and restoration, outreach and education concerning the project's benefits, proving dam removal impacts to funders and stakeholders, and offering valuable lessons for future dam removal projects throughout the West.

While planning to monitor the impacts of the Rattlesnake Creek Dam removal and restoration, the project lead, **Trout Unlimited** (TU), identified two overarching goals:

1. Understand the impact of dam removal on natural resources and stream processes through collaboration with agency, academic, and nonprofit partners.
2. Engage the public through citizen science and outreach.

TU and its monitoring partners understand that citizen science can help reliably meet some data needs, while also engaging local community members in the project. To integrate citizen science with professional monitoring efforts, TU built a team of partners who could help achieve this goal and join a planning process already underway.

Deb Fassnacht, WEN

4. Building a Team

CITIZEN SCIENCE MONITORING is typically a collaboration across organizations and groups. Getting started requires determining shared goals, assessing capacity, identifying important roles, and agreeing on a process for building a monitoring plan. These initial steps are crucial to building trust among the core team, overcoming challenges as the project takes shape, and sustaining the effort over time.

4.1 Understanding Your Stakeholders, Collaborators, and Participants

Dam removal generally requires local collaboration, and many dam removal and river restoration sites will involve organizations that have an interest in monitoring and/or experience working with volunteers in some capacity. So, for the development of a citizen science effort, there may be obvious collaborators, some of whom may already work with volunteers that might participate in the new project.

However, we recommend thinking broadly for two reasons. First, other local groups who are not the "usual suspects" may benefit from, and greatly contribute to, a monitoring effort, and you do not want to miss those opportunities. It is important to **ask yourself whose voices you are NOT hearing, and why, and how it might be possible to include them**.

Second, early conversations about the motivations, concerns, and expected benefits of participation will help to build trust and maintain clarity and transparency. Stakeholders who are considering participation generally expect to receive benefits and may express concerns about the process. This manual lists some major goals and concerns that can motivate stakeholder groups and individuals with respect to participating in citizen science projects (See Table 3 and Table 4).

Table 3. Typical goals and concerns that motivate *stakeholder groups*.[10]

Participation Goals	Participation Concerns
• Improving land/water stewardship • Improving community relations • Community development, capacity building and employment opportunities • Ensuring access to a resource for economic or traditional use • Influencing policy or management decisions for policy • Ensuring social and economic justice • Public education • Stretching limited resources, sharing work, working more effectively • Shared accountability and responsibility • Reducing conflict and litigation	• Freedom to complain or object might be co-opted by the collaborative process • Too expensive or time-consuming • Risk of failure • Data and findings might lead to unwelcome consequences • Data might not be trusted or used • Data ownership issues might be difficult • Others might have unrealistic expectations or lack willingness to commit to common action • Fear that others might sabotage or misuse the process • Collaborative decisions might counter vested interests, or Tribal sovereignty

[10] Adapted from Pilz (2006).

Table 4. Typical goals and concerns that may motivate *individuals*.[11]

Participation Goals	Participation Concerns
• Ability to influence others or policy • Ensuring access to a commercial resource • Improving one's resume • As an extension of one's job • Contrast to paid work • Testing leadership skills • Learning, gaining experience, and acquiring self-confidence • Using knowledge, skills, or abilities • A sense of power, success, and personal achievement • Gaining recognition or impressing others • Affiliation with a project or feeling a part of a team • Expressing concerns or ideas • Exploring job opportunities or testing a career change • Keeping track of what is happening in a place • Maintaining family or cultural traditions • Enhancing one's quality of life • Meeting new people • Setting an example for children • Mutual involvement with family or friends • Getting compensated to visit nice places • Keeping physically active by getting outdoors • Enjoying nature	• Fear of change • Shyness or lack of self-confidence • Lack of time • Being exploited • Lack of training • Exposing one's ignorance • Embarrassment • Insufficient support from family, friends, community, or employer • Lack of trust in others • Working hard on a project only to see it fail or be ignored

Representation

Sometimes an individual participant in a citizen science project will claim to represent a stakeholder group or organization, and organizers and participants should be careful to note these distinctions between individual and group representation. For example, a government agency representative typically distinguishes between expressing personal opinions and speaking on behalf of the agency. Similar or more complex situations may arise with Tribal representatives. Conflicts and misunderstandings can also arise when collaborators mistakenly assume that an individual's opinion or agreement represents the consensus of the stakeholder group they represent. Turnover in agency personnel often requires formation of new relationships with the new representative and renegotiation of previous agreements.

[11] Adapted from Pilz (2006).

➤ Steps You Could Take:

- When faced with a wide range of interests and voices in a planning process, a survey or questionnaire could both formalize the identity of groups and individuals (such as stakeholders, collaborators, or participants), and elicit information about their concerns and motivations.
- Map out stakeholder issues on paper. Create a simple table with stakeholder groups listed on one axis and a list of local relevant issues the other (e.g., concerns listed in Table 3 and Table 4).[12]

4.2 Assessing the Context of a Citizen Science Monitoring Project

The context of any citizen science project includes dimensions such as environment, institutions, politics, law, and regulations. An understanding of the context can inform decisions about who can and should be a part of project design, who participates in monitoring, and who has a stake in monitoring results. It can also help to determine what capacities and opportunities exist for involving volunteers in monitoring activities. Collaborators may have varied understandings of a local context, so an open discussion of this topic is an important early step in a planning process. A broad survey of stakeholder perspectives can give you a more comprehensive understanding of the context of the project, which in turn will inform subsequent decision-making.

Political Context

Political processes associated with dam removal and river restoration can impact the development of a related citizen science monitoring program. If a dam removal project has been particularly controversial or divisive, for example, this could create challenges and/or opportunities. Some groups might be averse to participating for political reasons. On the other hand, collaborative monitoring could present an opportunity to build trust and mutual understanding, if opposing groups can at least agree on what data should be collected in order to understand successes and failures of a project. This has been successful in a variety of natural resource contexts such as fisheries, forests, and grazing management.

Some additional political considerations include:

- Relationships between more powerful stakeholders (e.g., well-educated, higher income, English-speaking, or politically connected people) and less powerful stakeholders (e.g., people with less formal education, lower-income, or people for whom English is a second language).
- Relationships between federal, state, Tribal, and local government land management agencies, which will likely influence who gets involved, has control, and uses the data resulting from the citizen science monitoring project.

➤ Steps You Could Take:

- Can we break down political divisions? When starting a new monitoring project, consider how the political context might lead to a collaboration of the “usual suspects,” and whether there is an opportunity to expand the community of participants.
- How can we avoid political fall-out later in the project? Pay careful attention and dedicate sufficient time to building trust among participating stakeholders.

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[12] For more information on this “Stakeholder Analysis Matrix” activity, see the “Situation Assessment and Stakeholder Analysis for Citizen Science” webinar at citizenscience.org/2018/11/30/situation-assessment-and-stakeholder-analysis-for-citizen-science.

Policy, Legal, and Regulatory Context

Policies, laws, and regulations may constrain where and when monitoring can happen, who can participate, and the structure of the activities. For example, funding sources often impose specific conditions and requirements. Harvard Law School's Emmett Environmental Law and Policy Clinic prepared a state-by-state review of legal issues that potentially impact citizen science activities, which can be accessed through an interactive map.[13] Local agencies and organizations may also have policies that encourage or even require public service, or other activities that could be helpful to a volunteer monitoring effort.

There may be opportunities to inform policy and management with results from the monitoring project, even if these are ancillary to the question of dam removal and river restoration. For example, most states have adopted macroinvertebrate survey protocols for monitoring riverine ecosystem health. Using the state-adopted protocol could increase the value and relevance of the resulting data, beyond measuring outcomes of a dam removal. Aligning with such opportunities could expand the local relevance, and bring in additional collaborators, participants, and sponsors.

➤ Steps You Could Take:

- Consult online resources, experts, or lawyers to help fully understand the legal context and ramifications of a citizen science monitoring project. The Citizen Science Association has established a Law and Policy Working Group, which includes a tool for submitting questions to students at Harvard's Emmett Environmental Policy and Law Clinic.[14]
- Explore opportunities to link with and/or inform other local policy and management issues related to the watershed.
- Understand regulations that apply to volunteer activity, which may vary from one collaborating organization to the next. Organizers should strive to understand the policies of the participating organizations so they can appreciate the work that others need to perform.

Organizational Context

Organizational culture can present a significant challenge to new collaborations. The problem can be internal – if a collaborating individual is not receiving adequate support or recognition for his or her involvement in the project, for example. And, differences across organizations can also be challenging. For example, government agencies, Tribal governments, public schools, and nonprofits may all have different ways of working, different requirements, and different expectations about what it means to collaborate.

➤ Steps You Could Take:

- Encourage conversations among collaborators about what each person's organization expects or requires out of the project.
- Collaborators can serve as "ambassadors" within their own organizations to show the effectiveness of citizen science.

[13] Visit citizenscienceguide.com/map
[14] Visit citizenscience.org/get-involved/working-groups/law-policy-working-group/ask-a-legal-question

Environmental Context

The environmental context includes temporal and spatial components, as well as biophysical structure and processes. Some of these will relate directly to the conditions created by a dam removal project (e.g., will monitoring begin before or after dam removal occurs? What is the spatial scale of the project and expected resulting changes?). Others are more general considerations such as local hydrological cycles, or particular species of concern.

Some important environmental considerations include:

- How does the physical area to be monitored shape the scale and difficulty of the monitoring effort? (e.g., how many sites and/or access points will be needed? Is the terrain safely accessible to a wide range of volunteers? Is this project focused on a single dam, or many barriers throughout a landscape?)
- Information sources such as past scientific studies or historical records could help to characterize the environmental context, and point to promising citizen science approaches.

➤ Steps You Could Take:

- To help define how a monitoring project relates to ecosystem components, functions, or processes, create a conceptual map or model of critical indicators and other components of the system. This could be used as a diagnostic (i.e., to inform the decision about whether or not to pursue citizen science at all), or as an aid in planning.

Community Context

It is helpful to know the history of the local community regarding the dam and the watershed: who supports the dam removal project, and who opposes it? Community groups that have been heavily involved in other aspects of the project (e.g., advocacy, planning) may be willing to participate in monitoring. Monitoring could also bridge divides that have opened up during the project, where critics may have an interest in gathering good evidence about the benefits or harms of the project. At the very least, understanding and explicitly considering the community context can avoid exacerbating existing divisions, and identify opportunities to work on community issues related to stewardship, environmental education, and social justice via a collaborative monitoring process.

➤ Steps You Could Take:

- Research the historical context of the project with local press, local leaders, and stakeholders.
- Talk to local leaders to get their perspective on whether a community-based citizen science monitoring project could remedy, or exacerbate, existing divisions in the community, and how to make such an effort most successful and beneficial to the community.

Land Tenure Context

River restoration and natural resource management issues cross ownership boundaries, so land tenure must be considered. Public lands typically have different management goals and constraints than Tribal or private lands. Land tenure may raise issues such as access rights, allowable monitoring procedures, interactions with other land users, and public outreach.

➤ Steps You Could Take:

- Research relevant land ownership within the watershed and determine whether volunteer access is a major barrier; if it is, citizen science approaches may be of limited value.
- Explore the possibility of involving landowners in the planning (as collaborators) and/or implementation process (as participants).

Economic Context

The economic context of collaboration can be crucially important to some stakeholders and secondary to others. Some groups may have an interest in participating – indeed, they may feel entitled to participate for a variety of reasons – but lack resources to do so. We often assume that citizen science is carried out by uncompensated volunteers, but this may not be appropriate in some circumstances. Compensation can take many forms, including childcare, reimbursed costs, academic credit, or a stipend. Recognizing and accommodating different needs among participants are critical to a sense of fairness, and full participation on the part of all stakeholders.

At the same time, dam removal projects and the monitoring of project outcomes may directly relate to economic interests of organizations and private individuals. Stakeholder groups might have economic interests, for instance, in rural economic development through sustainable natural resource use. Some stakeholders, or even participants, might have a vested interest in the harvest of the particular natural resource that is being monitored, such as fish.

Finally, organizers often need resources to establish and sustain a citizen science project. **Section 7.5** discusses this issue in greater detail.

➤ Steps You Could Take:

- Whenever participants that favor a particular outcome are involved in citizen science, develop safeguards (e.g., thorough training or third-party auditing) to ensure accurate data and non-biased interpretation, and to maintain credibility.
- Directly ask participants (or potential participants) what resources would best support their involvement.
- Maintain trust and continued commitment among participants by communicating clearly and transparenty about compensation.

Cultural Context

Cultural differences can be as simple as when different corporate or work cultures clash, and as deep-rooted and historical as when indigenous groups and non-indigenous groups interact around land management and ownership. Individuals from different cultural backgrounds may have fundamentally divergent understandings of the world, what constitutes valid knowledge, and how humans should interact with nature. These cultural differences can be an asset to a community-based citizen science project. Local Tribal members might contribute valuable traditional ecological knowledge and resource management practices in particular, and other local people with extensive experience on the land may offer important local ecological knowledge to the project. Meshing multiple sources of knowledge can be challenging and requires mutual understanding, respect, and an open mind. Project organizers should address cultural diversity, and strive to promote equity.

➤ **Steps You Could Take:**

- In places with considerable cultural diversity, consider convening one or a series of group or one-on-one meetings with individuals from diverse perspectives, to better understand any potential barriers, and build trust in, and support for the project.
- Acknowledging and making space for cultural differences, open communication, and defining inclusive norms for the project, can help facilitate project development by fostering trust and mutual respect.

4.3 Decision-Making

Developing and preserving trust among collaborators and participants are important throughout the project, and identifying a clear and systematic decision-making process can help with this. **We recommend using clear, understandable, and jointly agreed-upon processes so that choices are seen as fair, logical, and equitable.** Some projects may already involve close collaboration and clear shared expectations around decision-making processes. In others, this issue may require explicit attention and effort.

Collaborative Decision-Making

Decision-making within groups can take a variety of forms such as majority rule, group consensus, or mediated discussions. A neutral facilitator can be crucial, especially in large or diverse groups. Even if some stakeholders disagree with results, prior agreement about decision-making principles and procedures can improve overall perceptions and acceptance of outcomes.

Applying systematic and collaborative decision-making requires particular skills. Depending on the existing skills of the project coordinators and scope of the project, organizers might benefit from formal training. Or, collaborators may choose to engage an outside facilitator, if resources allow.

Effective strategies for improving collaborative decision-making include:

- Start with small, short-term projects to test your process and build trust.
- Plan to make incremental improvements in the process.
- Create opportunities – and adequate time – for stakeholders to participate in decisions.
- Follow-up promptly with participants at each stage of the process. Make sure to address participant expectations.

- When interacting with participants, treat each other with respect, and illustrate with positive examples.
- Get help when needed.

➤ Steps You Could Take:

- Identify small initial planning steps with which to test decision-making processes and gauge buy-in from collaborators and other stakeholders.
- Solicit feedback on decision-making processes at key points during the planning process.

4.4 Effective Communication

Effective communication builds – and requires – trust. Clear communication can be challenging when your audience spans many different backgrounds. You can develop effective and appropriate communication strategies by first learning about participants' perspectives, their social relationships with each other in the community, and how these viewpoints shape their communication styles. One way of considering this is to **ask: "Who are the long-time residents in this community? Have they held social power and privilege, or been in groups that were denied access to institutions?"** For example, some groups might have high levels of formal education, and understand the local river ecosystem through scientific training. Some may have local indigenous or other cultural knowledge of the ecosystem.

