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The Role of Monitoring in Stream Restoration

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INTRODUCTION

Definition of Stream Restoration Monitoring:

Stream Restoration Monitoring: The systematic collection and analysis of data that provides information useful for measuring project performance, determining when modification of efforts is necessary, and building long-term public support for habitat protection and restoration (Thayer et al. 2005).

On the Need for Stream Restoration Monitoring:

All parties involved with stream restoration projects, from grantor to practitioner to land manager, are vested in the outcomes of these projects and therefore benefit from feedback on project successes and failures. Such feedback is critical for expanding our collective knowledge of the relatively young science of stream and watershed restoration, fine tuning techniques, and enhancing maintenance regimes. Also, by directing the maintenance of existing projects and improving the design of future projects, such evaluation may increase the credibility of restoration efforts in the eyes of participating landowners. More formally, grant administrators are requiring an increased level of accountability from grantees, including documentation that financial resources were used for the purposes requested and that they produced the desired results (Reeve et al. 2006).

From the New York Times (Science Times) "Follow the Silt" (June 24, 2008):

"Stream restoration is a big business with increasing popularity but patchy success. Since 1990, more than a billion dollars have been spent annually on stream restoration. Scientists wonder if it's being done right."
-Cornelia Dean, *New York Times*

"Many hydrologists and geologists say people embark on projects without fully understanding the waterways they want to restore and without paying enough attention to what happens after a project is finished."
-Cornelia Dean, *New York Times*

"An awful lot of stream restoration, if not the vast majority of it, has no empirical basis. It is being done intuitively, by looks, without strong evidence. The demand is in front of the knowledge. Most agencies want to spend the money making things happen and not spending the money finding out if they work."
-Dr. William E. Dietrich, Geomorphologist, University of California-Berkeley and NCED

"Unfortunately, we have not done enough monitoring to know what works and what doesn't."
-Chris Conrad, Environmental Engineer, United States Geological Survey

"Most people agree that the best approach is to create landforms and water flows that streams can maintain naturally. But how you translate that into action and at this stream rather than that stream really requires a lot of work to figure out."
-Dr. David R. Montgomery, Geomorphologist, University of Washington

"Efforts are underway to bring more academic rigor to the stream restoration business. Many opportunities to learn from successes and failures, and thus to improve future practices, are being lost."
-Cornelia Dean, *New York Times*

DEVELOPING A MONITORING PROGRAM

Project Goals and Objectives:

Ecological success in a restoration project cannot be declared in the absence of clear project objectives from the start and subsequent evaluation of their achievement (Dahm et al. 1995). Monitoring objectives are directly connected to the goals and objectives of the restoration project and the two should be integrated starting from the project design stage (Kondolf and Micheli 1995). Understanding this connection and integration of the project's expected outcomes with monitoring will increase the ability to use monitoring effectively as a management tool.

The clarity and direction of project goals and objectives can be improved by ensuring that they are specific, measurable, achievable, relevant, and time-based (USDA 2006). Project goals and objectives should clearly state desired outcomes that are measurable through monitoring. These anticipated outcomes provide the rationale for monitoring components (such as improvements to habitat or water quality). They also direct the selection of metrics—or attributes—to measure. Project goals and objectives determine monitoring goals and objectives (Lewis et al. 2009).

An example of project objectives, from Pine Creek (WI) Restoration Project:

- Restore 3,500 feet of stream bank and habitat in Pine Creek
- Increase numbers of Eastern Brook Trout by 40-50%
- Increase numbers of Eastern Brook Trout ≥ 10 inches by 50-100%
- Reduce stream bank erosion to 10% of pre-existing conditions
- Reduce fine sediment and increase coarse bottom substrate by 50%
- Increase aquatic macrophyte growth by 25%

Project Funding and Resources:

Confirming the amount and duration of funding needed or available to implement a monitoring effort is a critical and practical step in setting monitoring objectives that are realistic and achievable. Many grantors mandate that some level of funding be included in the project budget to ensure that monitoring is implemented. Plan a monitoring budget prior to submitting a project proposal by reviewing suitable methods and estimating the cost of staff time, training and materials needed to monitor each site for each desired stage of monitoring (i.e., pre-restoration, post-restoration, effectiveness). The percent of the project budget dedicated to monitoring must coincide with the unique terms outlined by the grantor (Lewis et al. 2009).

