OREGON WATERSHED ENHANCEMENT BOARD

Monitoring Restoration Initiatives

A GUIDE PREPARED FOR

Oregon Watershed Enhancement Board's Focused Investment Partnership Program

BONNEVILLE ENVIRONMENTAL FOUNDATION

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Contents

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For people using screen reading programs, page numbers will be read first, followed by the page content.

Warner Basin, OR

Introduction

The complex and dynamic nature inherent in ecosystems and the relatively young state of practices to restore ecological functions underscore the need for reliable feedback on project effectiveness.

Monitoring is the periodic collection and evaluation of data to build knowledge and track change.

Monitoring is a critical tool to:

- Measure progress toward restoration objectives,
- Inform project and program improvements, and
- Advance restoration knowledge

Conceptually, the idea of measuring the condition of a particular habitat or population over time is a relatively straightforward proposition. But, as most restoration practitioners find, the realities of collecting useful and reliable monitoring data often present a range of challenges.

Common monitoring challenges include:

- Lack of technical expertise
- Short term funding
- Staffing turnover
- Complexities of managing large data sets
- Need for effective communication and coordination

These common challenges suggest that there are difficulties inherent to monitoring that should be carefully considered, planned for, and evaluated throughout the life of a monitoring project or program.

This guide, developed within the context of the Oregon Watershed Enhancement Board (OWEB's) Focused Investment Partnerships (FIP) program, is intended to support the development and application of monitoring plans that fulfill the basic purposes of monitoring and offer ways to address common challenges. It describes critical considerations and steps to follow for developing a monitoring plan that will provide accurate and useful feedback in an efficient manner. Thoughtful selection of monitoring priorities, protocols, and data management practices will help ensure that monitoring is cost-effective, and results are useful.

This guide is a companion to two additional guides created within the context of OWEB's FIP Program - *Strategic Action Planning for Prospective Focused Investment Partnerships* and *Adaptively Managing Restoration Initiatives*. Figure 1 shows the elements of a monitoring plan and how they are integrated into strategic planning and adaptive management. This third guide draws on interviews with monitoring experts from eleven partnerships supported by the FIP program as well as current monitoring literature.

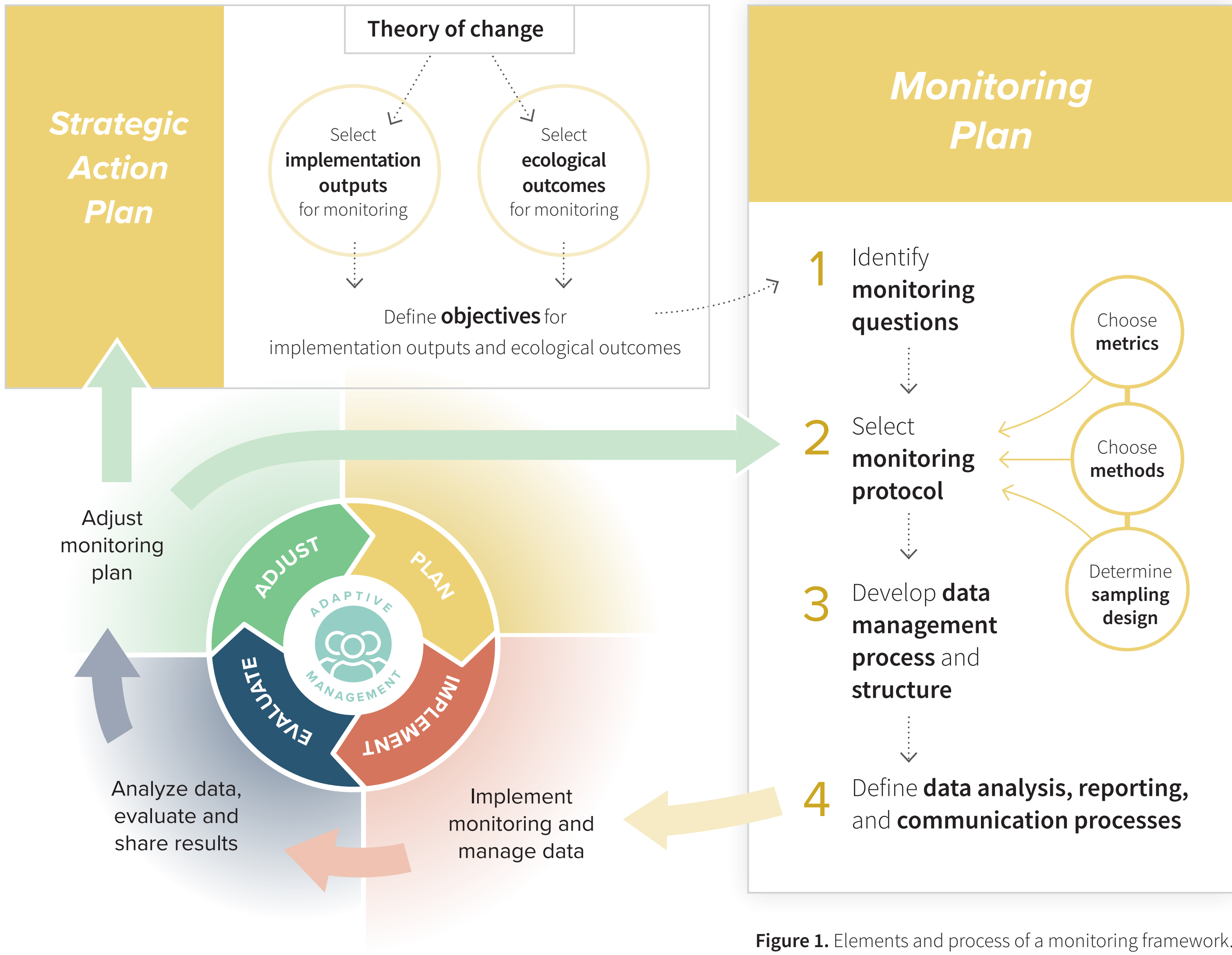


Figure 1. Elements and process of a monitoring framework.

As shown in Figure 1, monitoring is integrated into strategic action planning and the adaptive management cycle. As described in OWEB's strategic action planning guidance document, partners develop a theory of change which they can use to identify expected implementation outputs and ecological outcomes of planned actions. From these, and the objectives defined for each output and outcome, partners can select and prioritize monitoring questions. A monitoring plan defines monitoring questions and develops protocols (metrics, methods, and sampling design) to answer each question. The plan should also clearly describe data management and data analysis processes and how results will be shared. Strategic action and monitoring planning are the primary elements of the adaptive management planning process, and guide the implementation, evaluation, and adjustment steps in the process described in OWEB's adaptive management guidance document.

Why Monitor?

Monitoring helps a partnership track progress, inform adaptive management, reduce uncertainties, build support, and advance the field.

Greater Sage-Grouse *Baker Sage-Grouse Local Implementation Team*

The motivations that lead a partnership to invest in monitoring vary depending on its specific information needs. However, most ecosystem restoration programs seek to gather information in two areas:

Implementation Monitoring: The degree to which actions or treatments are carried out as planned.

Effectiveness Monitoring: The degree to which expected ecological responses are observed as a result of implementing restoration actions.

These two types of monitoring are often integrated, because implementation monitoring is a measure of treatment and effectiveness is a measure of the response. Rigorous implementation monitoring can be very important to connecting changes measured through effectiveness monitoring to actual treatment actions.

Most partnerships will also want to characterize and track progress toward a longer-term restoration vision — the fundamental definition of success. This level of monitoring **(status and trends monitoring)** is typically not designed to attribute outcomes directly to restoration actions, but it can help assess whether the cumulative effect of intermediate outcomes in response to restoration is contributing to long-term restoration goals. Status and trends monitoring can also build understanding about the ecosystem and restoration needs.

For some partnerships, social or economic outputs and outcomes may be a priority. For example, obtaining social license or policy changes may be a necessary precursor to completing restoration work. Similarly, forest restoration initiatives that seek to reduce the risk of high-intensity wildfires and associated hazardous air quality might identify the economic and social benefits of their actions as desired future conditions. While this guide focuses on ecological monitoring, the monitoring plan components and processes for developing them can also be applied to social and economic effectiveness monitoring.

*This guide focuses on **effectiveness monitoring** designed to track progress towards achieving ecological objectives and using that information to inform the partnerships' adaptive management.*

Purposes and Benefits

Track Restoration Progress

Strategic action plans define measurable objectives for both implementation outputs and desired ecological outcomes. Monitoring provides a systematic way to reliably measure, demonstrate, and communicate progress relative to the objectives a partnership has determined are necessary to achieving their restoration goals.

Inform Adaptive Management

Monitoring provides feedback for adaptive management by demonstrating where restoration actions are having desired effects and should be continued or expanded. If actions are not implemented as planned or if predicted outcomes are not observed, a well-designed monitoring plan will provide information that can be used to inform project and program adjustments. In some cases, monitoring results may suggest a need for more in-depth research to inform alternative or modified strategies.