You can also **be attuned to personal communication styles**, and accommodate varying preferences and comfort levels. Some individuals may dominate conversations and speak often, while others tend to listen and seldom speak up. Who speaks directly, and who speaks indirectly? Who tends to be impatient with talking and prefer action, and who prefers to discuss things before acting?

Use of language is another area to consider. The kinds of words, phrases, acronyms, and terminology used to express perspectives can differ widely between groups of participants. As an example, a hydropower owner will describe the local river ecosystem differently than university researchers, Tribal indigenous members, or farmers.

Meetings are where communication differences often arise, so determining the appropriate structure is helpful. Who will facilitate? Where will meetings be held, and are meeting times and locations ones that work for all participants? Are interpreters needed? How will tables and chairs be arranged, and what format will be used? Is everyone expected to speak up in large groups, or are there chances for people to talk about questions in pairs or trios? Do people need to be divided into subgroups by gender? It is also helpful to explicitly state, or even discuss, the norms of communication for each meeting.

➤ Steps You Could Take:

In some cases, bringing in a professional facilitator may help to address communication barriers. In others, it may be as simple as beginning each meeting by explicitly discussing and agreeing to shared norms of behavior. Additional ways to work through such issues together include:

- Creating vision statements and collaboratively framing issues
- Sharing reading assignments or viewing movies about the issues together
- Having guest speakers, or training courses that compare the scientific method with traditional indigenous ecological knowledge

4.5 Determining Goals

Determining the goals of the monitoring effort is important for building trust and mutual understanding among stakeholders; integrating effectively with other activities in the local area; and making decisions about practical details such as indicators, measures, and other design features. Goals may range widely among stakeholders. For local communities, it could be the desire to improve local waterways for recreational purposes such as boating and fishing. For Tribal groups, the context could be restoring the health of rivers and streams and passage of fish for cultural uses and traditional livelihoods. As part of the planning process, it is useful to hold one or more meetings focused solely on the high-level goals and objectives of the citizen science monitoring effort.

Your goals should be clear, and receive broad buy-in. There may be different priorities for different participants, but the broad goals of a monitoring effort, especially a citizen science monitoring initiative, should be clear, and receive buy-in from all stakeholders.

In addition to collecting data that inform the dam removal and river restoration efforts, there may also be project goals related to education, stewardship, and other community benefits. The fact that citizen science projects can work toward both environmental and community goals is of course a major advantage of this approach, but it also demands careful planning with respect to goals and expectations.

Integrating with Other Activities

In most cases, citizen science may be one piece of a broader monitoring effort related to dam removal and river restoration. There may also be related monitoring activities planned or already in place, such as those conducted by local, state, and federal agencies. **Shared high-level goals are important for avoiding duplication of effort, and for effectively integrating across monitoring activities.** Once collaborators have reached a shared understanding about these issues, there are a variety of details to address, such as indicators and measures, as well as data sharing and management, all of which are discussed later in this document.

➤ Steps You Could Take:

- Create a series of statements from the more general to the more specific (i.e. from vision, mission, goals, and objectives).
- Specify a point person, and an established process (e.g., a committee) for checking in and coordinating with related monitoring or management activities, to ensure effective integration with those efforts.
- Incorporate information about project goals and expected benefits into both internal and external communication.

4.6 Identifying and Filling Roles in a Project

Organizational Structure

An explicitly defined organizational structure is useful to stakeholders seeking to engage with the project. This could be housed with an established organization, or you may need to create an entirely new structure. Consider factors such as who initiates the project, the number of stakeholders, the context, anticipated duration, and the amount of coordination. There may be a single organization leading an entire project, or multiple organizations collaborating to address common goals (See Box 2 for an example of this process on the Rattlesnake Creek Dam removal project).

Who can/should serve as a lead organization? In cases where a single organization will serve as the lead, consider the advantages and disadvantages of institutional settings. Government agencies can provide long-term institutional support but may have political baggage. Universities can also be good long-term sponsors because they are typically perceived as more objective and may have a variety of technical capabilities that could be leveraged. For example, student projects, under the supervision of a professor, can help advance project objectives (e.g., data collection, community engagement) while also meeting educational goals. Independent nonprofits may provide effective project coordination and logistical support. Depending on their mission, they also can act as intermediaries between stakeholder groups and agencies.

What kinds of advice and other external input will you need? Forming groups such as advisory councils or task forces can be useful in communicating with stakeholder groups, or addressing specific issues (e.g., integrating citizen science monitoring with other monitoring efforts).

Box 2. Collaborative Monitoring on Rattlesnake Creek: Establishing Partnerships

Monitoring and research efforts on Rattlesnake Creek, in Missoula, Montana were already underway when planning for dam removal began. Montana Trout Unlimited (TU) assumed the role of coordinating monitoring efforts amongst diverse partners ranging from university groups, such as the University of Montana Department of Geosciences, to government agencies, such as Montana Fish, Wildlife, and Parks, to community-based organizations such as Watershed Education Network (WEN). WEN is a nonprofit environmental science education organization that aims to foster knowledge, appreciation, and awareness of watershed health in Missoula, Montana through citizen science and other hands-on outreach activities.

WEN's Stream Teams had been actively monitoring Rattlesnake Creek, making them a natural partner for collecting data on certain metrics while simultaneously engaging the public. Through ongoing conversations and meetings, both informal and formal, TU and WEN deliberated on which data were most suited to collection by citizen scientists and which methods were most aligned with WEN's needs and capacities. TU knew that WEN could play a role in the monitoring efforts, but there were some key challenges that could only be addressed through an iterative process that narrowed in on the details of a mutually beneficial collaboration.

Roles and Responsibilities

Especially if an organizational structure is multilayered, clear understanding of the roles and responsibilities of each collaborator will improve coordination. Consider also the role that each participant plays in representing other stakeholders or collaborating organizations, so that accountability is clear.

The following are roles that are common to citizen science monitoring projects. You may not need to fill all of these roles, but considering them up front is a useful exercise, both for organizing the project, and developing clear expectations about the level of work and commitment you can expect from fellow collaborators.

- Staffing a project coordinating body - either one organization, one staff person, or a team of people across organizations
- Coordination and integration with other monitoring and management activities
- Volunteer recruitment, management, and retention
- Outreach and communication (to volunteers, and to the public)
- Participant training, re-training, and certification
- Content development (e.g., identification guides) to support protocols
- Data quality assurance and quality control - ensuring rigor, validity, and reliability of methods
- Data management
- Data analysis and data visualization
- Technology development and maintenance
- Project evaluation
- Reporting
- “Super” volunteers - participants who become leaders, trainers, participate consistently, become sounding boards for the project leaders/coordinators
- Advisors from relevant communities (e.g. local community, particular academic disciplines)

➤ Steps You Could Take:

- Integrate discussions of organizational structure with goal-setting exercises, to build buy-in and commitment from collaborators.
- Develop a list of collaborator roles early in the process and seek additional collaborators in order to fill key gaps. Agree on which roles are crucial, and which are simply desirable.


Heidi Ballard

5. Building a Process

THIS SECTION WILL HELP you design the technical aspects of your monitoring project, while balancing crucial goals. An important theme throughout this section is the feedback loops between scientific rigor, feasibility, and participation. These priorities can sometimes appear to be in tension, but through careful planning, they can be mutually reinforcing.

5.1 Questions and Hypotheses to Guide Monitoring Plan Design

Selection of indicators, sampling design, and methods should be guided by key questions and hypotheses. The decision to remove a dam is motivated by assumptions about the probable environmental and other outcomes. It is important to design a monitoring plan to confirm whether actual project outcomes match original assumptions.

For many projects (as with the Rattlesnake Creek example mentioned in text boxes throughout this document), citizen science monitoring may form one piece of a broader monitoring puzzle, with other professional monitoring groups involved. In such cases, planning citizen science monitoring can focus directly on practical questions about indicators, measures, and sampling schemes. In others, citizen science collaborators will need to start with the questions and hypotheses before jumping into the practical details of a monitoring plan.

5.2 Identifying Indicators and Measures

Indicators are quantitative or qualitative variables that are monitored periodically to reveal trends. One challenge in selecting cost-effective indicators is **refining broad-scale indicators so that they are locally appropriate, practical, and credible**. For example, the Open Rivers Fund has identified indicators of interest for evaluating dam removal projects generally, but applying these in a local context, and determining which indicators and measures are most amenable to a citizen science approach still requires some deliberation and planning at the local scale. Selection of indicators and measures for citizen science monitoring involves considerations of the local context, the nature of the dam removal project, and the capacities, motivations, and interests of potential project participants, and the high-level questions that motivate the dam removal and restoration process.

There are many programs throughout the United States and beyond that have conducted citizen science monitoring of watersheds. **The indicators, measures, and methods used in other projects may be applicable to your project's context.** For example, an extensive guide to stream barrier removal, developed for the Gulf of Maine,[15] provides an integrated framework and detailed methodology for measuring eight key parameters that are commonly of interest:

1. Cross-sectional stream vertical and horizontal distances
2. Longitudinal profile of stream (horizontal distances and elevation)
3. Stream surface grain size distribution
4. Photo-plot stations
5. Water quality
6. Riparian plant community structure
7. Macroinvertebrate community
8. Fish passage

The potential for citizen scientists to monitor these parameters will vary across sites based on a variety of considerations related to the specific context (See **Section 4.2**).

[15] Collins, M., K. Lucey, B. Lambert, J. Kachmar, J. Turek, E. Hutchins, T. Purinton, and D. Neils. 2007. *Stream Barrier Removal Monitoring Guide.* Vol. 85. Gulf of Maine Council on the Marine Environment.

Additional Considerations for Selecting Indicators

Local considerations will shape decision-making about appropriate indicators for monitoring, and more specifically, which indicators are amenable to citizen science monitoring. For example, you might **examine resources about local historical ecological conditions to identify indicators most sensitive to change**. Local archives, county records, and older members of the community are all places to look for background data when selecting indicators. **Choosing indicators with pre-existing baseline information can be useful in generating results, and integrating with other projects.**

Participatory Approaches to Selecting and Testing Indicators and Measures

Involving stakeholders in selection of indicators can have many benefits. Stakeholders may hold local knowledge, such as where certain species exist, unusual ecosystem phenomena, or existing cultural use patterns. All of these might be useful for selecting indicators that are practical, important, or essential to measure (See **Section 5.7**).

In cases where citizen science is integrated with other approaches, iterative testing with volunteers can be a crucial part of the process. Such testing may not affect the choice of indicators to monitor, but it can directly inform decisions about which indicators are best suited for citizen science (See **Box 3**).

➤ **Steps You Could Take:**

- Field test particular methods to gain a stronger understanding of their viability within the local context, in terms of training and oversight requirements, accessibility, and other considerations.
- Develop an inventory of existing data sources, and consult with experts (professional or amateur) that have been involved in these efforts.
- Hold a planning meeting focused specifically on acknowledging and discussing the role of local and traditional ecological knowledge. Some traditional ecological knowledge and management practices may not be appropriate to share with non-Tribal members, so it's important to discuss the extent to which Tribes may be involved in identifying specific indicators and metrics.

5.3 Sampling Schemes and Protocols

Protocols and sampling schemes should be appropriate for addressing the priority measures and indicators identified by collaborators. We offer here some resources and lessons from other citizen science efforts. In addition, monitoring project leaders should take into account assessments of context, local capacity, and other topics raised in the previous section.

Choosing Sampling Schemes and Methods

This is obviously a crucial technical piece of any citizen science project. **The aim is to develop feasible, valid, and trusted designs and methods that accommodate the skills and capacities of participants.** We recommend careful attention to:

- **Leveraging expertise.** While any participant can be included in the process of developing sampling schemes and methods, ensure that the team possesses the requisite specialized knowledge and experience.
- **Aligning with goals.** Sampling schemes and methods must be valid and credible, *and* match project goals in terms of the information needed, as well as the level of rigor and intended analytical approach.

- **Matching resources and capacity.** Designs and methods must comport with available resources, participant skills, and logistical and practical considerations.
- **Complementarity with related projects.** Integration with other monitoring projects will be smoother if standardized measures, common formats, comparable units, and uniform sampling schemes are developed at the outset.
- **Consider which variables or portions of the protocol should be done by professionals, and which by citizen science volunteers.** Once the monitoring project organizers determine the full suite of variables and frequency with which the data needs to be collected, these can be sorted and distributed amongst professional teams and citizen science teams according to expertise and equipment required, availability, safety, and logistics.

Look at similar projects in other locations, and importantly, seek outside help if your project lacks the expertise needed to balance all of the above issues. Regardless of whether outside experts are involved in developing sampling schemes and methods, external peer review of your work can be extremely valuable. Consider calling on technical panels, advisory groups, other specialists, or program managers to provide peer review.

Sampling Schemes

Sampling schemes are the plans for how, where, and when data will be collected. They depend upon the statistical design of your project, the phenomena you are monitoring, field conditions, and other practical considerations. **Sampling schemes are only effective if they match participant knowledge, skills, or training, and can be implemented consistently.** You will probably need to consider standardization of methods at multiple levels – within the project, and with other local monitoring efforts. Considerations within the project include determining how and where to locate plots or orient transects, defining criteria for what to sample, deciding precisely how to measure an attribute (e.g., should a water temperature reading occur in the middle of a stream, or near the shore?), or establishing how to identify an organism. While the planning process is very important, so too are the documentation and training based on those plans.

Deciding how to actually record the data depends on factors such as equipment availability, the skills and training of participants, ease of checking for errors or making corrections, and anticipated conditions. There are advantages and disadvantages to both manual and electronic data gathering. Data entry forms (manual or electronic) can reduce errors by guiding participants through the necessary steps providing helpful reminders. For example, collaborators might prefer a written data sheet, in order to cross-check and identify data entry errors committed during electronic entry. On the other hand, hard-copy sheets can be lost, while electronic systems generally include multiple layers of backup and security.

Involving Participants in Sampling Scheme Design

As mentioned elsewhere in this document, participants may bring a variety of skills and knowledge to a project, including local knowledge of seasonality and terrain, and technical expertise – all of which can be valuable to discussions of sampling schemes. The process of designing sampling protocols can also be an important learning experience, and reinforce the importance of consistency and accuracy in the data collection process. If participants know *why* they are collecting data in a particular way, they will be conscientious and thoughtful contributors rather than simply technicians.

➤ Steps You Could Take:

- Create a scientific advisory board to inform and review sampling schemes (among other issues), which could include not only local professional scientists and Tribal representatives but also other community stakeholders.
- Document the process of sampling scheme design as a compelling story that can be used during training.
- Create a timeline with development and pilot phases, and agreed-upon opportunities to tweak and improve the approach.
- When balancing coordinating/integrating citizen science and professional monitoring, create a shared document that outlines respective data collection activities, and a process for revisiting over time.

5.4 Data Quality and Credibility

Data quality is related to both rigor of participants' work (e.g., training, documentation, valid protocols), and the processes in place for reviewing or assessing the results of that work. **You can improve data quality and credibility through policies and practices that occur before, during, and after data collection.** Collaborators should design these elements with a clear understanding of the intended use of monitoring results and the levels of accuracy and precision that will satisfy those goals.