Most contract periods allow for a minimum of one pre-restoration and one post-restoration monitoring visit to each site. At least one effectiveness monitoring survey of each site should be conducted before the close of the contract period whenever possible. Grantors with longer contract periods may support repeat monitoring visits over multiple years. These longer-term monitoring programs generally yield the most definitive confirmation of project outcomes (Lewis et al. 2009).

Understanding and Selecting Types of Monitoring:

It is important to have a good understanding of monitoring types as they relate to restoration monitoring (Harris et al. 2005; Mulder et al. 1991) before developing and implementing a monitoring program. Determining which of four principal questions are applicable will provide direction for which monitoring types will be used in a monitoring program. These four monitoring types include (Lewis et al. 2009):

1) **Pre-Project Assessment Monitoring:** Documentation of current site conditions and how they support project selection and design.
   Principal Monitoring Question: What are the existing site conditions and the reasons for implementing a project at the site?
2) **Implementation Monitoring:** Monitoring to confirm that the project was implemented according to the approved designs, plans, and permits. In other words, was the agreed upon work completed as planned? This is also a critical opportunity to identify any potential threats to project success so they can be addressed.
   Principal Monitoring Question: Was the project installed according to design specifications, permits, and landowner agreements?
3) **Effectiveness Monitoring:** Monitoring to assess post-project site conditions and document changes resulting from the implemented project. This is done through comparison with pre-project conditions to establish trends in the condition of resources at the site. Accordingly, effectiveness monitoring needs to occur over a sufficient period of time for conditions to change as a result of the project. Also, similar to implementation monitoring, effectiveness monitoring is a critical moment in the project timeline to identify and address threats to project success.
   Principal Monitoring Question: Did attributes and components at the project site change in magnitude as expected over the appropriate time frame?

4) **<u>Validation Monitoring</u>:** Monitoring used to confirm the cause and effect relationship between the project and biotic and/or physical (water quality) response. For example, this may include the change in use, presence, or abundance of desired aquatic flora and/or fauna at the project site. Similar to effectiveness monitoring, validation monitoring needs to occur over a sufficient period of time for biotic assemblages and/or water quality to change as a result of the project.
   Principal Monitoring Question: Did biotic assemblages and/or water quality respond to the changes in physical or biological attributes/components brought about by the restoration project?

It is often the case that multiple questions and monitoring types are of interest.

Qualitative and Quantitative Monitoring Approaches:

Each monitoring type can be conducted in a qualitative or a quantitative manner. Qualitative and quantitative monitoring approaches each have their place and purpose and can be complimentary to each other (Lewis et al. 2009).

Qualitative monitoring provides subjective observations of implementation, effective-ness, and validation outcomes. These observations may include a broad assessment of project site conditions with questions pertaining to multiple project objectives. Although qualitative monitoring can include some quantitative measurements, it is generally not necessary to identify specific attributes when conducting a qualitative evaluation. Photopoint monitoring is a very useful qualitative technique, achieved through a series of photographs taken to document site conditions before and after project implementation and over time as changes occur at the restoration site. Quantitative monitoring is data driven and assesses changes in project site characteristics as a means of objectively measuring project outcomes.

The choice to use qualitative methods, quantitative methods, or both will depend upon funding availability and duration as well as the level of detail required to meet needs for feedback on project outcomes. Determining which principal questions should be answered through monitoring and the choice to use qualitative or quantitative methods will influence the time, effort, and resources required to conduct monitoring. It may not be realistic in all cases, but where resources allow, qualitative monitoring should be conducted in conjunction with quantitative monitoring. Qualitative monitoring is able to identify a broad range of concerns with the project that might not be detected by a more narrowly focused quantitative approach. On the other hand, quantitative monitoring provides objective data that is less subject to varying interpretations of project outcomes.