Monitoring results — along with information obtained from research studies, anecdotal observation, and practical experience — contribute to a knowledge base that can inform future design of restoration programs, strategies, and projects.

Reduce Uncertainties

Uncontrollable environmental variability and incomplete knowledge about how species, habitats, ecosystems, and people respond to restoration actions will always introduce some degree of uncertainty into any given restoration effort. Identifying critical uncertainties and monitoring for changes in key metrics associated with predicted outcomes can help improve confidence that selected actions will lead to desired impacts.

Other Benefits

Monitoring provides benefits beyond the primary purposes of tracking progress and informing strategies including building and maintaining support for the restoration initiative and advancing the field of ecological restoration.

▶ *Maintain and Build Support*

Monitoring can build understanding within the partnership and among external stakeholders about the need for and benefits of ecological restoration and the underlying science, rationale, and uncertainties of a restoration initiative. Some partnerships use monitoring results to maintain or leverage commitment from funders and other stakeholders whose support is critical for successful project implementation and for stewarding restored ecosystems into the future. Monitoring results are also used in outreach efforts to build an appreciation among community constituents for the ecological values a partnership is seeking to restore and the actions they are taking to accomplish that.

Sharing monitoring plans and findings is also a means to recruit assistance from researchers who may support the monitoring effort through supplemental studies, refining monitoring practices to be more effective, and contributing towards the sustained long-term monitoring of ecosystem status and trends.

▶ *Advance the Restoration Field*

Monitoring results, when shared in peer reviewed journal articles, professional presentations, technical reports, or less formally at meetings, can contribute to advancing the field of ecological restoration. Many partnerships are testing new and innovative restoration techniques that may have application in other areas, and in some cases, monitoring is providing new knowledge of ecological system function.

Keys to Success

Experience has shown that having a dedicated monitoring coordinator and adequate and sustained funding are key to the success of a monitoring program.

Monitoring Coordinator

Monitoring a landscape-scale restoration initiative usually requires extensive coordination, communication, and commitment among multiple entities to ensure consistent collection, analysis, and reporting of high-quality, useful data. All partners must share the same clearly-defined monitoring vision and all participants—from seasonal field technicians to project leaders to funders — need to understand how any deviations from agreed-upon processes and protocols will affect the data analysis and its integration with the management of the initiative.

Identifying an individual whose role it is to oversee planning and operationalize monitoring is essential to obtain accurate and useful results. It is essential to fund this role and allocate capacity commensurate with monitoring needs. In the companion OWEB guidance, *Adaptively Managing Restoration Initiatives*, this role is called the adaptive management champion. Having one individual who leads both monitoring and adaptive management for a restoration initiative provides continuity and integration to incorporate monitoring into the adaptive management process.

▶ *Coordinator Roles*

Within different partnerships and restoration initiatives, the monitoring coordinator may operate at different scales and assume varied responsibilities. They may focus narrowly on compiling monitoring data from various efforts among partners (even if they are not directly involved in those efforts), they may coordinate monitoring projects implemented by a subset of organizations, or they may direct and coordinate all aspects of monitoring across the entire initiative where multiple projects are being carried out throughout the partnership's geography and be responsible for communicating results.

Key roles of a monitoring coordinator:

- Lead and facilitate the collaborative process of identifying monitoring priorities, selecting protocols, and ensuring data collection is completed according to restoration timelines.
- Organize annual review of monitoring efforts before the field season, and before implementing restoration actions, to ensure compatibility with the monitoring plan.
- Steward and manage monitoring data and perform or contract data analysis and reporting so that monitoring findings can be communicated, evaluated, and inform subsequent phases of restoration.
- Ensure communication among restoration practitioners, entities planning project implementation and associated monitoring, and technical advisors to keep monitoring and communication of results on track.
- Support outreach and communication efforts by translating technical information so it is accessible to more diverse audiences.
- Maintain commitment and enthusiasm for monitoring.

Articulating the roles and responsibilities of a monitoring coordinator in a restoration initiative proposal provides an opportunity to account for and budget the costs associated with funding this critical position. Allocating funding specifically for this role also allows the monitoring coordinator to prioritize monitoring responsibilities and activities at the level for which those activities are needed, particularly when general staff time is over-allocated and the monitoring coordinator is required to prioritize among other competing demands.

Depending on the scope of a monitoring plan and how much other partners are contributing to the effort, the amount of time allocated for monitoring coordinator responsibilities can range between 0.15 and 1.00 FTE. Some partnerships find the need to create a separate position to act as the data steward given this aspect of monitoring requires a specialized skillset and a significant allocation of sustained resources.

In most cases, the responsibilities of developing and implementing a well-integrated monitoring plan are distributed among multiple partnership member organizations where staff time, resources, and expertise can be leveraged. These monitoring teams or committees may be informally structured (sometimes on an ad hoc basis) or they may be explicitly called out as part the partnership's governance structure with specifically defined members, terms, responsibilities, etc. More formalized roles and responsibilities are often needed to implement more complex monitoring plans.

Adequate and Sustained Funding

To fully deliver its potential value, a monitoring program requires a sustained investment of time and financial resources from practitioners, funders, and engaged stakeholders. While the importance of monitoring is broadly acknowledged, it can be challenging to maintain funding over timescales where ecological responses are observed — which can often take years or decades to develop. For this reason, monitoring questions (See *Monitoring Questions,* pg.10) need to reflect what can feasibly be answered within a corresponding timeframe. Long-term monitoring requires a multi-year commitment and commensurate funding and can be difficult to sustain with only individual short-term grants.

Budget allocation for a monitoring program is influenced by a wide range of factors and can vary significantly from one initiative to another. If a partnership's restoration effort has a strong scientific foundation, a robust and thoroughly vetted theory of change, the monitoring roles and responsibilities are clearly defined (with capacity to carry time out them out), and there is significant in-kind contribution of agencies and academia, a 10% allocation of the total restoration budget allocation can be sufficient. However, in most cases, more funding is required to gain the values of monitoring. Otherwise, a partnership may have to compromise its expectations or revisit its priorities.

Restoration initiatives have shown creativity in how they develop and leverage funding and capacity to design and implement monitoring plans. Monitoring programs are often sustained by a mix of support including initiative-scale capacity funding (e.g., OWEB FIP capacity funding); stand-alone monitoring grants; state and federal agency, tribal, and university contributions of staff, expertise, and equipment; and support from research institutions where there is mutual interest. These partnership contributions may provide the added benefit of in-kind match in support of grants. The partnership's monitoring coordinator finds where these resources and opportunities overlap with monitoring needs and where there is the potential for a reciprocal relationship, facilitates agreements, and manages the relationships. Consistent funding of the monitoring coordinator is key to having the capacity to leverage these opportunities to implement a cohesive monitoring plan.

Expert Review

Expert review and consultation at the design stage can provide guidance with respect to data collection, management, and analysis methods, and can improve monitoring by increasing the expertise and experience applied to monitoring questions and methods (See *Consult Subject Matter Experts,* pg.16).

A partnership can also find it very useful to periodically invite independent technical experts to review a monitoring program after it has been implemented to address specific questions ranging from the overall monitoring approach and framework to the design of effective sampling methods. Outside experts offer objective perspectives and broad expertise and experience that can contribute to the evolution of a monitoring program. It is important that invitations to outside experts be made with full knowledge and agreement of all members of the partnership following a robust initial internal review process. This kind of solicitation for expert input is intended to support a partnership's monitoring plan development and management and is not meant to be used by outside interests (including funders) seeking an independent evaluation for other purposes such as funding decisions.

While experts may provide review as an in-kind service without requiring monetary compensation, staff time to coordinate the review should be accounted for in budgeting and in the monitoring project timeline.

Tips for Financing a Monitoring Program

Establish Partner Agreement

The full partnership needs to agree on how important monitoring is relative to other activities and commit the necessary level of support and resources to carry out monitoring that aligns with the partnership's expectations.

Beginning development of a monitoring plan early in a partnership's strategic planning process allows for a more complete understanding among partners of monitoring needs and the costs of monitoring, thereby contributing to informed partner buy-in. Having a well-defined monitoring approach before implementation begins also allows a more systematic collection of pre-project baseline information against which change can be measured.

Communicate with Funders

The coordinator and other key monitoring partners should seek to establish open and frequent communication with funders — especially funders who are engaged with and responsive to a restoration initiative's projects and needs. Robust communication ensures funders' expectations are understood and the partnership's needs are made clear. An open and transparent relationship with funders ensures that opportunities for flexibility and creative problem solving can be fully explored.

Recruit Regional Partners

In some situations, a partnership's work has relevance to larger regional scale restoration and monitoring programs. Local and regional groups involved in related restoration, monitoring, or research may be addressing similar monitoring questions. If relevant regional interests are not already members of the partnership, there may be value in targeted outreach.