A lot has been written about the challenge of QA/QC (quality assurance[16] and quality control[17]), and the overall challenge of both collecting good data, and demonstrating to others that this is the case (credibility). See, for example, Environmental Protection Agency (EPA) resources and others listed in **Section 5.9**. Attention to this topic is valid and warranted, but it is worth keeping in mind that **there is ample evidence that citizen science *can* be of very high quality and scientific utility when good QA/QC practices are used**.

Box 3, drawn from a paper by Margaret Kosmala and co-authors,[18] offers some basic guiding questions on data quality, which can be helpful in thinking through project design. These questions can also help to evaluate and communicate about a project's approach to data quality.

The overall credibility of a project is based on more than simply the empirical validity and/or quality of its data and results. Stakeholders and data users also need to see compelling *evidence* of quality, in order to take the project seriously. **Clear and comprehensive communication, or even promotion, about policies and practices related to data quality can help with credibility, as can processes such as peer review, or a standing science advisory board with well-recognized experts.**

[16] Practices that increase data quality during the design and implementation of a project (e.g., training, validation of volunteer skills, expert oversight).
[17] Practices that increase the quality of scientific outcomes after data are gathered (e.g., automated outlier flagging).
[18] Kosmala, Margaret, Andrea Wiggins, Alexandra Swanson, and Brooke Simmons. 2016. "Assessing Data Quality in Citizen Science." *Frontiers in Ecology and the Environment 14*(10): 551–60.

Box 3. Questions to Consider when Evaluating Citizen Science Projects for Data Quality

The following questions are based on existing research and are meant to aid creators, evaluators, and users of citizen science data. Creators of citizen science projects may find them useful for project development and are encouraged to reference them in project methods.

Does the project use iterative design? Developing tools and protocols for a project that produces high-quality data requires iteration, using one or more rounds of pilot or beta testing to ensure a procedure that volunteers can perform successfully without confusion or systematic errors.

How easy or hard are the tasks? Easy tasks usually have high accuracy with minimal bias. Difficult or complex tasks may require additional effort on the part of the project managers to promote accuracy and account for bias. Such efforts include training, pre-tests, ongoing volunteer assessment, expert validation, classification replication, and application of statistical tools.

How systematic are the task procedures and data entry? High-quality data require straightforward and systematic capture, classification, and data entry procedures for the volunteers to follow. For online data entry, fields should enforce type (e.g., counts must be integers) and for categorical variables, users should select from lists rather than entering freeform text.

What equipment are participants using? Any equipment used for measurements should be standardized and calibrated across volunteers.

Does the project record relevant metadata? Metadata is data that describes other data and is used to organize, find, and interpret your data. Projects should record metadata that may influence volunteer data capture or collection. Such data might include environmental conditions (e.g., temperature, precipitation, time of day, etc.), equipment or device settings (e.g., mobile device operating system version), or characteristics of the volunteers themselves (e.g., level of education or training). If characteristics of volunteers are collected, project managers should seek approval from the relevant human subjects review board. Projects should also retain volunteer identifiers (anonymized if necessary). These metadata can be used to statistically model bias to increase valid inference from project data.

Is collection effort standardized or accounted for in data analysis? Standardized effort (capturing data at specified places, times, and/or durations of time) is ideal for ensuring unbiased data. However, many projects cannot standardize effort; for these projects, it is imperative that effort is reported by volunteers and is accounted for in statistical models and analysis.

Does the project assess data quality by appropriate comparison with professionals? In reporting results, citizen science projects should compare volunteer data accuracy with that of professionals. Importantly, between-professionals accuracy should also be assessed so that variation due to individuals is not confused with variation due to volunteer-professional differences.

Are the data appropriate for the project's management objectives or research questions? In particular, data should be of sufficient quantity and should cover timescales and geographic extents commensurate with project objectives. Data may also need to be timely, depending on the application.

Are good data management practices used? Citizen science project managers should implement best practices in data management (See **Section 5.5**). In particular, data should be stored securely in a consistent and concise format that is easy to interpret and use and is made accessible to data users.

5.5 Managing Data

Without planning for data management, projects may become nearly useless, with valuable information existing only in piles of papers or digital spreadsheets that no one can access for analysis. **Data management is crucial for linking the efforts of project participants with the overall project objectives, and the outcomes that motivate participation in the first place.** Without careful planning and appropriate investment in data management, participants' time and effort may be wasted. On the flip side, data collection must be designed to fit well with data management capacity – superfluous data can overwhelm a project's ability to manage and use data effectively. For a small project with limited capacity and experience with managing scientific data, this topic can be daunting. However, there are many resources to guide your thinking, and tools that can draw your data into a larger system that addresses many of the following issues (See **Section 5.9** for resources and tools).

A report issued by Data Observation Network for Earth (DataONE) in 2013[19] provides a helpful overview of the data management life cycle. Box 4, drawn from that report with edits for brevity, describes each step of the data management life cycle. The cycle applies to many different kinds of science and monitoring, not just citizen science. The authors describe particular considerations and challenges that may arise for data management in citizen science, including:

- Difficulty of assessing the abilities of data collectors (especially with anonymous or highly distributed participants)
- Lack of experience with data management on the project team
- Vague or nonexistent policies for access, confidentiality, security, and intellectual property
- Data collection poorly aligned with data management capacity (e.g., an overly ambitious data collection plan can drive up data management costs, and care is needed to reduce superfluous data collection)
- Inadequate metadata – the why, who, what, when, where, and how of the project
- Tensions between privacy concerns of participants, the need for detailed metadata, and desire to give appropriate credit to participants
- Bringing participants into the data management life cycle in meaningful ways can be difficult, if there is low familiarity and comfort

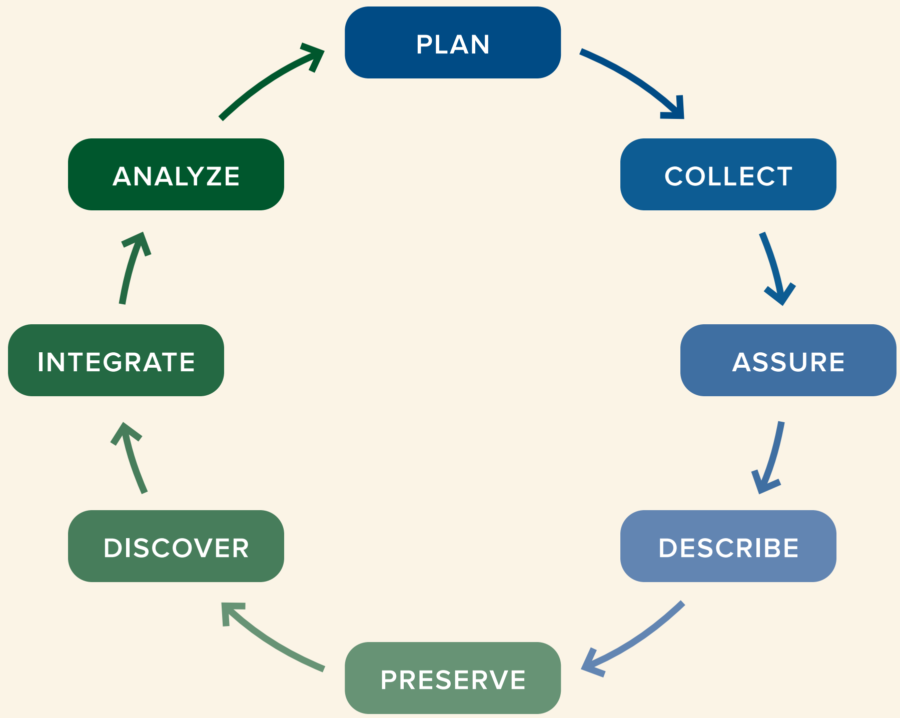
Any individual project must consider and plan for data management, because of the interplay between sampling protocols and the data management life cycle. This is true even if the technical systems that support data management are not under the purview of the project team.

➤ Steps You Could Take:

- Investigate data management solutions that others are using within the local region, or the state. Universities, in particular, may be willing collaborators.
- Integrate your methods and protocol development with your data management planning, in order to avoid inefficiencies and over-investments in both.

[19] Wiggins, Andrea, Rick Bonney, Eric Graham, Sandra Henderson, Steve Kelling, Gretchen LeBuhn, Richard Littauer, et al. 2013. *Data Management Guide for Public Participation in Scientific Research.* Albuquerque, NM: DataOne.

Box 4. The Data Management Life Cycle



1. Plan
Map out processes and resources for the entire data life cycle. Start with project goals (desired outputs, outcomes, and impacts) and work backwards to build a data management plan, supporting data policies, and sustainability plans.

2. Collect
Determine the best way to get information from participants into a usable data file. The end result of this decision process is a data model that describes the way the data are structured.

3. Assure
Employ QA/QC procedures that enhance the quality of data. Identify techniques to address potential errors.

4. Describe
Document data by describing the why, who, what, when, where, and how. Metadata are key to data sharing an reuse, and many tools such as software and standards can help.

5. Preserve
Plan to preserve data in the short-term to minimize accidental losses, and in the long-term for future use. Decide what data to preserve, where to preserve it, and what accompanying documentation is needed.

6. Discover
Identify complementary data sets that can add value to project data. This might include registering the project on a directory, depositing data in an open repository, and adding data descriptions to metadata clearinghouses.

7. Integrate
Combine project data with other sources of data to enable new analyses and investigation. Success depends on employing good data management practices throughout the life cycle.

8. Analyze
Use data for analyses that meet project goals, or serve needs of other stakeholders.

5.6 Documenting the Project[20]

Extensively documenting a project is important for building credibility, and ensuring sustainability. It can also help with integration across similar projects. Carefully documenting your project can be helpful in many different ways, including:

- Establishing credibility
- Improving communication
- Supporting high-quality data and results
- Creating institutional memory for future reference
- Protecting against liability claims or litigation
- Providing material for periodic review and evaluation
- Providing reference materials for funding applications
- Providing reference material for outreach or education
- Documenting processes such as decision-making or communication norms
- Documenting protocols such as how to conduct meetings or field sampling procedures
- Documenting safety, emergency, or quality assurance plans

Effective documentation can save time with issues in the above list, but it also requires work, and a clear understanding of who is responsible for various components. Depending on the scale of the effort (in terms of time, people, organizational complexity), and a variety of contextual factors such as political visibility, you may take a formal or informal approach to documentation. It may be that informal agreements and shared meeting notes are enough in some cases, whereas in others far more elaborate systems (e.g. websites) may be required.

Important project documentation might include:

- Contact information for participants
- Meeting notes, including decisions and action items
- Narrative descriptions of the project plan
- Signed release forms
- Contractual agreements
- Recruitment materials
- Evaluation forms
- Training manuals
- Sampling scheme
- Quality assurance and quality control plans
- Reference materials
- Reports of results
- Published articles
- Databases
- Data management plans
- Photographs or videos

[20] The lists presented in this section are adapted (and updated) from those that appear in a similar section of Pils et al. 2006.

Whatever the form or purpose, documentation should cover the essential categories of who, what, when, where, and how. It is also important to decide in advance who manages project documentation, distributes it, and keeps it up to date. Making this information available to all participants helps build trust. However, a project may also involve sensitive or proprietary information and collaborators need to decide how it will be handled. For example, traditional ecological knowledge held by a Tribal group might need to be handled separately from other data.

➤ Steps You Could Take:

- Communication systems such as Slack or listservs, can be useful for creating records of decision-making about, and discussion of policies and procedures.
- Cloud storage systems such as Box, Dropbox, or Google Drive can provide group access to essential information.
- A variety of toolkits and resource collections provide examples that could help in developing some of the documents listed above (See **Section 5.9**).

5.7 Collaborative Design

In some cases, the core group of collaborators on a project may want to involve a broader community of participants in the project design to tap into a variety of skills and expertise – including local and traditional ecological knowledge – that can benefit the project.

Participants can play a productive role in any phase of designing a citizen science monitoring project. Individuals without formal education in a topic (e.g., aquatic biology, hydrology) can still contribute to a complex project design if they have unique and valuable knowledge, information, or perspectives. For instance, local participants may be familiar with locations, the local watershed ecosystem, specific organisms, or practical considerations that managers, specialists, or scientists do not. **Local knowledge can be useful in identifying appropriate indicators, developing efficient sampling schemes, avoiding mistakes, planning logistics, efficiently using time and resources, and maintaining safety.** As noted previously in this document, be very aware and respectful of the sensitivities that may exist for Tribal members around sharing some aspects of traditional ecological knowledge.

In some cases, volunteers can provide technical expertise useful in planning sampling protocols, fieldwork procedures, data analysis and management, record keeping, equipment care, and other aspects of the project design and management. For instance, perhaps a retired geomorphologist or sediment specialist volunteers can assist the project, thus eliminating the need for outside technical expertise on that topic. Other participants might bring leadership experience. **The greater the number of participants in a project, the more likely there will be a need for some participants to assume extra responsibilities as leaders.**

Participants may also provide valuable input as reviewers of the project plan, particularly on issues such as feasibility and suitability of the approach.

5.8 Recruiting and Supporting Participants

Getting participants involved in monitoring includes recruitment, selection, ongoing support, recognition, and retention. These activities all shape participation in a monitoring project. You also need to define participant roles, and think about how to foster leadership among volunteers.

Who can and should participate? "Participants" refers to anyone actively involved in a citizen science monitoring project. While some people will choose to be actively involved in a project, others may be interested in the project but feel left out. Look for strategies to expand inclusion and equity of access, regardless of financial status, available resources, or social and political capital. Examining participant incentives early in the project's development can help with this (See **Section 4.1**). Similarly, honoring and rewarding participants throughout the project can ensure that the project is enjoyable, sustainable, and productive (See **Section 7.4**).

How will you encourage participation? Active recruitment is often necessary, especially when you are focused on equitable representation of stakeholder groups. Consider announcements in local newspapers, email lists kept by collaborating organizations, and word of mouth starting with existing project participants, or calls to targeted organizations. Consider hosting outreach activities to underrepresented groups, skeptical citizens, and other hard-to-reach groups.

The structure of a project has important implications for recruitment and retention. Some projects by their nature may be open to broad participation, and require no training or oversight. For example, participants may simply download an app, which guides them in contributing needed data in the form of photographs or other input. Such projects can attract broad participation at relatively low cost. But garnering participation still requires significant outreach, and careful attention to reaching a broad audience. And, there is likely to be significant attrition by volunteers who participate only once out of a passing interest.

Other projects might have a smaller pool of potential participants due to training, oversight, requisite skills, or physical requirements. For example, a project might involve teams of volunteers implementing protocols at a specific time and place, under the supervision of paid staff. Such projects involve a relatively high investment in each volunteer, and so recruitment efforts might be targeted directly at groups with related skills that are likely to participate, rather than a broad public audience.

Projects with schools have a built-in attrition rate as students participating through a class will naturally move on at the end of the term or school year. In such cases, collaborators will want to maintain strong relationships with teachers in order to sustain participation from year to year. As a result, each year the project must accommodate a new crop of participants in need of training.

How will you select participants? As mentioned above, some projects may be open to everyone, while others may have specific requirements. Some projects may even need to turn interested participants away, if capacity for volunteer support is limited. Participants can make or break citizen science projects, so you need a careful, thoughtful approach to recruitment and selection. Considerations include the minimum skill and physical requirements for fieldwork, and willingness to make long-term commitments to a project. Some people who could bring valuable skills to a project may need some support to help them participate. Examples include financial compensation, transportation, childcare, permission from job supervisors, or accommodations for physical disabilities.