MONITORING TECHNIQUES

Qualitative Monitoring Methods:

The California Department of Fish and Game's Coastal Monitoring and Evaluation Program provides an example of qualitative monitoring protocols that were developed to standardize stream restoration monitoring statewide (Collins 2007; Kocher and Harris 2005). These qualitative protocols are currently being used to assess projects funded through the CDFG Fisheries Restoration Grant Program.

Quantitative Attributes and Monitoring Methods:

To conduct quantitative monitoring, one needs to determine, on a site-by-site basis, which attributes are appropriate indicators of change in site conditions as a result of the restoration project. First and foremost, selection of attributes to be monitored and determination of the timing and frequency of monitoring should be driven by project goals and objectives (Lewis et al. 2009). It may be beneficial to create a list of common attributes that could be expected to change over time as a result of stream restoration, and also identify the preferred methods for monitoring change in those attributes.

Keep in mind that the identified protocols may be modified to suit unique project needs. However, using standardized methods rather than customized techniques will allow direct comparisons and analyses with other restoration projects. This offers the ability to quantify performance of multiple projects within a region and evaluate restoration technique effectiveness (Lewis et al. 2009).

While it is crucial that selection of attributes and methods be guided by specific restoration project objectives, additional factors such as the level of expertise and resources available must also be considered during monitoring plan development (Roni et al. 2005; Herrick et al. 2005). Consideration should be given to monitoring methods that can not only be implemented on a project-specific basis, but can also be learned through guidance documents and basic field training.

However, habitat use or population estimate monitoring requires more complex protocols. Such activities fall under the category of validation monitoring and include the response of aquatic and/or semi-aquatic biota (such as macrophytes, macroinvertebrates, fish, amphibians, etc.) populations as a result of changes in stream morphology and complexity (Duffy 2005; Dolloff et al. 1993). These methods generally require species identification (taxonomic) skills as well as monitoring program design expertise. They are also likely to require special agency permits for collecting and/or handling these organisms.

Water Quality Monitoring:

A common goal for watershed restoration projects is to improve water quality by reducing the delivery of sediment, nutrients, pathogens, and other pollutants to a stream. Confirming whether stream turbidity or another pollutant is reduced as a result of the project is an intensive undertaking depending on the constituent targeted. This is in part because the factors that influence water quality often operate at a scale that is larger than the project site. A typical restoration project is limited in length, compared to an extensive length of upstream channel above the project site. Various upstream conditions will likely hinder the ability of a monitoring program to detect a difference in stream sediment or temperature above and below a particular project site as a result of the restoration project. However, a strategic approach is recommended to validate water quality improvements where projects are implemented at a large scale or numerous projects connect over time (Lewis et al. 2009).

Scale of Attributes:

Although the focus of stream restoration monitoring is typically on a site or reach, remote sensing options such as Geographic Information Systems with aerial photography (Wehren et al. 2002) and infrared imagery can be applied to effectiveness monitoring. Information collected from such a broad scale can be used to help interpret the variability of data collected at a finer scale (Opperman et al. 2005). For further information on specific methods, refer to Roni (2005).

ADDITIONAL CONSIDERATIONS

Project Location Documentation and Photographic Monitoring:

All qualitative and quantitative monitoring should occur in conjunction with proper documentation of project location, as outlined in Gerstein et al. (2005) and Collins (2007). Also, photopoint monitoring (Gerstein and Kocher 2005) is recommended at all stream restoration sites, regardless of the monitoring type employed. As the saying goes, pictures are "worth a thousand words" and are particularly valuable when sharing your project results with the public. It is important to locate photo points so that they allow for repeated unobstructed photos once vegetation becomes well established. Detailed notes on the precise location and direction of photo points are also critical (Lewis et al. 2009).