Use Volunteers and Seasonal Field Crews

Citizen science and strategic hiring of field crews can contribute additional capacity. Working with dedicated volunteers and engaging the public can increase capacity to collect data, especially for temporally intensive (e.g., 1-2 sampling days) or spatially extensive (e.g., multiple tributaries) sampling efforts. However, adequate time needs to be dedicated to recruiting, managing and motivating volunteers.

Consider Cost-share Agreements

Establishing cost sharing agreements with agencies that have an interest in or mandate to collect data that meets the partnership's needs can expand monitoring capacity and provide in-kind match for other monitoring grants.

Monitoring Plan Design Efficiencies

To ensure that monitoring is streamlined and cost-effective, it is important to limit a monitoring plan to the minimum set of metrics a partnership needs to evaluate progress and select monitoring protocols that maximize implementation efficiency (See *Monitoring Protocol,* pg.14). For instance, partnerships should assess the cost-effectiveness of hiring seasonal field crews and providing training to conduct surveys versus contracting with a dedicated survey crew.

Plan Beyond Funding Cycles

Although funders recognize the importance of monitoring to document a return on their restoration investments, funding for monitoring is often limited and constrains the ability of restoration practitioners to implement consistent long-term monitoring programs. Ensuring continuity of monitoring staff (or institutional knowledge) is important for sustaining capacity, institutional knowledge, and experience. Many partnerships diversify their funding sources beyond primary project support to sustain monitoring beyond program funding cycles.

Entiat River Watershed, WA

Monitoring Plan Components

The first essential task in developing a monitoring plan is to determine what information is needed to evaluate restoration progress and inform adaptive management. The second task is to determine how best to efficiently acquire that information, so it is reliable and accurate. Other key components of a monitoring plan include data management and processes for data analysis, reporting, and communicating results (Figure 2). An example of a monitoring framework showing monitoring questions, protocols, and data management is provided in Appendix A.

1 Monitoring questions

Implementation and effectiveness monitoring are intended to measure the extent to which an initiative's expected outcomes are being realized and how well implemented strategies and actions are working in practice. For Focused Investment Partnerships, goals, strategies and actions, outputs, and desired outcomes are described in a Strategic Action Plan.

OWEB's strategic action planning guidance describes the theory of change, a useful tool for identifying and selecting key monitoring questions. The theory of change (which may consist of a results chain and narrative) articulates the hypothesized relationships between implementation outputs and ecological outcomes a partnership may want to measure to evaluate progress. The basic underlying assumption is that achieving implementation objectives will produce the desired ecological outcomes.

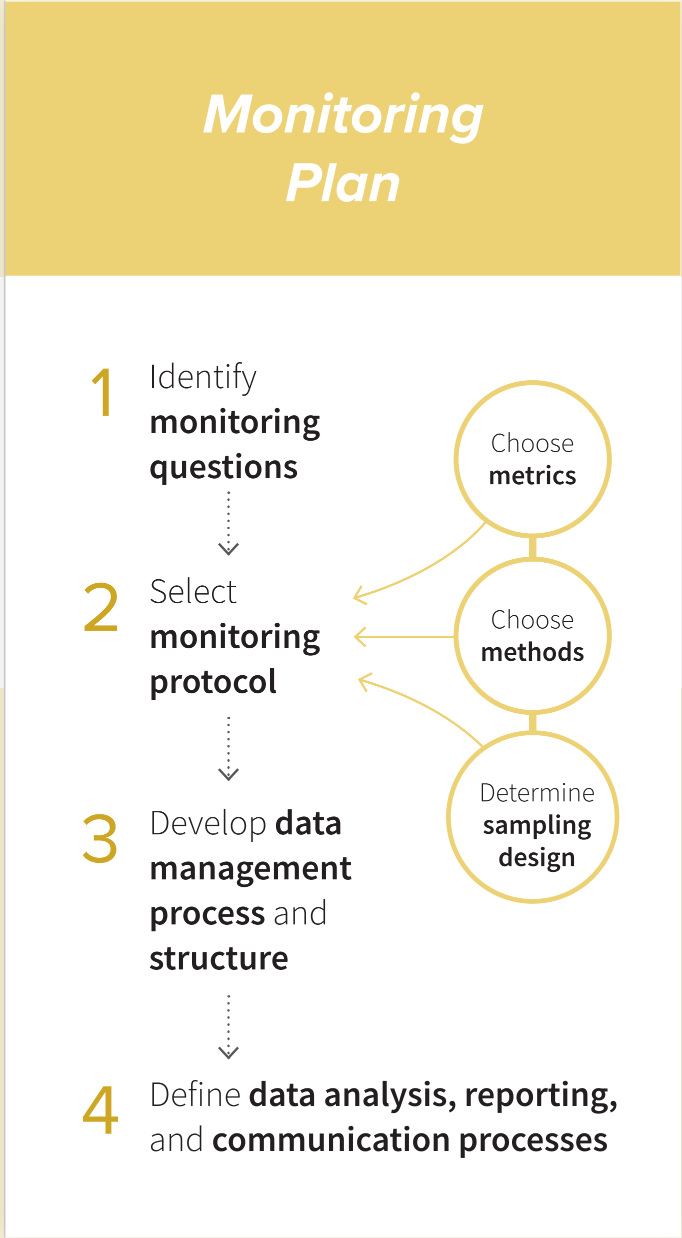


Figure 2. Steps in Developing a Monitoring Plan

A monitoring plan therefore seeks to answer three general categories of monitoring questions:

1. **Do the prescribed actions defined in the Strategic Action Plan (and resulting implementation outputs) produce desired ecological outcomes as defined in stated objectives?**
2. **Do the near term (or intermediate) ecological outcomes lead to longer term ecological outcomes and ultimately the restoration vision?**
3. **Is our understanding of hypothesized relationships between elements in our theory of change accurate?**

These overarching questions can be downscaled to address and frame monitoring for specific hypothesized outcomes. Figure 3 contains a partial hypothetical theory of change showing the key elements needed to develop a monitoring question. In this case the monitoring question could be: "Does restoring 30 cubic feet per second of flow lead to a desired stream temperature regime?"

The Progress Monitoring Framework section of the OWEB strategic action planning guidance outlines the step of defining measurable objectives for each selected output and outcome. An **implementation objective** states the type, scale, location, and timing of actions related to a strategy. An **ecological outcome objective** states the degree, direction, and timing of change predicted for a specific outcome.

Results chains are described in *Open Standards for the Practice of Conservation—Conservation Measures Partnership 4.0 2020*; and in the OWEB Strategic Action Plan guidance.