Identifying "Win-Win" Partnerships

Stakeholder groups with a direct interest in project outcomes are an obvious place to focus recruitment efforts. There may also be "win-win" collaboration opportunities when other organizations' goals align with project activities. In-school and out-of-school education programs for youth and adults may wish to partner. For example, a high school environmental science teacher, or a local Master Naturalist instructor, may wish to involve students in the monitoring activity. Boy Scout or Girl Scout troops may be able to earn badges for participation, or recreational anglers might be able to collect data while fishing, which helps with their own record-keeping. Below we focus on a few specific potential partnerships that are relatively common in citizen science monitoring.

Education (in-school and out-of-school)

There are many examples of citizen science activities in formal and informal education settings, for learners ranging from elementary school age through retirees. Educator partnerships can confer a range of individual and community benefits, in addition to generating needed data, but developing a plan that balances these goals effectively requires care. In some cases, professional development support for teachers can help in moving the activity from a fun add-on (requiring lots of extra effort) to something that meets core needs in the curriculum. Start early in planning with educators, in order to keep expectations clear and consistent throughout the project, and build strong relationships.[21]

Tribal Groups

Tribal groups are important potential collaborators for any monitoring project for at least two key reasons:

1. Most Tribal groups have, or should have, legal rights as sovereign nations or other legal rights based on historical use of the land and natural resources that are being monitored; and
2. Many Tribal members have traditional ecological knowledge (TEK) with which the Tribe has managed and monitored those natural resources for centuries, that they may choose to contribute to the collaborative monitoring project.

With respect to the former, Tribes may be federally recognized; recognized by state government; have formal reservations, rancherias, or other land set aside; or have Usual and Accustomed Areas that are designated public lands allowed for natural resource use and extraction. These are just a few of many possible arrangements. Regarding the latter, different Tribal members may be able to offer different types and forms of TEK. The integration of TEK and Western scientific knowledge can lead to an emergent whole that is greater than the sum of its parts as it relates to monitoring and understanding the watershed. However, care must be taken to avoid co-optation and ensure Indigenous control over how knowledge is mobilized and used. It is crucial to work with the Tribal group to determine what TEK is sharable, and when, how, and who is responsible for sharing it.

Local Tribal groups near a project site may be interested in community-based citizen science activities that might contribute to better understanding the effects of dam removal and any subsequent management regulations around use and conservation. Some Tribes may have their own monitoring programs that could be integrated with the citizen science project. A representative from a Tribe could ideally be a member of the core organizing committee for the citizen science project, linking the project to local schools or youth programs, or to Tribal members who are resource users. When possible, Tribal members may contribute a wealth of knowledge and historical context for the monitoring project, and these historical accounts could become part of the database of the project, as well as help shape the metrics for the protocol. In all cases, the citizen science project leaders need to respect that Tribal groups are sovereign entities and may have unique constraints and interests in the project.

[21] A variety of resources, including key practices and case studies, can be found at yccs.ucdavis.edu.

Recreational Users

Hunters, anglers, and other recreational users have a stake in natural resource management. Many spend considerable time in places where monitoring may take place, and bring a unique understanding of the watershed from years on the ground. There are examples of programs that specifically enroll anglers in monitoring, in processes that range from more informal to highly structured. Researchers in Los Angeles organized an iNaturalist project focused on cataloging the diversity of fish species in the LA River, to inform river health assessments[JT1] [RM2]. The California Collaborative Fisheries Research Project invites recreational anglers to participate in fishing cruises, in which catch and release data are recorded along predetermined transects, with careful oversight by scientists. More than thirty recreational anglers participated in a fish tagging effort along Rattlesnake Creek and other Clark Fork River tributaries near Missoula, MT, with many more contributing to the voluntary reporting of catch data in the ensuing two years, helping to track the movement of adult wild trout through the region. Each of these examples leverages the physical presence of participants and their fishing skills in monitoring.

Participant Roles

Participation is more than just data collection. Participants may provide expertise, convene and lead meetings, act as observers, take notes at meetings, collect data, analyze data, develop reports, and conduct outreach. Rotating roles and responsibilities among participants develop and broaden expertise, promote sharing of perspectives across the project, and help participants rely on one another for help.

Participants may also become leaders or champions for the project. Promote leadership by providing rewards when volunteers step up their involvement in significant ways. Incentives might include compensation, letters of recommendation, school credit for students, and additional training and responsibilities. Take care not to make participants feel less valued when others step into leadership roles. Leaders might take on, for example: recruiting, training and mentoring new participants, coordinating participant monitoring schedules, or helping to assure quality control in data collection and management.

5.9 Tools and Resources for Initiating Projects

Project Platforms

A variety of platforms provide software and other tools for citizen science project organizers. We describe several of the most prominent platforms in **Appendix A**. If there is a good fit, these tools can be enormously helpful, and save time and money. We recommend developing a basic familiarity with these options as part of the planning process, especially once collaborators have begun to focus on targeted indicators and associated methods. The platforms described in **Appendix A** are in a constant state of change, as developers improve and expand functionality, so visit their websites for additional information.

Drawing on Existing Citizen Science Resources and Projects

There is a wealth of resources, protocols, and guidance – ranging from technical, to programmatic, to philosophical – from other citizen science projects, including many focused on watershed monitoring. Many projects have published guides for their own volunteers, which can be useful to inform new projects focused on similar issues. Some have conducted and published the results of evaluations, offering lessons learned. Others have gone even further, and published generalized how-to guides for use by other projects outside of their specific context. In **Appendix B**, we highlight some examples of organizations that provide extensive technical and programmatic resources on citizen science monitoring which might be of use.

Tools and Guides for Specific Indicators and Methods

Here are some examples of existing resources and off-the-shelf tools for groups that are interested in starting their own citizen science monitoring program:

The Gulf of Maine Council on the Marine Environment developed a **Stream Barrier Removal Monitoring Guide** that describes eight high priority parameters for monitoring (See **Section 5.2**).

The U.S. Department of Agriculture's National Institute of Food and Agriculture **Volunteer Water Quality Monitoring National Resources Project** has published a **Guide for Growing Volunteer Monitoring Programs**[22], addressing how groups can start their own citizen monitoring program. While many of the resources in the guide are locally specific, they provide good examples of the kinds of parameters that monitoring project organizers in other watersheds should be considering. There are also useful resources, such as a list of equipment suppliers from across the U.S. and a matrix of monitoring activities that links a variety of structural considerations (e.g., frequency of activity, learning outcomes) for each type of monitoring parameter.

Monitoring Specific Parameters

Below we list some resources on specific parameters that may be relevant to dam removal and river restoration projects. While it may not be possible to adapt these to the specific context of a new project, each resource could serve as a useful guide.

- Turbidity/transparency/clarity:
  - University of Wisconsin Extension's WAV program has a **resources** section.[23]
  - The Virginia Department of Environmental Quality's website has a manual on Citizen Water Quality Monitoring (See **Section 4, Chapter 12**[24]).
- Fish counts:
  - East Coast environmental organizations monitor river herring. See the Ipswich River Watershed Association's **2016 Results report**,[25] or the Lowell Parks & Conservation Trust **training presentation**.[26] Counts are done via volunteer observations and from video camera footage.
  - West Coast environmental organizations monitor salmon and trout. Monitoring includes live fish, carcasses, and redds (nests of salmon eggs). Check out the Community Salmon Investigations: Highline, a King County, Washington **2017 training presentation**.[27]

[22] web.uri.edu/watershedwatch/guide-for-growing-extension-volunteer-monitoring-programs
[23] watermonitoring.uwex.edu/wav/monitoring/transparency.html
[24] deq.virginia.gov/Portals/0/DEQ/Water/WaterQualityMonitoring/CitizenMonitoring/Physical_Measures.pdf
[25] ipswichriver.org/wp-content/uploads/2012/11/2016-Ipswich-herring-count-report.pdf
[26] lowelllandtrust.org/what-we-do/concord-river-programs/anadromous-fish-restoration-program
[27] your.kingcounty.gov/dnrp/library/water-and-land/watersheds/central-puget-sound/miller-walker-creeks/monitoring/CSI_MEG/Training%20Presentation%202017.pdf

- Macroinvertebrate surveys:
  - The University of Wisconsin Extension's WAV program has **resources on monitoring biotic index**.[28]

- Water temperature:
  - See the University of Wisconsin Extension Water Action Volunteer site for **resources**.[29]

- Physical changes (geomorphology):
  - Examples include habitat assessment, sedimentation (bed condition surveys, aka 'pebble counts'; longitudinal/ Thalweg profiles, cross-sections of stream channels, road surveys).
  - Georgia's Department of Natural Resources produced a manual that describes what stream habitat parameters to monitor, and how to assess each parameter in their **Visual Stream Survey manual**.[30]
  - The Monterey Bay Sanctuary Citizen Network has a manual that describes sedimentation monitoring. See **Citizen Monitoring Guide**.[31]

Locally-based Projects

In any watershed, there may be ongoing or existing volunteer monitoring projects that could be leveraged.

1. Some groups may already be collecting data that could be useful for evaluating the effects of dam removal.
2. Organizers of existing projects may be open to adding new activities to their work, especially simple ones requiring minimal training, equipment, or time. For example, an existing water quality monitoring project may be open to bringing in a fish count activity, or snapping a photo from a "picture post" installation.[32]
3. In some cases, the network of volunteers can be leveraged. There are often "super volunteers" who are looking for more opportunities to get involved, and organizers of other projects will be able to connect those people with your new project.
4. Another important resource is the experience of other citizen science project managers in the local area. These individuals will have important local knowledge about challenges and opportunities of working with local volunteers, connecting with various communities, and navigating other aspects of the local environment, terrain, culture, and politics.

[28] watermonitoring.uwex.edu/wav/monitoring/biotic.html
[29] wateractionvolunteers.org
[30] adoptastream.georgia.gov/sites/adoptastream.georgia.gov/files/related_files/document/Visual.pdf
[31] montereybay.noaa.gov/monitoringnetwork/protocols.html
[32] Picture posts encourage photographs of the same location, and at a predetermined vantage point, by passers by, so that investigators can investigate phenomena over time.

Box 6. Collaborative Monitoring on Rattlesnake Creek: Developing a Monitoring Plan

TU coordinated with partners to develop a comprehensive plan for monitoring the impacts of the Rattlesnake Creek Dam removal. TU developed a series of specific, measurable, attainable, realistic, and time-bound (SMART) monitoring goals and associated questions. Through iterative meetings and communications, collaborating partners decided on WEN assuming responsibility over several field methods that would answer key questions about aquatic habitat parameters. However, WEN would need to evolve its protocols and train volunteers accordingly, in order to fulfill this new role.

WEN developed rigorous citizen science protocols to generate accurate data necessary to answer their monitoring questions and achieve monitoring goals. These new “level 2” protocols required more extensive training on the part of volunteers. Developing WEN’s “level 2” program was an iterative process of revising data collection protocols and pilot testing them with volunteers, to arrive at a version that was feasible for volunteers and that would provide the necessary data at an appropriate level of quality. For instance, volunteers are now measuring channel cross-sections and longitudinal profiles from fixed points so as to minimize bias from human error in calculating distances.

Ryan Meyer

6. On-the-Ground Implementation

PREVIOUS SECTIONS were primarily concerned with planning the *what*, *who*, and *how* of a citizen science monitoring project. This section focuses on what that will look like when it starts to come together on the ground. Citizen science monitoring raises many practical and logistical questions, from training participants, to the nuts and bolts of field activities, to participant safety. These questions are important in any monitoring project, but they become particularly important in a community-based citizen science project, when questions about data quality are often raised. In fact, citizen science projects are often treated with more skepticism and more scrutiny than monitoring projects that are undertaken solely by science professionals. Organizers can use the key considerations below to ensure a high-quality citizen science project.

6.1 Training Participants[33]

Some type of training, whether online or in-person, is required for most citizen science projects. If training is needed, **think creatively about how to get participants trained, and what goals you can accomplish in doing so**. Trainings can provide instruction for proper data collection and also facilitate communication between project leaders and participants. They may be one of the first chances for project leaders to reach out and engage participants in the scientific, conservation, and educational goals of the program. In other words, training is a chance to both impart needed skills and knowledge for the specific monitoring activity, as well as share information related to the overall context – the "why" of the project.

Training is also an important opportunity to establish and/or reinforce the culture of the project, and build productive relationships with participants. A well-organized training program shows volunteers that you value their time, and care about the quality of their work, and a well-documented training can build credibility among potential data users. In turn, trainings are often the first (and sometimes only) chance that participants have to communicate their interests and expectations to project leaders, which can help leaders make sure the project is meaningful for participants as well as effective. Therefore, careful planning, implementation, and evaluation of citizen science trainings can accomplish many of the goals of a citizen science project.

Things to focus on when designing a training:

- What can we learn from participants (e.g., feedback on our project; local knowledge)?
- What specific skills and knowledge do participants need to learn in order to participate?
- How can we best document training to show scientific credibility of our project?
- How can training help us to build community and establish positive, durable relationships?
- What learning goals do we have outside of the specific monitoring activities?

Setting Goals

Establishing the training goals and desired results is an important first step toward planning a successful training. Consider your audience of participants, the anticipated timeframe for their involvement (e.g., one day or ongoing), and the substantive aspects of their monitoring. In addition to accurate data collection, consider other goals you may have. For example, will participants need to be involved in analyzing and classifying data, or disseminating conclusions? Do participants need to understand why the research questions of the project are important and how they are contributing? Will participants play a teaching role with members of the public or other specific audiences?

[33] This section draws extensively on a book chapter co-written by Heidi Ballard and Emily Harris, which appears in: Lepczyk, Chris; Owen Boyle and Tim Vargo. *Citizen Science for Ecology and Conservation: A Practitioner's Guide*. Berkeley, CA: University of California Press.

Goal: Quality Control/Quality Assurance

Training is one of the key methods for quality control and quality assurance in citizen science programs, and lays the foundation for ongoing communication between the project's leaders and participants. Trainings can both instruct participants in the correct data collection methods and provide feedback on performance of the protocols. Importantly, **thoughtful and thorough training also helps to ensure that participants understand *why* they will be collecting data or accomplishing other parts of the project in a particular way.** With background knowledge about methods and overall goals, they will be conscientious and thoughtful contributors rather than simply technicians. And, they may be less likely to take shortcuts or deviate from protocols out of convenience.

Goal: Science and Environmental Learning

Collaborators often make a range of assumptions about what their participants will learn through participating in their project, such as a better understanding of the scientific process, a better connection to their local places and environment, and/or a stronger environmental stewardship or conservation ethic. For many projects, the training sessions provide the best and last chance for project leaders to describe the learning goals they have for their participants. Many facilitators assume that participants will learn through exposure to the larger conceptual or behavioral connections between the skills and tasks of the project and the bigger picture of science and the environment, but this is usually not enough. By providing the background, context, history, and bigger picture for the project during the trainings, you can target the key things you hope your participants will learn. It's also crucial to allow participants to *practice* the actual skills and tasks that will be part of the data collection process, not just read, listen to, or watch a demonstration.