Pre-Restoration

Post-Restoration

Monitoring Timeframe and Documenting Trajectory:

Baseline data should be collected shortly before the project begins or immediately following its completion. Implementation monitoring should occur as soon as possible within the first year after project implementation. Ideally, the duration of effectiveness monitoring should depend upon the expected amount of time required to reasonably ascertain whether project objectives have been met. In other words, the monitoring timeframe should reflect the time necessary for identified attributes to change as a result of the restoration project (Lennox et al. 2007).

Depending upon the attribute, monitoring project sites for ten years or more may be desirable (Lennox et al. 2007). However, this is generally longer than funding for most projects will allow (Reeve et al. 2006). Many restoration funding contracts last three to five years, with monitoring conducted during that time period. Site conditions three to five years post implementation may be reasonable indicators of whether the restoration project is likely to have the desired effects, even if the duration of monitoring is insufficient to ascertain a direct response and thorough achievement of project objectives. Ideally, subsequent visits at a minimum of three to five year intervals are recommended to document ongoing changes in site response and trends in trajectory (Reeve et al. 2006).

Because of their potential to influence monitoring survey results, environmental stresses, project maintenance, and seasonal factors should also be considered when planning the timing of effectiveness monitoring. Structural integrity is a concern for any type of stream restoration project (Gerstein and Harris 2005; Wehren et al. 2002). Ideally, stream bank structures and riparian vegetation should be assessed after high flow events to determine the project's ability to maintain its integrity following extreme physical conditions.

Monitoring should not be confused with maintenance. Ideally, a visual evaluation of the project site should be conducted annually by the contractor, project manager, or landowner to assess maintenance needs (Lewis, et al. 2009).

Control and Reference Sites:

A control site is a stream reach in the vicinity of a project site that is similar to the project site with regards to disturbance and impact, but has not been restored. A reference site is an unimpacted site that serves as an example of ideal restored conditions. When chosen carefully, control and reference sites can provide a useful context for interpreting project success and how soon the trajectory of each attribute will reach the "predisturbance condition" (Lewis et al. 2009).

Control sites serve to illustrate changes occurring naturally as a result of climatic and site conditions versus those occurring as a result of the restoration project. A control site is generally an unrestored stream reach with similar conditions and scale as the project site prior to treatment. An alternative form of a control site, useful for documenting the effect of specific restoration techniques, is a site with similar conditions that was treated with a different restoration method. This type of control site allows for the evaluation of restoration technique effectiveness (Lewis et al. 2009).

Monitoring appropriate control sites in conjunction with restored sites provides useful information and can more definitively document whether changes in site conditions are a result of the restoration project or a natural occurrence. Parties that have the necessary resources to locate and monitor control sites may find that they are valuable in ascertaining trends and isolating long-term project benefits. However, control sites that are directly comparable to restoration sites are often difficult to locate and access. For these reasons and the increased time commitment required, it is usually unrealistic to expect most parties involved in project monitoring to monitor control sites in conjunction with each restoration site (Lewis et al. 2009).

Reference sites illustrate ecological features of a pre-disturbance state and have been useful for both planning restoration projects and establishing quantifiable project objectives. Such sites are, however, elusive and difficult to find (Harrelson et al. 1994). In many cases, watershed scale impacts such as stream channelization or aggradation have precluded the ability of any stream reach to represent reference conditions for all attributes. In other instances, the debate and lack of agreement as to what predisturbance conditions are hinder reference site selection. Because of this difficulty, expending resources to identify and monitor such sites, beyond gathering input for project design, is not recommended (Lewis et al. 2009).

Control Site

Reference Site

Volunteer Monitoring:

For volunteer involvement with stream restoration monitoring, the "5 E's" should apply to the selection and use of monitoring (measurement) metrics:

- **Easy** (to understand and apply)
- **Economical** (to purchase the monitoring equipment)
- **Educational** (for the volunteers)
- **Extrapolated** (to other stream restoration projects)
- **Ecologically Relevant** (to demonstrate restoration success)