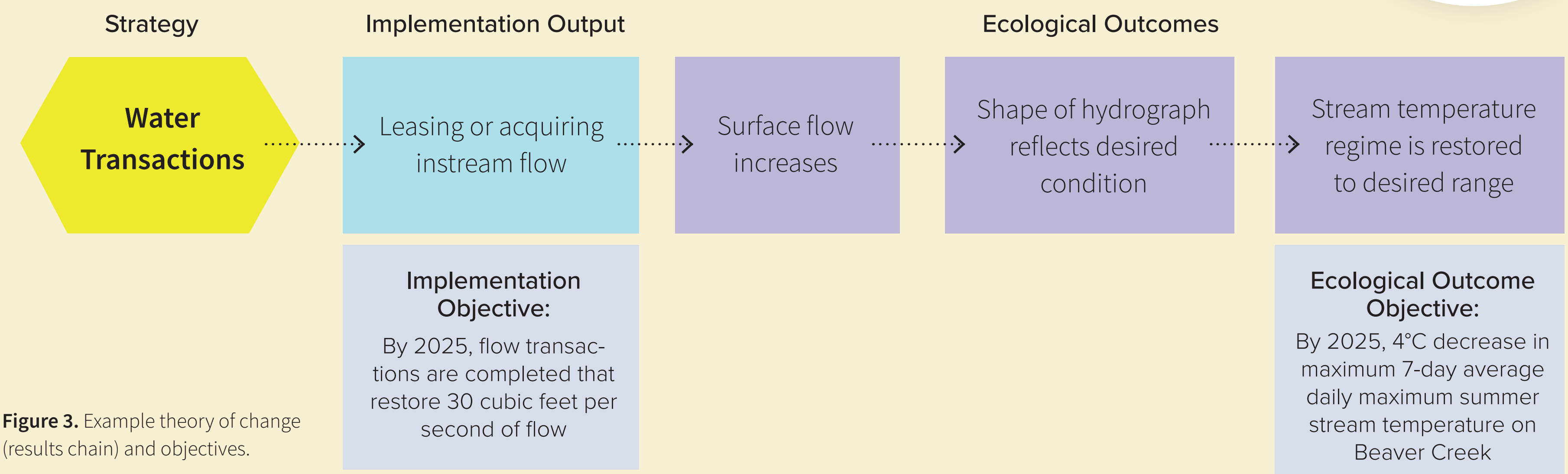
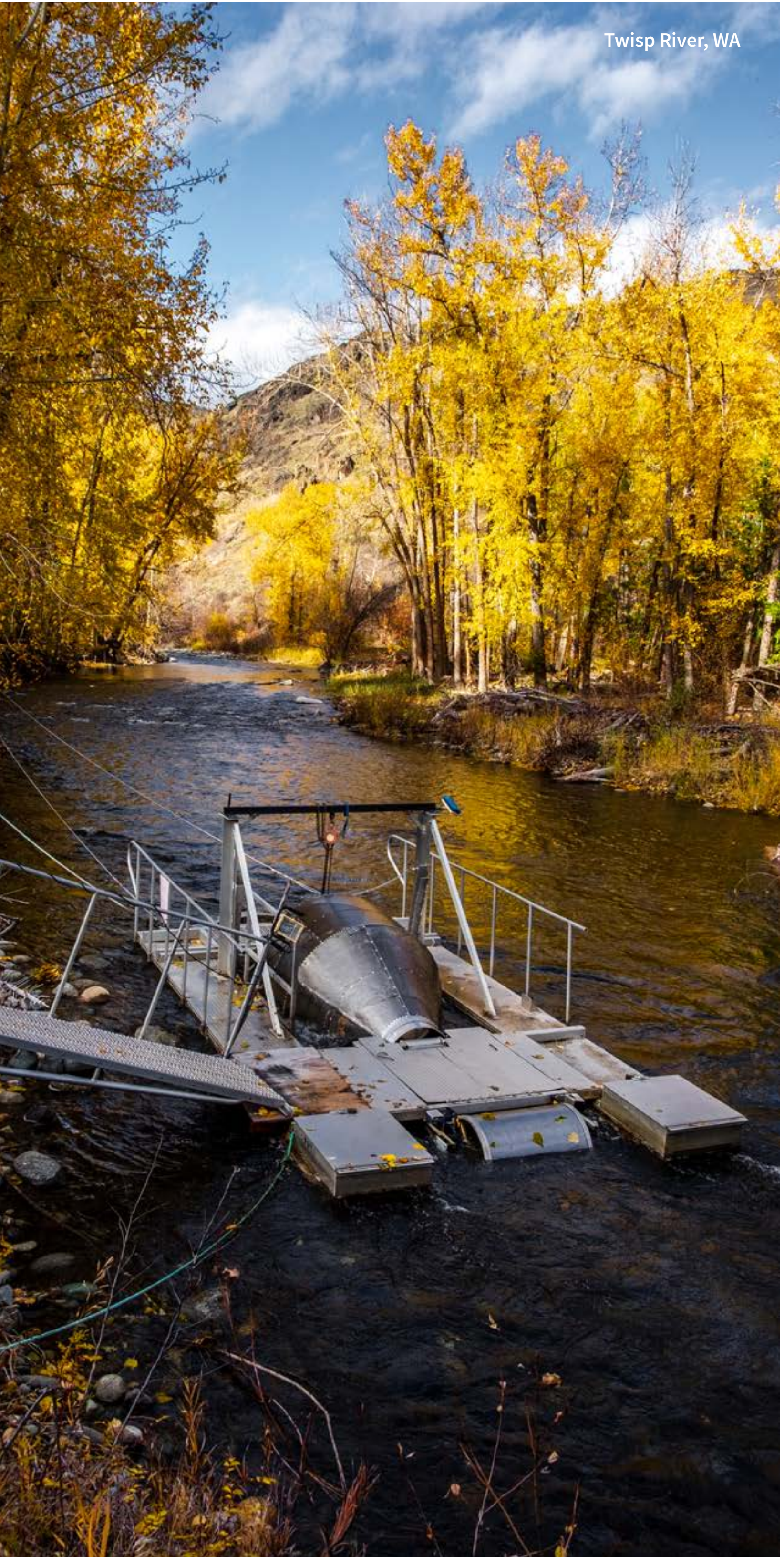


Figure 3. Example theory of change (results chain) and objectives.



Critical Uncertainties

Some of the most useful monitoring questions address situations where uncertainty is high, or outcomes of a particular action may be variable. Exploring these situations will likely mean deeper examination, additional time, and involvement of people with expertise in different aspects of the system being restored, including knowledge of the outcomes of past restoration efforts. In those deliberations, participants review not only planned actions, outputs, and outcomes but also insights from research and past monitoring data and experience.

Conceptual models and results chains (Figure 3) are particularly helpful tools for identifying areas of uncertainty. Both help partnerships articulate their assumptions for how an ecosystem functions and is expected to change as a result of implementing restoration actions under their strategic plan.

Ecological outcomes of restoration actions that are well understood and documented may be a lower priority or may require less rigorous or no monitoring at all.

Exploratory Research

In some restoration contexts, research may be needed to advance knowledge about drivers of ecosystem function that inform restoration strategies or define objectives. It can be helpful to differentiate which information needs are fundamental to describing outcomes of restoration and which require a research approach to inform what restoration actions are needed.

If there is a high degree of uncertainty about the set of environmental factors that contribute to the status of an ecological priority (species, habitat, or ecosystem) the partnership may choose to conduct focused research that answers key questions about the relative importance and nature of ecosystem stressors before it invests resources in strategy implementation.

Or, if the ecological circumstances are well understood but there is uncertainty or disagreement about the intervention (type, location, scale, or timing), a partnership may elect to conduct research in the form of ecosystem modeling to explore the potential effectiveness of a range of interventions or treatments.

Selecting and Refining Monitoring Questions

To provide useful feedback, selected monitoring questions should be answerable in a relatively short timeframe (months or years, not decades). Objectives selected for monitoring should be feasible to measure given available resources and expertise.

The temporal and spatial scale necessary to measure achievement of objectives will also inform selection of outcomes to monitor (and metrics to measure them). For example, changes in wildlife for fish populations may not be evident for several years or decades, but changes in habitat attributes important to the species of concern may be measurable in just a few years. Similarly, for a wide-ranging species, a landscape-scale metric such as habitat connectivity may be a more useful metric than a project-scale habitat attribute metric.

The list of questions below are useful for prioritizing which ecological outcomes a partnership may choose to monitor.

- Will it inform whether strategies and actions are helping achieve the desired outcomes linked to long-term restoration goals?
- Is there already general agreement about the probability that selected restoration actions will produce desired outcomes?
- Does the question address a critical uncertainty about the relationship between outputs and outcomes—or near-term outcomes and long-term outcomes?
- Do reliable and affordable methods exist for measuring the outcome?
- Is the monitoring required to answer this question feasible, given available partnership capacity and resources?
- Will monitoring data determine change in a useful timeframe?
- Will monitoring a specific outcome complement an existing monitoring effort?

2 Monitoring protocol

Monitoring questions are answered by gathering and analyzing data using a monitoring protocol. For the purposes of this guidance, a protocol consists of metrics, methods, and sampling design (Table 1).

ELEMENT	DEFINITION	EXAMPLE
Metrics	Specific measurable parameters that can help evaluate degree of action implementation or change in a desired ecological outcome	**Implementation metric:** acres of riparian area planted **Ecological outcome metric:** Number and percent cover of native riparian species
Methods	Specific techniques used to collect and analyze data associated with a metric	Wolman pebble counts
Sampling Design	Defines where, when (timing and frequency), and number of samples	Simple random sampling; stratified random sampling; line transects Before-After (BA); Before-After-Control-Impact (BACI); Extensive Post-Treatment (EPT)

Table 1. Elements of a monitoring protocol.

Protocols vary in their accuracy, reliability, and cost-effectiveness. Precise metrics, appropriate methods, and rigorous sampling designs can, when carefully applied, produce high-quality data that support inferences about ecosystem conditions and restoration outcomes. Rigorous effectiveness monitoring can be prohibitively costly for most restoration partnerships and tradeoffs are almost always required. Ultimately, the monitoring protocol selected or designed must be feasible given the partnership's data collection and analysis capacity and budget. It may be possible to find efficiencies or cost savings. *(See Adequate and Sustained Funding* pg. 8*).*

Another consideration when selecting a monitoring protocol is how the results will be used to answer the monitoring question. In some cases, the question may simply be to ascertain how key metrics at a project site have changed after treatment. In other cases, there may be a need to aggregate data from several projects to evaluate conditions at the watershed or landscape level, or to track conditions for a wide-ranging species. When there is a desire to compare or aggregate monitoring results, it is important that the protocols be similar enough that results can be accurately compared.

Steps in identifying and selecting a monitoring protocol:

1. Review established protocols
2. Match protocols to the scale of projects and anticipated ecological effect
3. Consult with technical experts to determine whether existing protocols can provide relevant and reliable results in a reasonable timeframe, given the specific ecosystem and restoration goals
4. Consider costs and benefits of alternative protocols
5. Select the most efficient and cost-effective protocols that will provide applicable and reliable results in a useful timeframe.

▶ *Review Established Protocols*

For many restoration contexts, there are standard protocols. Established approaches provide continuity and comparability with other monitoring efforts, advancing the ability of the restoration community to make inferences about restoration outcomes. Use of these protocols may offer a higher likelihood that results will be broadly accepted. In situations where established protocols do not adequately address monitoring questions they can still serve as a sound foundation for designing an enhanced or modified monitoring approach that is consistent with accepted standards. For example, protocols developed for in-stream habitat status and trends monitoring do not adequately measure wood placed on the floodplain during restoration, and may therefore be insufficient to evaluate floodplain restoration strategies, but in-channel wood measurements collected under a standard protocol can be supplemented with floodplain wood surveys.