In order for people to take up and apply the larger goals of a citizen science project, the trainings need to recognize participant motivations in addition to project goals for gathering high-quality data. Taking the time at the start of a training to find out what motivated people to come in the first place, and what they hope to get out of it, is an essential part of the process. This can be done either through discussion or a more formal pre-training questionnaire that facilitators can use to guide their approach to the training.

Types of Training

In-Person vs Online

Projects that involve field-based monitoring with specialized methods concentrated in a localized geographic area typically involve in-person training, with some combination of classroom and field-based activities. This approach provides the opportunity for hands-on work supervised and supported by leaders, and for immediate feedback. Such sessions can build rapport, and allow leaders to individualize their support of participants.

Field-based sessions, ideally in the watershed where volunteers will be conducting monitoring, provide extremely valuable hands-on experience and practice. But classroom sessions can eliminate some of the uncertainty. For example, if species identification is central to the activity, having a set of clear photos displayed on a big screen may be more effective than a field session where the species in question fail to make an appearance. Indoor trainings should include hands-on activities as much as possible, such as providing specimens to practice identification, or using special tools like calipers and hand lenses, so that participants engage with the materials they will be working with in the field.

The drawbacks of in-person training include the logistics of getting everyone together, and the resources required to support growing numbers of volunteers. Print or online resources supplement or replace in-person training programs.

Online training can't fully replace *in-situ* practice and interactions, but it also doesn't need to be an entirely passive learning experience for volunteers. A live webinar can support discussion and an opportunity to ask questions. Online courses could involve assignments or tests that help both participants and leaders assess progress. There may also be cases where protocols align with larger-scale efforts at the state, national, or even global levels (e.g., water quality, phenology). In such cases, collaborators may take advantage of existing training protocols available online, rather than developing their own.

Both online and in-person approaches have their challenges. Timing and location may prevent potential volunteers from attending in-person. Access and facility with computers may prevent some from participating online. Some of these issues might be solvable through careful attention to the needs of volunteers. For example, if a participant is not comfortable with an online form, paper copies could be provided.

Initiation vs Refresher

Projects often require training before a participant begins monitoring in the field as well as follow-up training from time to time. During the initiation/orientation training, the participant learns about the project goals, the content and background of the project, the tasks they will be doing, including protocols they will use, and data entry in the field or when they return home to a computer. Often these include an element of recruitment and encouraging participation, since this may be the time when participants decide if they are going to sign up and become ongoing participants.

Once a monitoring project is up and running, it may be important to provide ongoing trainings or refresher sessions for existing participants. This helps participants keep their skills sharp, and can provide a sense of community and social dimension to the project. Longer-term projects with long time spans between field seasons (e.g., once-a-year fish counts or seasonal projects) should consider providing these refresher trainings.

Planning Trainings

Once you have established training session goals, you can begin to design it. Training should include a mechanism for both participants and organizers to receive feedback. By the end of the training, how will you know that the participants understand and can do what is expected? Asking participants to perform a task similar to what they will later be expected to do on their own can determine whether you have met your goals. If, for example, participants need to be able to correctly identify an organism with 80% accuracy while monitoring with a partner, an appropriate performance task would be to have participants spend 15 minutes at the end of the training working in pairs to identify 20 organisms.

An example of a training plan designed around clear learning goals is provided in **Appendix C**.

Some additional recommendations for designing a training include:

- Balance presentation, hands-on practice, individual, and group-based activities.
- Incorporate audience participation in presentations.
- Divide complex activities into simpler, smaller tasks that can be practiced and improved, and then integrated.
- For complex tasks, consider a “gradual release of responsibility,” whereby the facilitator slowly shifts from leader/instructor, to a more advisory role as participants take ownership of content and activities.
- Help people feel comfortable and motivated to learn by choosing an appropriate space, providing food and other amenities, and considering issues of access and safety.
- Test all tools and gear in advance.
- Clearly communicate expectations and requirements in advance.

6.2 Safety and Emergency Planning

Participants should be informed about potential hazards associated with their work, and any plans in place for dealing with them and other potential emergencies. Training sessions should cover these issues.

Safety Plans

These plans outline the policies and practices aimed at preventing harm, injury, or death to all involved in the monitoring project. Areas to consider include accessing and negotiating difficult terrain and monitoring sites, extreme weather, risk of harm from plants and wildlife, treatment of allergies, essential and recommended safety equipment and use, appropriate clothing, safety procedures, First Aid/CPR, and emergency procedures.

Emergency Plans

These help staff and volunteers manage accidents and emergencies: how to help keep injuries minimal, facilitate the arrival of emergency responders, important considerations to cover during the crisis, and learning from past emergencies.

Example safety and emergency plans can be found in many different resources from existing monitoring projects. For example, follow the links in **Appendix D**.

Working in and around rivers raises specific safety issues, which need to be addressed by collaborators and others overseeing citizen science monitoring. Some common recommendations include:

- **Site hazards.** River sites are often rough (stream beds are rocky, water flows fast and/or is deep), which comes with increased likelihood of slipping and falling, injury, or even drowning. Volunteers are advised to monitor in pairs or groups. Volunteer safety is most important; do not monitor if you do not feel safe.
- **Weather.** Volunteers should dress appropriately for local conditions, especially when local stream and ambient air temperatures are cold or hot. Avoid monitoring when there is thunder/lightning or just after severe rainstorms, or during heat waves.
- **Clothing/accessories.** Volunteers should wear appropriate clothing, such as hip waders/boots, sunglasses, use a walking pole, and carry a life jacket, first aid kit, an extra set of dry clothing, and shoes. Secure valuables such as cell phones and car keys in waterproof pouches, and wear blaze orange vests during hunting season.
- **Hazardous plants and wildlife.** Training should include information about how to identify and avoid hazardous plants and wildlife such as poison ivy/oak and stinging/biting insects.
- **Site access.** Clearly describe where and when volunteers can access monitoring sites. If monitoring on private property, provide clear protocols for accessing sites.
- **Equipment safety.** Follow all appropriate safety procedures when using equipment such as rebars or sharp fish gutting knives.

6.3 Field Activities

The implementation plan should carefully describe the steps involved in successful fieldwork and the systems in place to support those efforts.

How will you schedule field activities and communicate that information?

Some projects may have a very straightforward, regular schedule for field activities, but others may depend on a variety of external factors such as weather, river conditions, or other events that affect safe access to, or condition of, the site, or availability of participants. It is important to develop and constantly utilize processes for determining and communicating when field activities are initiated or cancelled (e.g., through email, a website, or other communication tool.)

How many people are needed, and how will they reach the field site?

Some activities are individual and independent, and others require teams. Assembling a team requires bringing together the right number of participants with the right mix of skills and knowledge to accomplish the intended fieldwork. These include data measurement and recording, but might also include photography and other documentation, driving vehicles, and managing snacks and meals.

How long will field activities last?

For projects lasting many hours, or throughout the day, consider logistics such as bathroom access, appropriate rest and meals, or establishing shifts for participants.

What supporting activities will be necessary before and after the fieldwork?

Support activities might include prepping equipment and data sheets, or preparing meals, before the activity. Clean-up, data entry, lab work, and reporting are examples of post-fieldwork activities. All of these tasks might be less appealing to volunteers who enjoy being out in the field, but they are often crucial to success, from the standpoint of data quality, volunteer experience, and safety.

Box 7. Collaborative Monitoring on Rattlesnake Creek: Working with Volunteers in the Field

New volunteers start out collecting Level 1 data – data used as part of regular Stream Team programs – alongside WEN staff, who host a series of orientations to recruit volunteers from both the University of Montana student body and the broader Missoula community. With Level 2 data collection requiring more complex protocols to answer specific questions, WEN has identified volunteers who have embraced the higher level of rigor and commitment. Level 2 volunteers have taken on informal leadership roles, helping train and mentor other volunteers in properly using data collection protocols while in the field.

Intentional conversations in the field serve to deepen learning opportunities amongst participants, helping foster greater understanding of why the data they are collecting matter. Staff at WEN and TU have noticed that volunteers who understand how their work fits into the larger system context are more invested in the program and committed to collecting accurate data.


Jason Jaacks

7. Follow-through and Sustainability of the Monitoring Project

WHILE THIS SECTION appears at the end of the manual, these topics should not be an afterthought. The issues addressed here are crucial to project success: if your project does not have, for example, the ability to analyze and report results, or a strong sense of how those results will be used, it will be difficult to maintain buy-in among collaborators and participants.

7.1 Analyzing Data and Interpreting Results

All participants, having invested time and effort in the project, have a stake in the analysis and reporting of the data they have collected. Data analysis helps to meet certain evaluation objectives, but it can also support retention of volunteers, and learning outcomes of the project. Thinking through data analysis plans in advance can also help to inform methods, protocols, and data quality plans.

Planning Data Analysis Early

Planning for data analysis at the early stages of the project will ensure that sampling methods and protocols are well-aligned with the ultimate use of the data, and that the right expertise (e.g., statisticians, scientists from relevant disciplines) and tools (e.g., analysis software) are available. **If needed, collaborators should make sure that resources are available to bring in outside experts at the appropriate time.** Not all data may require sophisticated analysis. For example, presence/absence protocols focused on range extensions of targeted species, or early detection of invasive species, are typically simple but compelling analysis and reporting.

Advance planning can also help to avoid biases that arise from post-hoc exploration of data, in search of a relationship. Such “data mining” runs the risk of identifying correlations that, in reality, are not meaningful.

In some cases, where there is tight coordination with other monitoring efforts, data analysis might not be needed within the citizen science project. In such cases, it is still a good idea to communicate clearly to participants about how that process works, and set their expectations for when and how they will have access to the results of their work.

Involving Participants in Data Analysis and Interpretation

Data analysis is often seen as highly technical and beyond the reach of most project participants. However, **bringing participants into the process can be valuable, both for improving analysis and interpretation, and for building community and hearing feedback**. Some programs, such as the California Collaborative Fisheries Research Program, hold celebratory gatherings that include presentation of preliminary results, and a chance for participants to comment on and help with the interpretation of those results. They may also help to shape analytical questions and hypotheses for subsequent phases of research and monitoring. Such “data parties” are also becoming common in the field of participatory evaluation.

➤ Steps You Could Take:

- To counter the idea that data analysis seems mysterious and burdensome, use “data parties” to help participants see the big picture for the data they collected.
- Provide graphs, tables, maps, and other visual representations of data and ask for participants’ impressions and interpretations of what they see as interesting, and how these compare with their own experiences of the landscape.
- Provide food whenever people are helping to analyze and interpret data, and make it a social experience.

7.2 Disseminating Results

Similar to data analysis, reporting results of the monitoring project can be useful for engaging participants, in addition to informing the key issues that motivate the monitoring project. Citizen science participants can be a key audience for the results, and they also help to present results to outside audiences. Thinking ahead about dissemination can help you anticipate conflicts that might arise, and opportunities for the monitoring results to make a meaningful impact. Here we briefly address several important considerations associated with the reporting process.

Tailor Your Reporting to the Needs of Key Audiences

Both the format and the timing of reporting should be based on what is most likely to be useful. The needs of a local land manager will differ from those of an elected politician, or a university scientist. Above all, **remember that project participants want to know how their data are being used** Consider products and events that deliver the results to your participants, in addition to others who might use them. Formats to consider include:

- PDF report delivered electronically and hard copy. Such static products can serve as a milestone or timestamp in the course of a project. It may be informal and simple, or carefully designed and produced through an official process.
- Newsletters and other periodic updates are less official, while affording an opportunity to stay in touch with key audiences.
- An online platform can allow for dynamic, interactive features such as maps and graphs that update almost in real time.
- Contributions to other media outlets, such as radio, television, podcasts, and blogs can be a good way to communicate results, and other aspects of the project.
- Academic products, such as journal articles, book chapters, slide decks, and posters can provide deeper analysis.

Beyond the needs and interests of key audiences, reporting should also be sensitive to the overall project context, including political disputes, and other controversies or disagreements that might relate to the results. In some cases, participants in the citizen science monitoring project might be uniquely positioned to help communicate the results to particular audiences. For example, Tribal representatives on the project leadership team, and Tribal members who participated in data collection, are typically the best voices for communicating the results of the project to their own and other Tribal councils. Similarly, students from local schools who helped collect data can help present alongside the professional scientists to the local city council.

Build in Time and Resources for Review

Appropriate review of reports and other products can ensure quality, and bolster credibility and buy-in to the monitoring project. Review processes can vary greatly in their form and complexity, from a close read by one or more “critical friends,” to review panels composed of experts and stakeholders with a range of specialized knowledge. Review protocols should be informed by the needs and goals of the project. Some factors to consider are:

- If results are meant to inform particular decisions or processes, are there specified technical review requirements?
- Will your project need its own review process, or is it part of a larger effort with its own predetermined review process?

- Should stakeholders be consulted about the appropriate form of review, or perhaps directly involved in the process itself? This is recommended when results may inform controversial decisions.
- What disciplinary knowledge will be required for review? If multiple, how will you integrate reviews from diverse perspectives?
- Is publication in an academic journal a goal? This can provide legitimacy and credibility to results, but also typically requires commitment of time and resources.

Consider Authorship and Other Forms of Credit and Attribution

In journal articles, reports, and other products, it is important to give credit where credit is due. Individuals that have made substantial contributions to the science, even if they are volunteers, should share authorship. This would not be necessary or appropriate when very large groups of volunteers made relatively small contributions.[34] Other forms of credit such as formal acknowledgments, or letters of recognition (See **Section 7.4**), can honor participants, and signal that community-based citizen science contributed to the project in important ways.

7.3 Evaluating and Evolving

Collaborators may want to conduct internal or external evaluations to improve the project over time, and rigorously communicate the value and impact of the program for a variety of audiences (e.g., participants, funders, practitioners, local communities, or government). Evaluations could focus on the impact and utility of results for resource management and decision-making; success with recruiting, motivating, and retaining participants; participant outcomes such as learning, motivation, self-efficacy and agency; and many other factors.

The questions that could motivate project evaluation (See **Appendix D**) are highly varied, and so too are the options for tracking and addressing them. For example, in order to learn about participant experiences, written questionnaires can be integrated with trainings and other gatherings of volunteers. Sending surveys out by email at a later day may get a much lower response rate, with poor recall of the experience, but may be more feasible if in-person gatherings are infrequent. Some questions about data quality may require outside expertise, and may only be addressable after the project has been in operation long enough to accrue a robust data set. **Developing an evaluation plan can help to determine the priority questions, and the most efficient and effective approach to addressing them.**

An evaluation plan should also address the question of when and how the insights from evaluation will be analyzed and used to shape the program. This may include a broad participatory process, involving participants and other stakeholders, or it may be done with a smaller group of core collaborators. Adapting a project as a result of evaluation is one way to show participants that their input is valued.

From some aspects of evaluation, consider working with one or more independent reviewers. These reviewers may provide a valuable outside perspective and help to address issues that participants might find controversial or hard to discuss candidly. Outside reviewers also lend credibility to the project. Scientists or government researchers can help to recommend independent reviewers.

[34] Although there are cases in which hundreds, and even thousands of authors have been listed on a journal article reporting the results of citizen science!