CONCLUSIONS

Documenting changes in site conditions before and after restoration project implementation is critical to determining whether a project has achieved its objectives. Planning a monitoring program in conjunction with a restoration project facilitates the development of realistic, measurable project goals and objectives and the use of suitable protocols to assess project outcomes. In addition to documenting intended beneficial effects, consistent and systematic monitoring may also highlight inadvertent effects of restoration on target ecosystems. The information obtained through monitoring provides critical feedback to project participants and grantors. Furthermore, qualitative and quantitative monitoring outcomes can help restoration professionals decipher the reasons behind project successes and failures and apply those lessons to their practice. When project outcomes and the resulting lessons are presented and shared, they help increase the overall knowledge of stream ecosystems and shape the growing science of stream and watershed restoration. Even "unsuccessful" projects that fail to meet their stated objectives can contribute valuable information to this process. As stated by Palmer et al. (2005): "Assessment is a critical component of all restoration projects, but achieving stated goals is not a prerequisite to a valuable project. Indeed, well documented projects that fall short of initial objectives may contribute more to the future health of our waterways than projects that fulfill predictions." To make this possible, it is highly desirable and beneficial to communicate project outcomes and monitoring results beyond project partners, to restoration practitioners, permitting agencies, scientists, landowners, and other stakeholders (Lewis et al. 2009).

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Regional Drivers and Needs for Stream Restoration Monitoring: Kent's Thoughts

MPCA's Tiered Aquatic Life Use (TALU) Framework:

The Minnesota Pollution Control Agency (MPCA) is working to revise state Water Quality Standards (Mn Rule Chapter 7050) to incorporate a Tiered Aquatic Life Use (TALU) framework for rivers and streams (http://www.pca.state.mn.us/water/talu.html). The TALU framework represents a significant revision to the Water Quality Standards of the state's aquatic life use classification. Basically, the TALU framework will set biological expectations for different types of lotic systems throughout the state, with condition measurement via Indices of Biological Integrity (IBI) for fish and macroinvertebrates. If IBI values for a stream do not meet TALU standards, the stream is listed as impaired. Major stressors (chemical variables, flow regime, habitat structure, biotic factors, and/or energy source) are then identified and remediation measures must be taken to restore biological integrity. Given the poor habitat quality in numerous Minnesota streams and rivers, I would anticipate that many will be listed as impaired under the new TALU framework, and that stream restoration will play a major role in the re-establishment of biological integrity. As such, monitoring will be critical for documenting stream restoration success and de-listing these impaired waters.

Current Stream Restoration Monitoring Efforts:

Some stream restoration monitoring is being conducted as a part of the Trout Unlimited Driftless Area Restoration Effort (TUDARE). The National Fish Habitat Action Plan (NFHAP) provides significant federal funding for aquatic habitat improvement and encourages monitoring to document restoration success. Twin Cities Metro Area and Minnesota stream monitoring, conducted by a broad variety of federal, state, and local governmental agencies, is almost entirely focused on assessing compliance with physical and chemical water quality standards (such as temperature, dissolved oxygen, pH, turbidity/TSS, bacteria, nutrients, etc.). Very little geomorphic and/or biological monitoring is being conducted, including in conjunction with local stream restoration projects. As a general rule, stream restoration monitoring efforts are "patchy", relatively uncoordinated, and may be lacking sound, scientifically-derived metrics that clearly link stream restoration to biological improvement. The timing is excellent for the development of standardized and scientifically-grounded monitoring protocols for evaluation of stream restoration success.

Development and Application of Stream Restoration Monitoring Protocols:

PRRSUM could establish pilot locations throughout the Upper Midwest, for the development and application of stream restoration monitoring protocols. Sites could be located within the Twin Cities Metro Area, within the TUDARE network, and at other Upper Midwest locations identified with partner input. Both warm- and cold-water streams should be included, and selection criteria for pilot streams could consider multiple factors influencing stream disposition, including geology, hydrologic scale, ecoregion, watershed size, land use, etc.