Examples of Established Protocols

by Ecological Priority

The following resources may provide a starting point for partnerships developing monitoring protocols.

Aquatic Habitat for Native Fish Species; Coho Habitat and Populations along the Coast

- Pacific Northwest Aquatic Monitoring Partnership offers a suite of tools and resources that support coordination of monitoring efforts and cost-effective planning. https://www.monitoringresources.org/
- The Oregon Department of Fish and Wildlife's Aquatic Inventories Project provides quantitative information on habitat condition for streams throughout Oregon and provide information for the establishment of monitoring programs. https://odfw.forestry.oregonstate.edu/freshwater/inventory/index.htm
- The Oregon Department of Fish and Wildlife Natural Resources Information Management Program provides data standards for research and monitoring associated with monitoring salmonid populations and their habitats. https://nrimp.dfw.state.or.us/nrimp/default.aspx?pn=datastandards

Closed Lakes Basin Wetland Habitat

- The approach developed by J. Patrick Donnelly (USFWS) and others in two published articles provides example approaches for monitoring both long-term and short-term changes in wetland or shallow water habitat distribution.

  Donnelly et al. 2019 https://doi.org/10.1002/ecs2.2758
  Donnelly et al. 2020 https://doi.org/10.1111/gcb.15010
- Albano et al (2020) outline an approach to monitoring that accounts for variation in climate, shallow groundwater, and groundwater dependent vegetation in Harney Basin, OR. https://www.researchgate.net/publication/340237424_Status_and_Trends_of_Groundwater_Dependent_Vegetation_in_Relation_to_Climate_and_Shallow_Groundwater_in_the_Harney_Basin_Oregon

Coastal Estuaries

- Tidal Marsh Monitoring offers information on tidal marsh monitoring design, selection of appropriate methods, and downloadable standard operating procedures, datasheets and database templates, and a restoration forum for restoration practitioners, managers, scientists, and the interested public. http://www.tidalmarshmonitoring.net/index.php
- The Lower Columbia Estuary Partnership updated their habitat restoration monitoring protocols in 2018 and 2019 for habitat attributes such as hydrology, water quality, elevation, plant communities, and fish communities. https://www.estuarypartnership.org/our-work/monitoring/monitoring-protocols

Dry-Type Forest Habitat

- The Lakeview Collaborative Forest Landscape Restoration Project Monitoring Plan describes a process used to develop and prioritize ecological, social, and economic monitoring questions, the role of a science team, and metrics, protocols, data storage, and budgets for answering each of the selected monitoring questions. The document includes references to more detailed protocols for specific metrics. https://ewp.uoregon.edu/sites/ewp.uoregon.edu/files/WP_60.pdf
- The Front Range Roundtable Collaborative Forest Landscape Restoration Project's 2018 Ecological, Social and Economic Monitoring Plan includes detailed protocols for forest vegetation structure and composition, fire behavior and severity, and economic impacts, and discusses approaches to monitoring wildlife, spatial heterogeneity, and levels of collaboration. This document also discusses monitoring in an adaptive management framework. https://cfri.colostate.edu/wp-content/uploads/sites/22/2018/10/2017_FR_CFLRP_Monitoring_Plan_Typeset_2018.pdf

Oak Woodland and Prairie Habitat

- The Cascadia Prairie-Oak Partnership's website contains a comprehensive technical library with links to resources that include reports and approaches to monitoring a variety habitats and species. https://cascadiaprairieoak.org/technical-library

Sagebrush/Sage-Steppe Habitat

- Upper Columbia Basin Network Sagebrush Steppe Vegetation Monitoring Protocol (Yeo et al. 2009) contains a protocol narrative and a set of standard operating procedures which detail the steps required to collect, manage, and disseminate the data representing the status and trend of sagebrush steppe ecological condition in the Network.
- Chapter 3 (Monitoring Conservation Actions) of the Greater Sage-Grouse Comprehensive Conservation Strategy (Stiver et al. 2006) outlines all aspects of monitoring sage-grouse population and their habitats.

▶ *Consult Subject Matter Experts*

When restoration plans include outcomes not easily measured using existing protocols, and when restoration projects present high complexity or uncertainty, it can be useful to recruit outside technical expertise to provide guidance.

Experts can help:

- Identify the most appropriate or useful metrics,
- Share new methods that might not be widely applied or previously considered, and
- Support development of an appropriate sampling design.

Using clear questions to guide discussions with technical experts (rather than seeking a general critique) can serve to retain a focus on what practitioners need to know to develop an appropriate monitoring approach.

One possible avenue for recruiting technical expertise is to establish partnerships with research institutions, including working with university graduate advisors and students. Consultants can also provide expertise and add capacity, particularly in instances where a specific product is needed. State and federal agencies that have research departments such as the Oregon Department of Fish and Wildlife Corvallis and La Grande Research Stations, the US Geological Survey Oregon Water Science Office, and the US Forest Service Pacific Northwest Research Station are examples where partnerships have gained expertise in planning and implementing effectiveness monitoring efforts.

Choose **metrics**

Metrics are measurable variables (also sometimes called indicators) used to define the degree and direction of change in an output or outcome, for example, water temperature, biota abundance, spatial extent of a habitat type, etc. The most appropriate metrics to measure are those that provide the information most relevant to the objectives defined in the strategic action plan.

For a given **ecological attribute** ***(aspect of an ecological priority that defines its status or condition)***, there are typically standard metrics that have been demonstrated, often through published studies, to be accurate and reliable measures of change in a particular ecological parameter. In cases where an established sampling protocol is selected, the metrics will, to some degree, be dictated by the protocol. Similarly, measurement and reporting of specific metrics may be required as a condition of receiving funding from various sources. Partners should carefully evaluate which if any of the metrics required will provide information on the ecological outcomes they have selected for monitoring, while also accounting for the monitoring needed to fulfill the funding requirement.

Factors to consider when selecting metrics:

- Responsive to restoration: sensitive enough to measure change resulting from restoration actions and responsive within monitoring timeframe
- Can be directly measured
- Ease and cost-effectiveness of measurement
- Whether baseline data already exists
- Spatial and temporal scale, as the variability in the metric might change with scale
- Keep it simple — measure as few metrics as possible.
- Account for natural variability
- Collect more detailed data for some parameters for greater nuance

In restoration contexts where there is high uncertainty about the relationships between actions and ecological outcomes, commonly used metrics might not fully describe or quantify the aspect of an outcome assumed to be important, and new metrics might be proposed for measurement and evaluation.

For example, specific metrics and criteria that have been used to describe salmon spawning habitat in degraded streams, such as habitat unit, depth, percent gravels, and percent fine sediments, might not capture the range of conditions salmon can use for spawning in more connected, restored stream-wetland complexes. In such cases, it can be useful to work with subject, monitoring, or research experts to identify appropriate metrics.

Selecting the minimum set of metrics that will give you the necessary information will allow you to collect critical information as cost-effectively as possible.

Choose **methods**

Methods are the techniques used to gather data on selected metrics. For example, composited samples collected from several locations using a kick-net are a common method for sampling benthic macroinvertebrates in a stream. It is important that the chosen methods are appropriate for the expected ecological outcome and the associated objective. They should provide information that is specific, accurate and reliable, and be cost-effective and feasible to measure.

The methods used to measure parameters or ecological conditions determine the **quality** ***(accuracy and precision)***, **repeatability, and comparability of that information.** For many restoration contexts, established and published methods exist for generating metrics of interest, as well as for meeting Quality Assurance and Quality Control (QA/QC) standards required by some funding programs (e.g., Clean Water Act 319 grant program). Using established methods provides a basis for comparability across restoration projects and sites. There are situations where partnerships may need to identify alternative methods that will provide the desired information with a supportable investment of time, funding, and staff capacity. One such example is in the case of new or emerging restoration strategies or approaches, such as "Stage 0" projects designed to reactivate floodplains, where new methods are needed to evaluate novel outcomes associated with this restoration approach. In other cases, programmatic sampling protocols (e.g. the Columbia Habitat Monitoring Program, CHaMP) might be prohibitively extensive or expensive for restoration practitioners to implement on their own.

Mattole River Watershed, CA

Considerations when choosing methods:

- Use measurement techniques that reduce subjectivity and opportunity for observer bias, e.g. sampling grids for plot estimates
- Combining protocols or introducing new methods or metrics can result in lack of comparable pre-project data or inability to assess change over time. Changes made to protocols should be carefully considered before implementing them (See *Adaptively Managing Monitoring Plans,* pg. 8).
- Due to the need for consistent protocols, long-term monitoring programs need to be thoughtful when incorporating advances in monitoring methods such as remote sensing, eDNA, etc.
- Ensure that new protocols can be compared to baseline data and that information gained is worth added cost for labor-intensive methods
- Ensure contractors and field crews understand programmatic implications of changing methods or not implementing methods consistently

Determine **sampling design**

Sampling design determines the ability of a monitoring effort to provide the desired statistical rigor or confidence in the resulting information.