As with other topics in this manual, we recommend drawing from existing resources and similar projects when it comes to evaluation. **There are many different guides to project evaluation in general, and there are also resources specific to citizen science.**

- The Volunteer Water Quality Monitoring network, a nationwide network sponsored by the United States Department of Agriculture (USDA), has a variety of evaluation resources, including a short **fact sheet**[35] on evaluating water quality monitoring programs.
- For evaluating learning outcomes in particular, there are guides, sample survey questions, and other resources available through the **Cornell Lab of Ornithology's toolkit**.[36]

From Project to Program

Sometimes a small project can grow into a broader long-term program. This manual is focused on dam removal and river restoration, but these goals are both in service of long-term watershed health. Citizen science can help to monitor watershed health, and **some projects focused on dam removal may be able to evolve into long-term programs that fill that role**. For example, as the Watershed Education Network is building its program to generate data about removal of the Rattlesnake Creek Dam, it is simultaneously thinking about other watersheds in the local area where monitoring might meet various data needs, and how they could expand into those locations.

Some considerations include:

- Is volunteer interest and commitment sustainable beyond the specific project?
- What funding would be needed to expand and sustain the program?
- What specific long-term data needs are not already being met through other means?
- To what extent is the dam-focused project a strong proof of concept (to funders and other stakeholders) for longer-term programming? What evaluation data could help make this case?

7.4 Honoring and Celebrating Participation

A successful project is likely to rely on a wide variety of organizations and individuals who feel valued, inspired, enthusiastic, and as though their efforts are contributing to something important. There may be many kinds of activities, honors, or other gestures that validate and celebrate those contributions along the way. The ideas below are adapted from Pilz et al. (2006).

One important way to honor participation is simply to meet the expectations of participants by working hard and following through on the analysis of data and delivery of results back to participants and the audiences who need them. In many cases, the greatest reward for participants is to see the project making an impact, even in small, incremental ways. Don't assume that participants will automatically find out about such impacts: decision-making processes may take place behind the scenes, and it may not always be obvious how citizen science data played a role.

[35] acwi.gov/monitoring/vm/publications/articles/article_Evaluating_Your_VM_WQ_Program.pdf
[36] birds.cornell.edu/citscitoolkit/evaluation

Public rewards and celebrations may focus on individual participants, or on the group as a whole. Examples include:

- Special reports about individuals in newsletters
- Veteran or star participants leading field tours
- News reports about accomplishments
- Gatherings such as parties, potlucks, and award ceremonies
- Enrichment opportunities such as educational events, and guest speakers.
- Dedications

Consider the ways in which official acknowledgement can both celebrate and support participants. Examples include:

- Plaques or certificates
- Official letters of appreciation
- Monetary awards
- Employment referrals, letters of reference, or even direct employment

Gifts could include commemorative items with the logo of the project on them, such as clothing, stickers, and posters. Another approach is letting participants keep items acquired by the project, such as field equipment, maps, or books.

Celebrations can happen any time, even early in the development of a project. **Periodic celebrations – in whatever form – can build momentum and continuity in citizen science projects.** They can also educate the public about issues such as conservation and restoration, and the ways in which citizen science is contributing to those goals.

7.5 Funding and Other Resources

Whether using external funds, contributing their own resources, or a mixture of both, collaborators on a project should map out the ongoing needs and available resources. This includes resources outside of direct funding, and opportunities to think creatively about what a local community, as well as partners at a variety of levels, may have to offer.

Set Clear Expectations about Funding Needs

As mentioned near the beginning of this manual (See **Section 3**), collaborators need to communicate clearly about the support they need in order to participate, and the capacity that they bring to the table. This includes funding, and the timelines associated with available funds. Transparency on these issues can help collaborators to support each other and share knowledge about ways of securing needed resources.

Strategize to Expand Fundraising Potential

Earlier in this manual, we discuss opportunities to integrate a citizen science monitoring effort into other ongoing monitoring efforts, and the potential to create “win-win” partnerships related to, for example, teachers and schools, nonprofit organizations, education, or tribal interests. Such partnerships can also expand the range of potential project funders, and the collaborators who might be willing to partner on fundraising efforts.

➤ Steps You Could Take:

- Create a designated role for seeking out fundraising opportunities that collaborators can pursue together.
- Look for funds from local businesses as well as local, state, and federal government sources.
- Create communication materials aimed directly at funders, such as a wishlist of concrete needs, that can be tied directly to community and environmental outcomes supported by your project.

Box 8. Collaborative Monitoring on Rattlesnake Creek: Capacity-Building for the Future

A well-supported collaborative process can have program-wide benefits for partner organizations. In the case of WEN, for instance, participation has led to:

- Updated and improved Level 1 protocols as a result of working with science advisors and TU to develop Level 2 protocols
- Increased interest and commitment from volunteers when activity is framed as supporting the dam removal project
- Opportunities for expanding Stream Team to additional sites both on the Rattlesnake Creek and in other watersheds
- Stronger partnerships with local conservation organizations

Deb Fassnacht, WEN

Appendices

Appendix A. Project Platforms

Crowdsourcing Observations with iNaturalist[37]

iNaturalist is a platform for observing and learning about natural history. Through both artificial intelligence and the participation of a vast social network, citizen scientists can learn about the living things that they observe and report. Observations made through iNaturalist can also become "research grade" biodiversity data. iNaturalist provides the ability to create projects focused on a particular place or phenomenon. For example, organizers could encourage participants to make observations of species of interest and report them using iNaturalist, within the framework of a carefully designed iNaturalist project.

Project Management with CitSci.org[38] and Fieldscope[39]

CitSci.org and Fieldscope aim to provide support to citizen science projects through a set of tools made available online (and, for CitSci.org, for tablet and other mobile devices). These platforms are far more customizable than iNaturalist, and offer, in some cases, technical and other resources that can be adapted from other projects (e.g., protocols, data sheets, etc.). Projects can focus on any environmental phenomena, and the platforms allow direct data entry and data visualization. CitSci.org accommodates open and private projects and offers resources to support a wide range of functions beyond data collection (e.g., recruitment, data management, and visualization). Fieldscope emphasizes its capacity for networked programs that run at large scales, and may encompass multiple projects (e.g., for phenology, or large-scale water quality initiatives), as well as its sophisticated mapping and visualization tools. For teams that want to develop online or app-based components, each of these platforms may be a good option as an alternative to developing customized software tools.

Starting a project with Fieldscope (as of November 2020) requires discussion with Fieldscope staff to explore project needs and determine an appropriate fit with the platform, whereas CitSci.org is open to anyone at any time. As of late 2020, the CitSci.org database includes a large variety of stream and river-focused projects focusing on invasive species, fish, insect biodiversity, and water quality, among other things. Several of the most robust projects (as judged by the number of measurements contributed) are focused on water quality. Existing projects on CitSci.org are potential resources for organizers: the project managers may be willing to share experiences and advice about the CitSci.org platform, protocols, and other resources.

Data Processing with Zooniverse[40]

Zooniverse enables data processing through an online interface. Anyone can create a Zooniverse project, and examples on the site range from disaster response via satellite photos, to characterizing "camera trap" photos, to transcribing ancient texts. The common thread is that project organizers need help from "the crowd" to add contextual information to existing (usually image-based) data. The fact that such projects can be undertaken in the comfort of one's own home or office comes with some obvious advantages in terms of tapping into large audiences, and very low investments of time and resources in each volunteer. There are also ways to "gamify" the experience by adding a competitive element to participant activities, such as a scoring system, or other reward for performance on the project. The flip side of these advantages is the low level of direct engagement between researcher and participant.

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[37] inaturalist.org
[38] citsci.org/CWIS438/Websites/CitSci/Home.php?WebSiteID=7
[39] fieldscope.org
[40] zooniverse.org

Zooniverse might not seem like an obvious choice when there is a strong focus on fieldwork in the watershed. However, numerous Zooniverse projects focus on participants processing camera trap data of wildlife, some of which were cameras set up in the field by volunteers, while others were set up by professionals. For example, if the monitoring project organizers might place automated camera traps triggered by movement to take photos of wildlife activity at strategic spots along a water body, or use timed photos to simply observe physical changes in a river system. A Zooniverse project could help with the processing of these data. Researchers at UC Davis are taking this approach with sage grouse research in the Eastern Sierras, working with local high school students to conduct field work and using a Zooniverse project for help in processing camera trap data of lek attendance.[41]

Recruiting and Tracking Participation with SciStarter[42]

Unlike the platforms discussed above, SciStarter does not provide core functionality related to data collection, management, or processing. However, as the most prominent clearinghouse of citizen science opportunities, and with its tools for finding locally relevant projects, SciStarter can help to expand participation in a project. For example, if organizers want to enlist the general public in tracking the range of an invasive species of concern, and potential changes in the wake of dam removal, they can post the project on SciStarter. The project would then appear in search results for anyone looking for citizen science opportunities in the local area. SciStarter.com is also a good place to examine other projects and get ideas for your own context.

[41] More information at education.ucdavis.edu/yccs-tracking-sage-grouse-field-and-online
[42] scistarter.com

Appendix B. Drawing on Existing Citizen Science Resources and Projects

In this Appendix, we highlight some examples of organizations that provide extensive technical and programmatic resources on citizen science monitoring. Especially in the area of water quality, there are many regional, state, and national groups that coordinate and support citizen science monitoring efforts. While it is beyond the scope of this manual to exhaustively review these resources, we provide a few examples here.

US EPA Citizen Science Resources[43]

The US Environmental Protection Agency has supported citizen science (in various forms and by various names) – especially related to air and water quality projects – for decades. The website offers a repository of guides and other resources, including the Handbook for Quality Assurance (2019), which includes examples and recommended templates for citizen science projects. EPA-approved guides and protocols are designed to help project creators match data quality to project purpose. There are also resources targeted at streams, estuaries, and lakes at **epa.gov/citizen-science/data-collection-and-quality-assurance**.

Regional and State Guidance and Resources

There are many programs that facilitate or coordinate watershed monitoring, either statewide or across multiple states in a region. **Organizers should check for statewide volunteer water monitoring programs in their home state.** These programs can provide useful resources for starting monitoring efforts, and may also have guidance about state-approved standards which, if followed, would increase the utility and relevance of the data collected. A few examples that could provide useful guidance are described below.

- **California Clean Water Team (CWT)[44].** The CWT is a citizen monitoring program housed within a statewide effort: the State Water Resources Control Board's Surface Water Ambient Monitoring Program. The CWT produces comprehensive resources on citizen monitoring, including monitoring manuals, a toolbox for managing water quality data, online videos, a field methods multimedia course, and a smartphone water quality monitoring app.
- **Wisconsin Water Action Volunteers (WAV)[45] Program.** The WAV program is a statewide framework that invites and supports community-based water monitoring throughout the state, at multiple levels of sophistication. Through a tiered approach, WAV provides extensive resources for entry-level projects (focused on temperature, dissolved oxygen, streamflow, transparency, habitat, and invasive species), including training videos, methods manuals, data sheets, and a curriculum for educators.
- **Chesapeake Monitoring Cooperative.[46]** This cooperative provides multiple resources, including presentations, publications, quality assurance project plans, standard operating procedures, methods manuals, and fact sheets for tidal and nontidal bodies of water, water quality, and benthic macroinvertebrates. They advocate for the inclusion of citizen and nontraditional monitoring into monitoring efforts of the Chesapeake Bay by scientists and other professional experts.
- **South Yuba River Citizens League (California).** This group provides a **variety of reports and manuals**[47] related to river monitoring. This is an example of a locally based program that received a grant to support development of resources with much broader utility. The two-volume "Citizen's Monitoring Handbook" provides both programmatic and technical advice for citizen monitoring of water quality as well as flow and geomorphic fluvial change.

[43] epa.gov/citizen-science
[44] waterboards.ca.gov/water_issues/programs/swamp/cwt_volunteer.html
[45] wateractionvolunteers.org
[46] chesapeakemonitoringcoop.org/monitoring-resources/toolkits
[47] yubariver.org/our-work/river-monitoring/water-quality-resources

Appendix C. Example of a Training Session Program

This slightly-modified example of a plan for a training session appears in: Ballard, Heidi L., and Emily M. Harris. (2020). "Training." In *Citizen Science for Ecology and Conservation: A Practitioner's Guide*, edited by Chris Lepczyk, Owen Boyle, and Tim Vargo, 99–118. University of California Press. The plan is "backwards-designed," which means that the activities are built around clearly defined goals for, and indicators of, learning.

Goals

Participants will be able to:

1. Identify the correct phenophase 85% of the time when working with a partner.
2. Upload the data to the project website.
3. Give a 5-minute "elevator pitch" (very short, succinct explanation that could be delivered in the span of time one has on a ride in an elevator) about what they are doing, questions the project is trying to answer, and the importance of their work to the project.

Evidence of Learning

At the end of the training participants will:

1. Work with a partner to fill out the datasheet
2. Upload their data to the project website
3. Practice their five-minute elevator pitch with a partner

Learning Activities Plan for Each Day

Day 1: In the classroom with time to practice with the same plants, but not the same trail

9:00 a.m. – 9:15 a.m. Sign-in (coffee, bagels, mingling; anticipating some people will come late)

9:15 a.m. – 10:15 a.m. Introduction

- Icebreaker – activity to get to know each other
- Personal introductions – group discussion where everyone shares
- Project introduction - PowerPoint presentation on project goals

10:15 a.m. – 10:30 a.m. Break (coffee refills, bathroom visits)

10:30 a.m. – 12:00 p.m. Meet the plants and prepare for monitoring

- Look at cuttings in courtyard – hands-on activity
- Estimation Game – hands-on activity
- Botany 101 refresher - PowerPoint presentation with cuttings

12:00 p.m. – 12:45 p.m. Lunch

12:45 p.m. – 2:00 p.m.	Practice the monitoring protocol • Group Plant Practice and Datasheet – whole-group discussion and modeling the monitoring protocol • Observation practice in the Arboretum in small groups/pairs – small group practice using the protocol with several individual plants
2:00 p.m. – 2:15 p.m.	Break
2:15 p.m. – 2:45 p.m.	Uploading the data • Orient participants to data entry online – presentation • Participants enter data together in small groups – guided practice
2:45 p.m. – 3:00 p.m.	Closing • Closing activity • Post survey

Day 2: In the field at the location of the trail

9:30 a.m. – 10:00 a.m.	Introduction and Icebreaker • Plan for the day
10:00 a.m. – 10:15 a.m.	On-site materials • Orientation to different trails – hand out maps • Demonstrate lock box and proper storage of data sheets
10:15 a.m. – 10:45 a.m.	Whole group plant monitoring • Participants practice together on one plant and then whole group discussion
10:45 a.m. – 12:00 p.m.	Small group monitoring • In groups of 3-4 people, participants practice monitoring *Facilitators circulate to answer questions and provide feedback
12:00 p.m. – 12:30 p.m.	Elevator pitches • Develop elevator pitches • Practice giving these pitches to other participants
12:30 p.m. – 1:00 p.m.	Lunch and closing circle • “Tell the group one thing that surprised you today” • Post-survey

Appendix D. Questions to Guide Evaluation

Jordan et al. (2012)[48] suggests that citizen science can be evaluated at the individual level (the learning and experiences of the participants), the programmatic level (the effectiveness of the program itself), and the community level (the ways that the citizen science project might impact the capacity and social fabric of the community). Similarly, the following sets of example questions (adapted and expanded from Pilz et al. (2006)) can be used to work toward evaluation objectives:

High-Level, Core Project Outcomes

- Is the chosen approach (project structure, methods, protocols, training, etc.) the best way to meet identified data needs and other project goals?
- Do project monitoring goals or targeted indicators need to be altered?
- Were any contextual considerations overlooked in the planning process?
- Is the project sufficiently staffed and resourced?
- Does the project adequately represent all interested stakeholders?
- How can the evaluation process itself be improved?