It may make some sense to establish a toolbox of standardized monitoring protocols that span a range from simple to complex, yet relevant geomorphic and biological metrics. A toolbox approach may be important, as expertise and cost will help define who uses these monitoring metrics. State and local volunteer monitoring programs are a good example of the application of simplified monitoring protocols (transparency tube, Secchi disk) that allow consistent comparisons of ecologically-relevant metrics. Nonprofit organizations such as Trout Unlimited have the capability to garner enthusiasm for volunteer monitoring, but may lack the scientific expertise and funding for more sophisticated and/or complex monitoring. On the other hand, agencies, colleges/universities, and consultants may very capably implement more complex monitoring protocols.

Consideration should be given to expanding stream restoration monitoring protocols to include the riparian area, as described by Lewis et al. (2009). The Minnesota Shoreland Rule (currently being revised) requires a 50-foot buffer along both sides of streams and rivers, extending from the ordinary high water mark. This buffer must be maintained in permanent vegetation. The MN Shoreland Rule has been suffering from a lack of enforcement; however, the importance of this rule is growing as the MPCA develops TMDLs that address sediment and nutrient impairments in streams throughout the state. Stream buffers will also serve as important best management practices (BMPs) to help address biological impairments driven by poor habitat quality (see TALU above).

Prioritizing Stream Restoration Projects:

With limited resources for stream restoration work, can we establish a prioritization scheme for targeting streams to achieve the greatest benefits for the resources invested? Can synoptic monitoring play a role in this prioritization process? Trout Unlimited and the National Fish Habitat Action Plan (NFHAP) have established a Driftless Area Restoration Effort (DARE) to restore and protect the coldwater streams of the Driftless Area of Minnesota, Wisconsin, Iowa, and Illinois. Considerable stream restoration work is occurring throughout the Driftless Area, primarily driven by local interest and capability. Informed by synoptic monitoring, can a more strategic approach be developed for targeting and prioritizing Driftless Area stream restoration, thereby maximizing both ecological outcomes and resources invested?

Informing Project Planning and Management:

Should we be conducting pre-restoration monitoring to inform project planning efforts, including the establishment of restoration goals/objectives and development of the restoration plan? What are the underlying geological, hydrological, and morphological conditions that will impact project success? What are the critical factors for developing a successful restoration plan? Is post-restoration monitoring useful for identifying and managing any problems that arise after restoration work is complete?

Demonstrating Success:

Funding for stream restoration projects emanates from multiple sources, including federal, state, and local governments, businesses, nonprofit organizations, and the general public. Given the considerable resources invested in stream restoration projects, are we measuring success, learning from our experiences, and practicing adaptive management? How can monitoring support this process and assure funders that valuable resources are well spent? Could a monitoring plan with appropriate physical, chemical, and/or biotic indicators (metrics) be developed and consistently used for evaluating the ecological success of restoration projects throughout the Driftless Area? NFHAP recognizes the need for sound science and data to assess the nation's fish habitat. NFHAP has created a framework for this assessment process and has also developed a 5-year plan that prioritizes research and monitoring needs. NFHAP is also encouraging monitoring as an important component of the restoration grant funding that it provides. Funding derived from Minnesota's Clean Water, Land, and Legacy Amendment will certainly promote stream restoration for water quality and habitat improvement. Clearly monitoring is critical for demonstrating restoration success, but should it be conducted in a more standardized and better-coordinated fashion? Those who can demonstrate success are often in an advantageous position to receive future funding.

From a study conducted by Bash and Ryan (2002) of stream restoration and enhancement projects in Washington:

"While stream restoration and enhancement projects in Washington State often share the goal of improving habitat for salmon, it is not immediately clear whether the projects are achieving this aim. There is a perception within the natural resource community that many restoration and enhancement projects are planned and implemented with little or no monitoring of their effectiveness." "Although monitoring appears to be taking place in slightly more than half of the projects surveyed, the nature of the data collected varies widely across projects, and in most cases the monitoring effort is voluntary. This suggests that project sponsors, funders, and managers must consider the issues involved in requiring appropriate monitoring, establishing standardized monitoring guidelines, the time frames in which to monitor, providing other incentives for conducting monitoring, and ensuring adequate funding for monitoring efforts."