Sampling design components include:

- Sampling locations and reference sites;
- Sampling timing and frequency;
- The number of samples necessary for the desired level of statistical rigor (confidence in monitoring data);

The degree of uncertainty about the relationship between restoration actions and desired ecological outcomes can inform the degree of statistical rigor that is appropriate and needed to evaluate changes in selected ecological outcomes. The amount and duration of funding, staff, and technical capacity available for effectiveness monitoring will also inform the level of effort or investment (monetary or time) a partnership can support. These two considerations can in turn inform development of a sampling design.

Where there is a clear, well-established, and widely accepted relationship between restoration actions and desired ecological outcomes, it might be sufficient to focus on implementation monitoring and demonstrate effectiveness without using a rigorous sampling design. Examples include: elimination of barriers to fish passage for species with well-understood requirements for passage, and proven treatments for controlling invasive weed populations.

Where there is greater uncertainty, controversy, or stakeholder interest about the effects of restoration actions or a desire to demonstrate a causal relationship, use of a statistically rigorous sampling design may be required to provide the data necessary to evaluate cause and effect (for example, use of power analysis to determine sample size).

Finally, practitioners should evaluate what sampling design was used to collect any existing pre-restoration data that could be used as a baseline for future monitoring and, if appropriate, align the sampling design to ensure data collected are comparable to baseline data.

▶ *Sampling Location, Timing, and Frequency*

On large-scale projects where it is not feasible to monitor every project site or area, it will be necessary to select a subset of representative sampling locations. The most common spatial sampling designs are to randomly select sites across all possible locations (simple random sampling), or to group sites according to variables that are expected to influence ecological responses - and then randomly sample within each group (stratified random sampling). For example, in the case of stream restoration, sampling across multiple projects might be stratified by time since restoration action(s) are completed, so that projects restored in different years would each have the same number of randomly located samples. However, stratified random sampling will often require a larger overall sample size to meet sample size requirements.

The timing and frequency of sampling will vary depending on the metric being measured. Time of day, season, and weather conditions may all cause variations that should be considered. Because ecological change and response to restoration actions can take years or decades, sampling design needs to be aligned to the timeframe over which an ecological response is expected to occur for any given metric.

The appropriate sample size may be determined based on a power analysis to identify how many samples are needed to provide the desired level of statistical certainty. Roni et al (2005) provide a useful discussion of how to perform a power analysis.

Spatial and temporal considerations when determining sampling timing:

- Align timing to the project and monitoring objectives (e.g., projects that improve winter habitat for fish should be monitored during winter low flows).
- Consider species life history and limiting factors when determining monitoring timing and location.
- The frequency of monitoring for different parameters should be evaluated.
- Determine the sampling window for each metric.

▶ *Accounting for Variability*

High variability can make it difficult to detect change resulting from restoration, compare data between years, or examine trends. Variability should be accounted for in both the design and implementation phases. During the design phase, use of stratification, selection of less variable parameters, creation of rigorous protocols, and identifying the sufficient number of samples to be collected can reduce and mitigate unnecessary variation.

During the implementation phase, unnecessary variation can be minimized by maintaining consistent sampling locations/timing and field methods, reducing observer bias (i.e., training to reduce differences in how observers collect data), and managing data well. Similarly, ensuring collection of a sufficient number of samples (and potentially collecting more samples than the minimum number needed in the event of data loss) can improve the ability to detect differences due to restoration.

▶ *Control and Reference Sites*

In restoration initiatives where uncertainty or natural environmental variability is high, it may be desirable to incorporate control and/or reference sites. These are locations a partnership can monitor (in addition to sites where projects are implemented) to account for the natural variability in the ecosystem and any unanticipated environmental changes. Control sites share similar attributes to the restoration site(s) but are locations where no restoration action is implemented; reference sites are sites that represent the desired condition of restoration sites, but which remain in an undegraded state. Integration of appropriate reference and control sites improve a partnership's ability to distinguish between changes they observe that are the result of the restoration action taken and those that are the result of natural variability (See *Examples of Sampling Designs,* pg. 20*).*

In spite of the potential value, most restoration partnerships find it challenging to integrate control or references sites into their monitoring plans because it adds to monitoring costs, locations that are well-matched (in terms of size, character, etc.) to project sites reaches are difficult to find and maintain, and withholding restoration from sites that need treatment (control sites) can compromise a partnership's project implementation schedule (See *Examples of Sampling Designs* for alternatives, pg. 20*).*

Examples of Sampling Designs

Three designs have emerged as the most commonly and successfully applied for evaluating the effectiveness of aquatic restoration projects: Before-After (BA), Before-After Control-Impact (BACI), and Extensive Post Treatment (EPT) (Roni 2005, Roni et al 2018). Although the following summary of sampling designs is drawn from studies of stream, river, and watershed restoration initiatives, these designs are also applied in other ecotypes, such as forests, woodlands, and grasslands.

In a BA design, effectiveness monitoring data are collected before and after restoration project implementation at an individual or multiple restoration project sites. A BACI design adds data collection in a control site characterized by similar pre-project conditions as the restored site, over the same time frame as data collection in the restored site. A BACI design is often considered the gold standard for effectiveness monitoring but is not always feasible in terms of monitoring time and money, or, in some cases, suitable control sites are not available. EPT designs use data collected, using standardized methods, only post-restoration, but in paired treatment (restored) and control sites. (Table 2)

These designs can be applied to evaluate projects at various scales (Table 3). A multiple Before-After-Control-Impact (mBACI) approach coordinates monitoring of multiple restoration projects using a BACI design replicated across projects within one or multiple watersheds. A variant of this design is multiple Before-After (mBA). Case studies of individual projects using BACI or BA design and mBACI or mBA approaches can answer questions about individual projects but have limitations in terms of cost, timely results, and feasibility. A meta-analysis can provide broadly applicable results by comparing results of multiple case studies but is dependent upon a large number of case studies and technical review being completed. EPT designs are used with an EPT monitoring approach to evaluate multiple projects and their paired control sites post-treatment, also within one or multiple watersheds or other geographic units. By requiring only one sampling event per paired control and treatment site with a longer return interval or none at all, the EPT approach can provide relatively quick and easy-to interpret results, but requires a large population of completed projects and careful selection of controls (Roni, Aberg and Weber, 2018). The Intensively Monitored Watershed approach most often uses BACI and BA designs to evaluate effects of multiple or large-scale projects throughout a watershed. Hybrid approaches employ elements of multiple study designs, for example using a combination of more intensive BACI case studies of individual projects at a small number of sites, and an EPT design at a larger number of sites.

Monitoring Approach or Design	Sampling (Experimental) Designs	Description
Multiple Before-After Control-Impact MBACI	**BA** or **BACI**	Evaluation of multiple projects using a before-after or before-after control-impact and standardized data collection methods so the data are analyzed collectively rather than by individual projects. Thus, including multiple treatment (impact) and control reaches or watersheds.
Extensive Post-treatment EPT	**EPT** (of treatment and control site)	Evaluation of multiple projects post-treatment (after restoration has occurred) using paired treatment (restored) and control reaches and standardized data collection methods.
Intensively Monitored Watershed IMW	Various, most often **BACI** or **BA**	Evaluation of restoration efforts (cumulative effects of multiple projects or effects of large-scale projects) throughout a watershed, using standardized data collection methods, to determine the wider response of biota and physical habitat.
Hybrid	Combination of **BACI, BA,** and/or **EPT**	Use of any combination of the approaches to evaluate effectiveness of restoration projects or techniques. A combination of designs (BACI or BA and EPT) can also be used to monitor different indicators within the same project.

Table 2. Example monitoring approaches for evaluating multiple restoration projects and applicable sampling (experimental) designs (modified from Roni 2005 and Roni et al 2018).

The most appropriate sampling design depends on:

- the information needs or monitoring questions that the partnership desires to address,
- the spatial and temporal scale at which detection of a response is expected, and
- the scale of inference.

Name	Scale	Designs	Notes/examples
Reach	~ few hundred meters to several kilometers	**EPT, MBACI,** or hybrid of the two	Most restoration projects occur at scale of a few hundred to few thousand meters (2 km). EPT is most efficient if lots of projects, MBACI often feasible for small number of projects, except for riparian projects.
Network	Few kilometers to 100 kilometers	**BA**	Examples: Middle Entiat, Yakima Gap to Gap; BACI may be possible, but finding a within basin control is often difficult for long reaches.
Watershed	Entire drainage basin 50 km^2 to 1000s km^2	**BACI** or **BA**	Straits, Hood Canal, Asotin IMWs

Table 3. Three major scales at which restoration and effectiveness monitoring can occur and optimal experimental designs for each. Used with permission from Phil Roni; modified from Roni 2005 and Roni et al 2018.