Implementation Objectives

- Is project documentation adequate and useful?
- Are the sampling schemes and protocols adequate and appropriate?
- Are the data valid and of consistently high quality?
- Are the data being analyzed correctly?
- Is the project meeting deadlines and holding to a timeline?
- Are collaborators communicating and making decisions well?

Participant Experience and Outcomes

- Who is participating, and how well do the participants represent the surrounding community?
- What reasons or motivations did participants have for joining the project that might help further recruitment?
- Are the participants finding the experience personally rewarding?
- Have participant skills and expertise been appropriately matched to tasks?
- Is the project being conducted in a safe manner?
- Are trainings, field procedures, logistical arrangements, and support activities adequate?
- Would any participants like to be more involved in other parts of the project?
- Have project participants gained an understanding of the watershed, the scientific process, and/or ways that science can inform natural resource management?
- How can the project be made more rewarding for all concerned?

Broader Impacts

- How can lessons learned be communicated and applied to other projects?
- What are the project's impacts beyond those directly involved (e.g., in a community, or in a scientific field)?

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[48] Jordan, Rebecca C.; Heidi L. Ballard; Tina Phillips. 2012. Key issues and new approaches for evaluating citizen science outcomes. *Frontiers in Ecology and the Environment 10*(6): 307-309.

Appendix E. Example Monitoring Plan

The monitoring plan in the following pages was developed collaboratively by Trout Unlimited (TU), the Watershed Education Network (WEN), and other partners in Missoula as part of the removal of Rattlesnake Creek Dam.

The entire plan is instructive; however, readers may wish to focus on **Table E2**, where the respective roles of the field monitoring partners are noted. We have highlighted the activities of the Watershed Education Network's volunteers in green.

A few key points that emerge from review of this plan are:

- This plan begins with goals and questions that monitoring should answer, and the methods flow directly from those top-level elements.
- Citizen science plays a significant role in the project, but WEN is just one of seven different field monitoring partners. For some activities, WEN is solely responsible, whereas in others, WEN will collaborate with other field monitoring partners.
- The collection of activities to be carried out by WEN is the result of iterative discussions with partners, and is highly dependent on the specifics of the Rattlesnake Creek Dam project, and the local context.

RATTLESNAKE CREEK DAM REMOVAL MONITORING PLAN

Project Background

The Rattlesnake Creek Dam Removal project aims to enhance fish and wildlife habitat, improve public safety, restore natural ecological processes to the watershed, and increase recreational and cultural resources. Monitoring the project's success in meeting these project goals will be critical to adaptive management, outreach and education concerning the project's benefits, and the continued evolution of dam removal and river restoration projects in the region.

Rattlesnake Creek flows from the Rattlesnake Wilderness, into the heart of downtown Missoula, Montana. Because of its proximity to town and to the University of Montana, substantial monitoring and research efforts were already underway when the dam removal project was proposed. Trout Unlimited (TU), has assumed the role of coordinating dam removal monitoring efforts by identifying the key monitoring metrics, data being collected, and data gaps that should be filled to quantify the impact of dam removal. TU developed the following monitoring plan in coordination with its partners to outline the questions, methods, and timelines related to monitoring the impacts of Rattlesnake Creek dam removal.

The overarching goals for this monitoring program are to:

1. Understand the impact of dam removal on natural resources and stream processes through collaboration with agency, academic, and nonprofit partners; and
2. Engage the public through citizen science and outreach.

Monitoring Goals and Monitoring Questions

Goals for monitoring, and the associated monitoring questions, were developed based on several overarching factors:

1. Dam removal impacts will likely occur across a range of spatial scales, from the immediate dam removal site, to the broader watershed. The monitoring plan aims to document changes across this range of scales. Goal 1 focuses on impacts at and immediately below the dam site while Goal 2 aims to document broader ecosystem trends and patterns. TU recognized that they likely will not be able to document watershed-scale responses to dam removal; to do so would require a much more intensive and expensive research effort. Collecting baseline watershed health data, however, will illustrate the context, and relative influence, of dam removal on the ecosystem.
2. Dam removal impacts will occur over a range of temporal scales. Some impacts may be evident in the year following removal and restoration, while others may not be clear for decades. Their monitoring plan addresses the need for short, and long-term monitoring.
3. Monitoring questions are SMART: Specific, Measurable, Attainable, Realistic, Time-bound.

Based on these considerations, TU and partners developed the following monitoring goals and associated monitoring questions.

Goal 1. Evaluate the impact of dam removal on stream and floodplain conditions at or below the dam site.

a. Did dam removal increase fish passage?
b. Did dam removal and site restoration improve aquatic habitat at, and immediately below, the dam site?
c. What was the impact of dam removal on sediment transport and channel form downstream of the construction site?
d. What was the impact of dam removal on riparian health at and below the former dam site?
e. What was the impact of dam removal on streamflow (flood peaks and baseflow)?

Goal 2. Collect baseline data to assess watershed health and impairments.

a. How have human activities impacted Rattlesnake Creek over the last century?
b. What are the spatial patterns of native fish abundance and reproduction throughout Rattlesnake Creek?
c. How do temperature, groundwater inflows, and habitat complexity vary throughout the Rattlesnake? Do these factors spatially correlate with native fish abundance?
d. How does headwater physical habitat complexity (LWD volumes, beaver dams) compare to conditions in other parts of the Rattlesnake, or other comparable systems?

Partners

Partnerships have been essential to the development of this monitoring plan and will continue to be integral to its successful implementation. Partners not only offer efficiency and expertise in data collection, but also completeness in our monitoring perspective.

Field Monitoring Partners

Field monitoring partners are entities who will implement this monitoring plan through data collection and analysis. These groups have collected data on Rattlesnake Creek historically and have engaged in this plan and shifted their methods to answer specific questions about dam removal impacts. They include:

- Montana Fish, Wildlife & Parks, Fisheries Division (MFWP)
- Watershed Education Network, Citizen Science Program (WEN)
- Trout Unlimited (TU)
- University of Montana, various departments (UM)
- Missoula Valley Water Quality District (MWQD)
- Montana Department of Natural Resources and Conservation (DNRC)
- City of Missoula

Guidance Partners

Guidance Partners are individuals with technical expertise who have guided the development of this plan and/or specific methods therein. They include:

- Craig Groves (Dam removal monitoring plan development)
- David Cole (Citizen Science advisor)
- Ladd Knotek, Wildlife & Parks, Fisheries Division (Habitat monitoring methods)
- Sean Sullivan & Rennie Winkelman, Rhithron Associates, Inc. (Macroinvertebrate sampling and analysis)
- Terry Carlson (Monitoring plans and stream survey methods)
- Morgan Valliant, City of Missoula (Vegetation response)
- Dan Brewer, U.S. Fish and Wild Service (Fisheries monitoring)

Methods

The methods described below are driven by our specific monitoring questions, but wherever possible, existing data and partnerships are being used to reduce monitoring costs and encourage broader project engagement. **Table E1** outlines the timeline of monitoring and dam removal, while **Table E2** outlines the methods and analysis we will employ to answer each monitoring question. **Table E2** is a summary table; each partner listed is responsible for a Sampling and Analysis plan, with QA/QC and data management for their respective monitoring method.

Goal 1 methods generally follow a BACI (Before, After, Control, Impact) design with sampling occurring before (2019 or earlier) and after (2020/2021 or later). Generally, we use upstream sampling locations as our control, and the dam site or downstream as our impact area. Goal 2 methods vary in design, but either rely on annual, watershed-scale monitoring to show trends over time, or a single monitoring effort to document current conditions. The map on page 8 delineates how monitoring efforts are distributed across the watershed.

Table E1. Timeline

2019	2020	2021	2022	2024	2026
Pre-Construction Monitoring	Dam Removal and Restoration*		1 Year Post-Construction	3 Years Post-Construction	5 Years Post-Construction

*Dam removal will take place between 2020-2021. Monitoring activities will occur during this construction window, as appropriate.

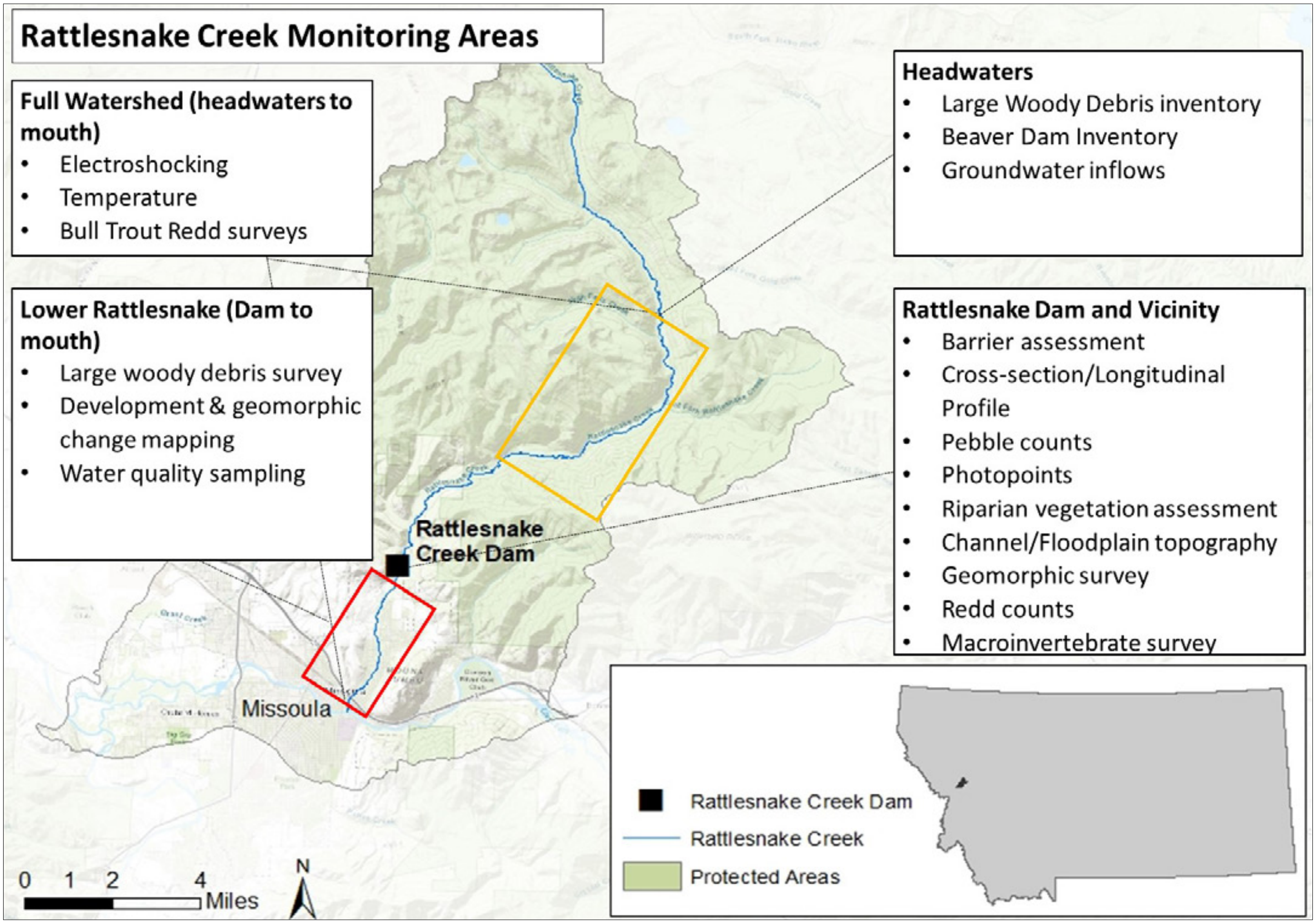
Table E2. Monitoring Methods

Goal 1: Evaluate the impact of dam removal on stream and floodplain conditions at, or below, the dam site.				
Monitoring Question	**Field Method**	**Lead Entity**	**Description/Analysis**	**Interval**
Did dam removal increase fish passage?	Annual electrofishing	MFWP	Evaluate changes in abundance and/or species composition, correlated to timing of dam removal.	Annual
	Barrier assessment	TU	Estimate the number of days/years that the dam creates a passage barrier, based on velocities. Compare against a fully passable river system and known timing of aquatic organism movement.	2019, 2022
Did dam removal and site restoration improve aquatic habitat at, and immediately below, the dam site?	Redd counts at dam site	MFWP	Compare number of redds present at the dam site pre- and post-dam removal. Redd counts at other locations will serve as a control.	Annual
	Macroinvertebrate survey	WEN w/ lab analysis	Compare macroinvertebrate community assemblage pre- and post-dam removal, above (control) and below (impact) the dam site.	Annual
	Channel/Floodplain topography	TU	Evaluation of pre-construction LiDAR/surveys vs as-built design to identify changes in topographic complexity (e.g., habitat diversity, floodplain area, etc.).	2022
	Large woody debris survey (dam to mouth) before and after removal	WEN/TU	Compare LWD volumes below the dam, pre- and post-dam removal.	2019, 2022, 2024, 2026

Goal 1: Evaluate the impact of dam removal on stream and floodplain conditions at, or below, the dam site.				
What was the impact of dam removal on sediment transport and channel form immediately downstream of the dam removal site?	Channel cross-sections	WEN	Compare changes in channel cross-sections pre- and post-dam removal above (control) and below (impact) the dam removal area.	Annual
	Channel longitudinal profile	WEN	Compare changes in channel longitudinal profile pre- and post-dam removal above (control) and below (impact) the dam removal area.	Annual
	Pebble counts	WEN	Compare changes in sediment grain size distribution above (control) and below (impact) the dam removal area at established cross-sections.	Annual
	Geomorphic survey	UM	Evaluate channel topography, shear stress, and sediment transport potential before and after dam removal, below the dam.	Bi-annual
	Photopoints	WEN	Establish photopoints at each cross-section (across, upstream, downstream).	Annual
What was the impact of dam removal on riparian plant communities at and below the dam site?	Floodplain topography assessment	TU	Using pre-construction LiDAR and as-build designs, assess changes in floodplain area and width (potential riparian area) before and after dam removal and restoration.	2019, 2022
	Aerial imagery	TU/RLF	Collect high resolution aerial images pre- and post-restoration to assess and illustrate changes in floodplain width and vegetation recovery.	2019, 2020, 2022, 2024, 2026
	Riparian vegetation structure	WEN	Establish transects for assessing vegetation structure pre- and post-dam removal above (control) and below (impact) the dam removal area, close to channel cross-sections.	Annual
	Photopoints	WEN/TU	Establish photopoints within the construction area to document vegetation pre- and post-dam removal.	Annual
What was the impact of dam removal on streamflow (flood peaks and baseflow)?	Stream Gauge	DNRC, USGS	Continuous hourly measurements of stream discharge and stage (1899-1967; 2017-present) will be compared to reference sites in the basin to identify changes in flood peak and baseflows in the lower Rattlesnake.	Continuous, Hourly

Goal 2. Collect baseline watershed-scale data to assess watershed health and impairments.				
Monitoring Question	**Field Method**	**Lead Entity**	**Description/Analysis**	**Interval**
How have human activities impacted Rattlesnake Creek over the last century?	Municipal Development/ Geomorphic mapping	UM	Map and quantify changes in stream length, side channel length, riparian width, and land use over the last century.	2019
	Water Quality Sampling	MWQD	Collect nutrient and Total Suspended Solids data throughout the lower Rattlesnake to understand impacts of septic systems, roads, and other human impacts.	2008, TBD
What are the spatial patterns of native fish abundance and reproduction?	Annual electrofishing	MFWP	Evaluate longitudinal distribution and abundance of native/non-native fishes from headwaters to mouth.	Annual
	Redd counts	MFWP	Document number and location of Bull trout redds over time.	Annual
How do temperature, groundwater inflows, and habitat complexity vary throughout the Rattlesnake? Do these factors spatially correlate with native fish abundance?	Longitudinal array of temperature loggers	MFWP	Deploy temperature loggers annually, from headwaters to mouth, to collect continuous (hourly) temperature measurements Spring – Fall. Map with fish distributions and groundwater concentrations.	Annual
	Groundwater inflows	WEN, UM	Collect and analyze Radon-222 concentrations to identify areas of groundwater inflows in winter and summer. Map with redd count results and temperature data.	2019, TBD
	Headwater large woody debris inventory	WEN	Document large woody debris volumes in the Rattlesnake headwaters. Compare areas of high LWD concentrations.	2019, TBD
	Headwater beaver dam inventory	WEN	Map and photograph beaver dam locations in the Rattlesnake headwaters. Map with native fish abundance, groundwater, and temperature data.	2019, TBD
How does headwater physical habitat complexity (LWD volumes, beaver dams) compare to conditions in other parts of the Rattlesnake, or comparable systems?	Headwater beaver dam inventory (GPS and photograph)	WEN	Evaluate distribution of beaver dams throughout the Rattlesnake headwaters.	2019, TBD
	Headwater large woody debris inventory	WEN	Document large woody debris volumes in the Rattlesnake headwaters. Compare against regional reference volumes.	2019, TBD

Figure E1.