3 Data Management

Data management, including data recording, data storage, and data file sharing, determines the quality, accessibility, and ultimate utility of data collected during monitoring. A monitoring plan should include a clear, rigorous approach for data management to address in detail each stage of the data life cycle as well as the roles and responsibilities of data providers, managers, and users.

Monitoring data represent a significant investment of time and resources, and diligent data management is essential to ensure data are accurately recorded and readily available for restoration practitioners and partners to use to evaluate their restoration efforts and inform future work.

The US Geological Survey (2021) describes best practices for each stage of the data life cycle as well as for the three "cross-cutting" elements that occur throughout the life cycle. These best practices are summarized below.

The data life cycle includes:

1 Planning;
2 Acquisition;
3 Processing and analysis;
4 Storage and sharing, including publication

Three additional elements occur throughout the data life cycle:

- Description and documentation;
- Quality assurance and quality control; and
- Data backup.

Planning for Data Management

Planning for data management should include developing and detailing data management systems for documentation, quality assurance and quality control, and data backup throughout data acquisition, storage, and sharing.

Practices shown to improve the success of data management include the following elements:

1 Consider data management needs and costs early in monitoring planning.

2 Explicitly identify the data manager roles and responsibilities. Where resources allow, assigning data management responsibilities to someone other than the monitoring coordinator can increase the effectiveness of both roles.

3 Include data management activities and deliverables in project budgets and contractual requirements.

Description and Documentation

Metadata provide a description and documentation of how, when, and where data are collected, compiled, or created; by whom; and for what purpose or within what context. Documentation may include a description of the methods or techniques used to collect, process, and analyze data; of the accuracy and precision of the data; and methods of quality assurance. Metadata allow any user of the data to evaluate its quality and applicability for other purposes. However, there are situations where participating landowners may request that personal and/or commercial information is not disclosed or made publicly available, for example, landowners enrolled in the programmatic Candidate Conservation Agreement with Assurances (CCAA) programs associated with greater sage-grouse conservation.

▶ *Spatial Data*

Maintaining a complete inventory of monitoring locations and available data for each location avoids loss of utility as a result of not being able to associate data with a spatial location. Maintaining accurate spatial location data can also facilitate communicating and coordinating with local and regional monitoring partners to reduce duplication of efforts in the same location.

Quality assurance and quality control

Quality Assurance and Quality Control (QA/QC) measures applied before, during and after data collection ensure data are collected and validated using standard practices and that the resulting values are within acceptable ranges of accuracy and precision. Quality assurance is conducted prior to data collection and is designed to prevent the creation or recording of defective data. Quality control is conducted during and after data are collected and serves to detect defective data. For some commonly sampled parameters, QA/QC measures are well-established and examples can be located in existing protocols. Some funders may require grantees to develop and operate under a Quality Assurance Project Plan or Sampling and Analysis Plan for certain parameters to ensure data meet federal, state, or other institutional quality standards. For monitoring parameters without established QA/QC practices, it is important to document the process followed for data validation and to provide a record of whether, how, and according to what information, data were corrected or manipulated.

▶ *Protocol Documentation and Training*

Clear, standardized, documented sampling and analysis protocols reduce measurement bias and variance and are especially important when multiple entities are doing the data collection and analysis and when there is a desire to aggregate or compare data from multiple sites. Protocols should be documented, and documentation should be updated when protocols change for any reason to reduce uncertainty and erroneous conclusions when comparing data. The protocol documentation should be considered part of the monitoring plan metadata and maintained as such.

Protocol training contributes to quality assurance by ensuring data are collected according to the selected methods and protocols. Building in ample time and budget to train field crews in sampling and survey protocols promotes more consistent implementation of protocols resulting in more accurate and repeatable data.

Chain of custody, describing the series of individuals who manage data from collection to reporting, is also important to record, and may be documented within protocols.

Data Backup

Backing up data at every stage of the data management process ensures the resources invested in data collection result in discoverable and useful data. For paper survey forms this often means routinely digitizing forms at the earliest possible opportunity, while retaining the original forms. For survey forms in spreadsheet software on tablets, this may mean uploading a form edited offline to cloud or computer storage. When data collection is complete, raw and processed data may be preserved within a cloud storage service.

Data Acquisition

Considerations for data acquisition include use of data standards; data templates; and organization of files and data.

▶ *Survey Forms and Data Templates*

Building a survey form (datasheet) that accounts for the comprehensive list of measurements included in a sampling protocol reduces error and omissions in data collection. Entering data directly into spreadsheet software on a tablet reduces time and eliminates potential error in data entry. However, it also introduces the need for careful management of the spreadsheet file on the tablet. Building an app-based survey form through a proprietary or open-source platform (e.g. Claris FileMaker, Survey123 by ESRI, or open-source QField developed by QGIS) can provide the additional benefits of associating and exporting spatial data and other documentation such as photos, but often presents a learning curve and requires time investment up front. In most or all of these software programs, forms can be created so that only a certain data type can be entered in a field, and pull-down menus can be built to restrict entries to a pre-defined list of options, further reducing opportunity for error. For monitoring projects that represent one element of a broader landscape-scale or regional effort, a survey form may be generated from and integrated into an existing database. If using or adapting an existing methodology or protocol, a survey form or template may be included with the methodology or protocol.

▶ *Data File Organization*

The data files resulting from data collection represent a significant investment of time and resources, and diligent data file management is essential to ensuring data collected are not lost and remain available in an accessible format for restoration practitioners and partners to use. Establishing and documenting a clear, logical organizational structure and using consistent naming conventions for files and folders improves the accessibility of data. Using consistent naming conventions to denote file versions provides version control. Using automated backup software mirrors and preserves file structures. Backing up data as soon as possible after it is collected, by scanning hard copies and storing electronic files in multiple locations, reduces risk of data loss and promotes good organization of data files that in turn contributes to data sharing and use. Entering and proofing data immediately after collection allows the best opportunity for any questions about recorded data to be resolved. Rosgen et al. (2018) wrote that using scripted QA/QC processes to review data, rather than people familiar with reach-level data, resulted in an inability to identify major survey errors that emerged after many years of data collection.

Data Storage and Sharing

A data storage system can be as simple as an electronic filing system or as sophisticated as a customized database developed by a consultant. At a minimum, a data storage system should include redundancy, with files backed up in a second location, on a server which backs up files at regular intervals, or in cloud-based storage. Ideally a data storage system includes some documentation of file or database structure that will allow someone other than the primary data manager to navigate the system to access data. Increasingly, cloud-based file storage services are a solution for some of the persistent challenges in data management, providing storage for larger file sizes such as those associated with aerial imagery products, opportunities to easily share data, and storage where data is automatically backed up. Data security and access should be explicitly addressed in developing storage systems including in contracts with third parties to store data.

Best practices for creating and managing databases:

- Design database to facilitate data entry and analysis
- Design user-friendly databases to the extent possible
- Train users
- Review and update codes each year
- Summarize annually using consistent methods to check for outliers

High Desert, OR

Many departments of natural resources and environmental quality have designed and use databases that can be adapted or leveraged for data management by restoration initiatives; universities may also have capacity and databases or systems for storage of large volumes of data. One example is the Ambient Water Quality Monitoring System (AWQMS), the water quality monitoring data portal used by Oregon Department of Environmental Quality (DEQ). AWQMS also provides a direct exchange to the Water Quality Exchange network to integrate DEQ water quality data with US Environmental Protection Agency and US Geological Survey data.

Making data available through a website or online database can facilitate access by partners and the public and support analyses that provide new information about a system or contribute to management decisions.

4 Data Analysis, Reporting, and Application

Data processing describes the preparation of collected, compiled or generated data for distribution and for analysis. Data processing may include validation, transformations, integration of multiple disparate datasets, and/or derivation of new data values. Process documentation, recording how data were processed, allows others to understand what steps were taken and what decisions were made from acquisition through use.

Data Analysis and Reporting

Data analysis is the process of using established methods, tests, or models to descriptively or quantitatively evaluate the information conveyed by data.

There are three common approaches to data analysis:

1. **Comparative analysis**, wherein data from a restored site is compared statistically or graphically with data associated with the target
2. **Trend analysis**, wherein trends or changes in metrics are evaluated through time; and
3. **Predictive modeling assessment**, wherein values modeled from restoration project data are used to evaluate restoration outcomes.

Trend analysis requires data collected over a sufficient timeframe to measure change over time. The methods used to analyze effectiveness monitoring data should be informed by and correspond to project monitoring questions and monitoring design.

The monitoring plan should describe the milestones at which study design, data collection, data analyses, and findings will be reported in a technical report. To be most useful, monitoring data should be summarized annually and synthesized every 3-5 years. Methods or workflow for data analysis are ideally documented in a protocol, technical report, or appendix to a technical report.

Timely completion of data analysis and reporting relies on the monitoring coordinator to establish clear analysis and reporting timelines with partners and contractors and maintain clear communication about the status of analysis and reporting relative to those timelines. As with all other elements of monitoring, a budget should allocate funding for staff time or contracted services for data analysis and reporting.

Interpreting, Communicating and Applying Results

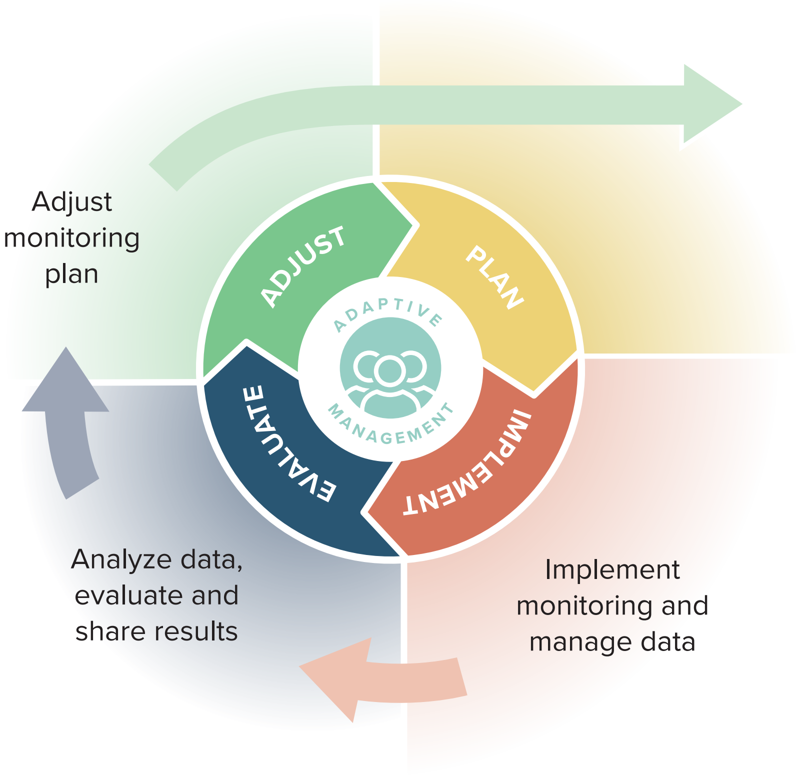
While data analysis is most appropriately conducted by monitoring experts, it is important to vet findings with a broader range of interests to bring relevant knowledge to bear and reach a common understanding of the implications of interim monitoring results for ongoing and future restoration work. Ideally, this is done collectively in regularly scheduled meetings (often annually) that include all relevant parties involved in the restoration effort. This may include, but is not limited to: practitioners who bring on-the-ground implementation knowledge, and those with expertise in different aspects of the system, such as tribal members with traditional ecological knowledge, aquatic biologists, botanists, and wildlife biologists, and landowners. By collectively reviewing analyzed data in the context of restoration actions undertaken to date and other system variables, the group can consider their implications for both future monitoring and future restoration activities.

These reviews are best done periodically, because in some cases it is possible to use interim monitoring results to assess project effectiveness and make midcourse corrections. In addition, it may be desirable to adjust monitoring questions, metrics, methods, or sampling designs based on new information.

Using the strategic action plan and theory of change diagram (results chain) can be particularly helpful during these reviews, as they help the partnership discuss monitoring results in the context of planned strategies and actions and expected outputs and outcomes. Participants may identify areas where changes in implementation plans affected outcomes, or where there have been unexpected outcomes. They can then discuss what, if anything, they might want to change to achieve better outcomes.

In addition to formal group reviews, it is helpful for all partners to know who is gathering and analyzing data, so they know who to go to when they have a question that may be informed by the data. In cases where monitoring collects information relevant to longer-term status and trends monitoring, communicating and distributing monitoring data and results to those partners who are monitoring status and trends ensures they are able to leverage and incorporate the new data and findings.

Adaptively Managing Monitoring Plans



With ongoing experience, research, and monitoring, our collective understanding of systems improves and monitoring methods evolve to reflect that new knowledge. It is useful to periodically review monitoring questions, metrics, methods, and sampling designs to determine which are useful and should be continued, which are no longer useful, and which should be changed to produce more useful or more reliable data.

OWEB's adaptive management guidance recommends that partnerships schedule regularly occurring review sessions at the end of the field season (e.g., annual or biennial). A review of the monitoring plan should be included in that initiative-scale reflection. Regularly scheduled, well-designed meetings allow partners to plan and prepare for substantive participation that informs the management of all aspects of the initiative. They also promote a culture of learning and a willingness to think critically about generally accepted practices and explore innovative or alternative practices. However, because the generation of useful and reliable data requires long-term consistency in effort and methodology, changes to monitoring plans need to be considered very carefully (See *Choose Methods,* pg.17).

In addition to technical peer review at the design stage, periodic review at pre-established intervals throughout the life of a monitoring project can improve monitoring questions, data quality, analysis, and interpretation. Independent scientific reviews can also provide guidance to improve the effectiveness of monitoring programs; using an iterative process for monitoring planning provides points of intervention to allow for implementation of recommendations that result from technical review.


Deschutes River, OR

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Crooked River, OR

Appendix A

Example tabular form of a monitoring framework adapted from the River Restoration Centre's monitoring planner
https://www.therrc.co.uk/monitoring-planner

1 Identify **monitoring questions**	2 Select **monitoring protocol**						3 Develop **data management process** and **structure**
WHY *What are the **objectives** (implementation or ecological outcome) to be monitored?*	WHAT *What **metrics** will you measure?*	HOW *What **methods** are you going to use?*	CONFIDENCE *What **level of robustness** is needed?*	WHEN *What **periods over the year** and **how often**?*	WHO ***Who** is going to do this?*	COST *What will it **cost**?*	EVALUATION *How will monitoring results be collated and evaluated?*
To increase the area of pool, riffle, and clean gravel habitats by 80% over 2km	To monitor increased habitat diversity and change in macro-invertebrate and fish assemblages	**Fixed-point photography**	**MEDIUM**	**Pre:** June, October 2015 **During:** March 2016 **After:** April, June, October 2017; April, October 2018 *All at five locations*	**In-house**	In-kind	Photos georeferenced and stored on server. Evaluated after every set of photos (in-house). To be included in final evaluation report.
		Habitat mapping	**HIGH**	**Pre:** September 2015 **Post:** September 2016	**Environmental consultant**	$600	Report from consultant after every survey. To be included in final report
		3-minute macroinvertebrate kick-sampling; α-diversity, PSI index	**MEDIUM**	**Pre:** April and October 2015 *at five locations + one control* **Post:** April and October 2017, April and October 2019 *at five locations + one control*	**In-partnership**	$1700	Data recorded on standard sheets. Evaluated after survey (in-house). Separate pre- and post-monitoring reports to be included in final evaluation report.
		Electro-fishing; taxa, age, weight, length	LOW	**Pre:** May 2015 at two locations **Post:** May 2017 at two locations	**In-partnership**	$2,000 + equipment	Data recorded on standard sheets. Evaluated after survey (in-house). Separate pre- and post-monitoring reports to be included in final evaluation report.

1 Identify **monitoring questions**

2 Select **monitoring protocol**

3 Develop **data management process** and **structure**

WHY *What are the **objectives** (implementation or ecological outcome) to be monitored?*	WHAT *What **metrics** will you measure?*	HOW *What **methods** are you going to use?*	CONFIDENCE *What **level of robustness** is needed?*	WHEN *What **periods over the year** and **how often**?*	WHO ***Who** is going to do this?*	COST *What will it **cost**?*	EVALUATION *How will monitoring results be collated and evaluated?*
Remove weir to increase the total number of fish (abundance) passing through the reach and increase total number of fish spawning on upstream gravels within two seasons.	To monitor increase in fish passing through the reach in November before and after weir removal; and monitor increase in Brown Trout spawning on upstream gravels.	**Electro-fishing; taxa, age, weight, length**	**MEDIUM**	**Pre:** November **Post:** November 1 and 2 years after removal	**Environmental Consultant**	$3,200 + equipment	Report from consultant after every survey. To be included in final report.
		Catch returns, taxa	**MEDIUM**	**Pre & Post:** Up to 3 years data	**Local volunteers**	$300	Data recorded on standard sheets. To be included in final evaluation report
		Redd counts	**MEDIUM**	**Pre:** November the year before **Post:** November 1 and 2 years after removal	**In-partnership**	$500	Data recorded on standard sheets. Evaluated after survey (in-house). To be included in final evaluation report
Reduce the channel width by 30% for 60m upstream of the weir using locally sourced tethered wood.	To monitor channel narrowing and morphological adjustment after weir removal.	**Fixed-point photography**	**HIGH**	**Pre and during removal;** 1 month, 1 year and 2 years after	**In-Partnership**	In-kind	Photos georeferenced and stored on server. Evaluated after every set of photos (in-house). To be included in final evaluation report.
		Cross-sections and flow measurements	**HIGH**	Before, immediately after and 1 year after	**University**	Equipment	Data compiled in short report; to be included in final evaluation report.