Rattlesnake Creek Monitoring Areas
Full Watershed (headwaters to mouth)
• Electroshocking
• Temperature
• Bull Trout Redd surveys
Lower Rattlesnake (Dam to mouth)
• Large woody debris survey
• Development & geomorphic change mapping
• Water quality sampling
Headwaters
• Large Woody Debris inventory
• Beaver Dam Inventory
• Groundwater inflows
Rattlesnake Dam and Vicinity
• Barrier assessment
• Cross-section/Longitudinal Profile
• Pebble counts
• Photopoints
• Riparian vegetation assessment
• Channel/Floodplain topography
• Geomorphic survey
• Redd counts
• Macroinvertebrate survey
Rattlesnake Creek Dam
Missoula
Rattlesnake Creek Dam
Rattlesnake Creek
Protected Areas
0 1 2 4
Miles
N

Appendix F. Further Reading

The following resources consist of academic publications, books, and practitioner guides focused on the design and implementation of citizen science initiatives for biodiversity and ecological monitoring. While some of these resources are geared specifically toward dam removal and watershed restoration, most are more broadly applicable to citizen science in other contexts. You can access an online version of this list that will be periodically updated with new resources as they become available at: **education.ucdavis.edu/ccs-manual**

Terminology of Citizen Science and the Range of Models and Approaches

Eitzel, M. V., Cappadonna, J. L., Santos-Lang, C., Duerr, R. E., Virapongse, A., West, S. E., Kyba, C. C. M., et al. (2017). Citizen science terminology matters: Exploring key terms. *Citizen Science: Theory and Practice*. doi.org/10.5334/cstp.96

Shirk, J. L., Ballard, H. L., Wilderman, C. C., Phillips, T., Wiggins, A., Jordan, R., McCallie, E. et al. (2012). Public participation in scientific research: A framework for deliberate design. *Ecology and Society, 17*(2): 1–20. dx.doi.org/10.5751/ES-04705-170229

Pros and Cons of a Citizen Science Approach

Shirk, J. L., Ballard, H. L., Wilderman, C. C., Phillips, T., Wiggins, A., Jordan, R., McCallie, E. et al. (2012). Public participation in scientific research: A framework for deliberate design. *Ecology and Society, 17*(2): 1–20. dx.doi.org/10.5751/ES-04705-170229

Types of citizen science, with particular focus on how volunteers may participate.

Pocock, M. J. O., Chapman, D. S., Sheppard, L. J., & Roy, H. E. (2014). C*hoosing and using citizen science: A guide to when and how to use citizen science to monitor biodiversity and the environment.* NERC/Centre for Ecology & Hydrology. nora.nerc.ac.uk/id/eprint/510644

An accessible guide to thinking through the pros and cons of a citizen science approach.

Conrad, C. C., & Hilchey, K. G. (2011). A review of citizen science and community-based environmental monitoring: Issues and opportunities. *Environmental Monitoring and Assessment, 176*(1–4): 273–91. doi.org/10.1007/s10661-010-1582-5

A review of benefits and challenges of community-based monitoring, based on diverse examples and published literature.

Pilz, D., Ballard, H. L., & Jones, E. T. (2006). *Broadening participation in biological monitoring: Handbook for scientists and managers* (Gen. Tech. Rep. PNW-GTR-680). US Department of Agriculture, Forest Service, Pacific Northwest Research Station. fs.fed.us/pnw/pubs/pnw_gtr680.pdf

A list of advantages and disadvantages of citizen science – for both individuals and organizations – begins on page 20.

Building a Team

Exploring How to Broaden Participation, and Address Community Concerns and Issues of Equity and Ownership

Pandya, R. E. (2012). A framework for engaging diverse communities in citizen science in the US. *Frontiers in Ecology and the Environment, 10*(6): 314–17. doi.org/10.1890/120007

Soleri, D., Long, J. W., Ramirez-Andreotta, M. D., Eitemiller, R., & Pandya, R. (2016). Finding pathways to more equitable and meaningful public-scientist partnerships. *Citizen Science: Theory and Practice, 1*(1):9, 1–11. doi.org/10.5334/cstp.46

Partnerships for Impact: A Workbook for Informal Science Educators and *Outreach Specialists Working with Diverse Communities and Meaningful Collaborations: A Workbook for Community Leaders, Educators, and Advocates Working with Science Institutions.* **power30icbos.blogspot.com/2019/03/our-workbook-for-community-based.html**

These two workbooks, while not focused on citizen science specifically, provide valuable guidance on productive partnerships that explicitly recognize power imbalances and aim to improve equity, diversity, and inclusion in STEM through research.

Goals of Citizen Science

Newman, G., M., Chandler, M., Clyde, McGreavy, B., Haklay, M., Ballard, H., Gray, S., et al. (2016). Leveraging the power of place in citizen science for effective conservation decision making. *Biological Conservation, 208*, 55–64. doi.org/10.1016/j.biocon.2016.07.019

On connecting to, and developing a, sense of place.

Peters, C. B., Zhan, Y., Schwartz, M. W., Godoy, L., & Ballard, H. L. (2016). Trusting land to volunteers: How and why land trusts involve volunteers in ecological monitoring. *Biological Conservation, 208*, 48–54. doi.org/10.1016/j.biocon.2016.08.029

Goals of, and lessons learned from, land trusts who use citizen science in their approach to land management.

Ballard, H. L., Dixon, C. G. H., & Harris, E. M. (2017). Youth-focused citizen science: Examining the role of environmental science learning and agency for conservation. *Biological Conservation, 208*, 65–75. doi.org/10.1016/j.biocon.2016.05.024

McKinley, D. C., Miller-Rushing, A. J., Ballard, H. L., Bonney, R., Brown, H., Cook-Patton, S. C., Evans, D. M., et al. (2016). Citizen science can improve conservation science, natural resource management, and environmental protection. *Biological Conservation, 208*, 15–28. doi.org/10.1016/j.biocon.2016.05.015

Cigliano, J. A., Meyer, R. M., Ballard, H. L., Freitag, A., Phillips, T. B., & Wasser, A. (2015). Making marine and coastal citizen science matter. *Ocean & Coastal Management, 115*, 77–87. doi.org/10.1016/j.ocecoaman.2015.06.012

Aceves-Bueno, E., Adeleye, A. S., Bradley, D., Brandt, W. T., Callery, P., Feraud, M., Garner, K. L., Gentry, R., Huang, Y., Mccullough, I., Pearlman, I., Sutherland, S. A., Wilkinson, W., Yang, Y., Zink, T., Anderson, S. E., & Tague, C. (2015). Citizen science as an approach for overcoming insufficient monitoring and inadequate stakeholder buy-in in adaptive management : Criteria and evidence. *Ecosystems, 18*, 493–506. doi.org/10.1007/s10021-015-9842-4

Building a Process

Selecting Monitoring Indicators and Measures for Dam Removal and Stream Restoration

Bellmore, R., Duda, J. J., Craig, L. S., Greene, S. L., Torgersen, C. E., Collins, M. J., & Vittum, K. (2017). Status and trends of dam removal research in the United States. *Wiley Interdisciplinary Reviews: Water, 4*(2). doi.org/10.1002/wat2.1164

Highlights common metrics that have been used in dam removal studies across the United States.

Kibler, K. M., Tullos, D. D., & Kondolf, G. M. (2011). Learning from dam removal monitoring: Challenges to selecting experimental design and establishing significance of outcomes. *River Research and Applications, 27*(8), 967–75. doi.org/10.1002/rra.1415

Discussion of experimental design for dam removal monitoring.

Collins, M., K., Lambert, L. B., Kachmar, J., Turek, J., Hutchins, E., Purinton, T., & Neils, D. (2007). *Stream barrier removal monitoring guide*. Gulf of Maine Council on the Marine Environment. gulfofmaine.org/streambarrierremoval/Stream-Barrier-Removal-Monitoring-Guide-12-19-07.pdf

Data Quality and Data Management

Wiggins, A., Bonney, R., Graham, E., Henderson, S., Kelling, S., LeBuhn, G., Littauer, R., et al. (2013). *Data management guide for public participation in scientific research*. DataONE: Albuquerque, NM. **old.dataone.org/sites/all/documents/DataONE-PPSR-DataManagementGuide.pdf**

Kosmala, M., Wiggins, A., Swanson, A., & Simmons, B. (2016). Assessing data quality in citizen science. *Frontiers in Ecology and the Environment, 14*(10), 551–60. doi.org/10.1002/fee.1436

Borer, E. T., Seabloom, E. W., Jones, M. B., & Schildhauer, M. (2009). Some simple guidelines for effective data management. *The Bulletin of the Ecological Society of America, 90*, 205–214. doi.org/10.1890/0012-9623-90.2.205

Wiggins, A. (2013). Free as in puppies: Compensating for ICT constraints in citizen science. *Proceedings of the 16th ACM Conference on Computer Supported Cooperative Work and Social Computing*. San Antonio, TX, 23–27 February, 2013. doi.org/10.1145/2441776.2441942

Involving Participants in Project Design

Fernandez-Gimenez, M., Ballard, H., & Sturtevant, V. (2008). Adaptive management and social learning in collaborative and community-based monitoring: A study of five community-based forestry organizations in the Western USA. *Ecology and Society, 13*(2). doi.org/10.5751/ES-02400-130204

Recruiting and Supporting Participants

West, S. E., & Pateman, R. M. (2016). Recruiting and retaining participants in citizen science: What can be learned from the volunteering literature? *Citizen Science: Theory and Practice*. doi.org/10.5334/cstp.8

Arnold, J. S., & Fernandez-Gimenez, M. (2007). Building social capital through participatory research: An analysis of collaboration on Tohono O'odham tribal rangelands in Arizona. *Society and Natural Resources, 20*(6), 481–495. doi.org/10.1080/08941920701337887

Trade-offs Involved in Technological Approaches to Collaboration in Citizen Science

Wiggins, A. (2013). Free as in puppies: Compensating for ICT constraints in citizen science. *Proceedings of the 16th ACM Conference on Computer Supported Cooperative Work and Social Computing*. San Antonio, TX, 23–27 February, 2013. doi.org/10.1145/2441776.2441942

On-the-Ground Implementation

Jordan, R., Eherfeld, J. G., Gray, S. A., Brooks, W. R., How, D. V., & Hmelo-Sliver, C. E. (2012). Cognitive considerations in the development of citizen science projects. In J. L. Dickinson and R. Bonney (Eds.), *Citizen Science: Public Participation in Environmental Research*. Comstock Publishing Associates (pp. 167–178). researchgate.net/profile/Wesley_Brooks3/publication/230640134_Cognitive_Considerations_in_the_Development_of_Citizen_Science_Projects/links/09e415024c46199254000000/Cognitive-Considerations-in-the-Development-of-Citizen-Science-Projects.pdf

Overview of learning outcomes from training and other aspects of citizen science.

Lepczyk, C., Boyle, O., & Vargo, T. (2020). *Citizen science for ecology and conservation: A practitioner's guide*. University of California Press. ucpress.edu/book/9780520284791/handbook-of-citizen-science-in-ecology-and-conservation

Follow-through and Sustainability

Analyzing and Interpreting Data

Franz, N. K. (2013). The data party: Involving stakeholders in meaningful data analysis. *Journal of Extension, 51*(1). joe.org/joe/2013february/iw2.php

Authorship and Other Forms of Credit for Participants

Brand, A., Allen, L., Altman, M., Hlava, M., & Scott, J. (2015). Beyond authorship: Attribution, contribution, collaboration, and credit. *Learned Publishing, 28*(2), 151–55. researchgate.net/profile/Amy_Brand/publication/274098676_Beyond_authorship_Attribution_contribution_collaboration_and_credit/links/565b08c608aeafc2aac60656/Beyond-authorship-Attribution-contribution-collaboration-and-credit.pdf

Resnik, D. B., Elliott, K. C., & Miller, A. K. (2015). A framework for addressing ethical issues in citizen science. *Environmental Science & Policy, 54*, 475–481. doi.org/10.1016/j.envsci.2015.05.008

Evaluation Guides and Advice

Jordan, R. C., Ballard, H. L., Phillips, T. B. (2012). Key issues and new approaches for evaluating citizen science outcomes. *Frontiers in Ecology and the Environment, 10*(6), 307–309. doi.org/10.1890/110280

Overview of evaluation issues in citizen science.

Kushner, J., Klink, J., Stepenuck, K., Genskow, K., Herron, E., & Green, L. (2012) Evaluating your volunteer water quality monitoring program. *National Institute of Food and Agriculture (NIFA)*. cels.uri.edu/docslink/ww/406Modules/EvaluationXVI.pdf

This short fact sheet points to a wide range of useful resources on evaluating citizen science, including methods.

Preskill, H. & Jones, N. (2009). *A practical guide for engaging stakeholders in developing evaluation questions.* Robert Wood Johnson Foundation. rwjf.org/en/library/research/2009/12/a-practical-guide-for-engaging-stakeholders-in-developing-evalua.html

Though not focused on citizen science, this guide examines a range of ways that stakeholders can play a valuable role in evaluation.

Phillips, T. B., Ferguson, M., Minarchek, M., Porticella, N., and Bonney, R. (2014). *User's Guide for Evaluating Learning Outcomes in Citizen Science*. Ithaca, NY: Cornell Lab of Ornithology. birds.cornell.edu/citizenscience/wp-content/uploads/2018/10/USERS-GUIDE_linked.pdf

Learning-focused framework and guide.

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