FROM SAMPLING TO SUSTAINABILITY: USING INDICATORS TO CONNECT MONITORING TO GROWTH MANAGEMENT

SESSION INFORMATION:

No individual papers were submitted for this interactive workshop and discussion session

Moderator:

Otto Gutenson, USEPA

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Workshop participants explored the question, “If we adopted the framework of sustainability as the guide for our monitoring efforts, what types of information/indicators/measures would we want to collect/monitor?”

Indicators are direct or indirect measures of some valued component, or quality, of a defined system, used to assess and communicate the status and trends of that system’s health. Indicators are used for a variety of purposes, including Monitoring and Evaluation. For Monitoring and Evaluation purposes, indicators should answer the question, "How is the system changing?" They may help users to identify areas to monitor related to goals; determine measures of success; monitor changes in the community; or judge the effectiveness of actions taken. In the context of a watershed management, a system of indicators has many potential uses:

- To monitor and communicate watershed status and trends
- To measure progress on watershed management plan goals and objectives
- To point toward reference data underlying the indicators, facilitating information, sharing and creating synergy
- To demonstrate linkages between scientific research and policy decisions, and environmental results
- To identify data gaps and research/policy needs
- To demonstrate watershed or local-level commitment, and follow through to decision makers outside the watershed

There are hundreds of components in a watershed system, many of which might have value for various reasons in a watershed, but it is not reasonable to measure them all. Watershed managers need a way to organize the components, and there are several frameworks available, including Pressure-State-Response, EPA's Hierarchy of Indicators, Chesapeake Bay's Hierarchy of Indicators, Government Performance and Results Act, and so on. The

Green Mountain Institute, working with sustainable community projects, has developed a framework that can be useful for thinking about a system of indicators of sustainability.

Sustainability is defined as the ability to meet existing needs without compromising the ability of future generations to meet their own needs. Andrew Grigsby, from the City of Austin, discussed the Central Texas Sustainable Indicators report with participants, including considerations and challenges related to developing water quality indicators. There are several ways for watershed groups to connect with sustainability initiatives:

- hand over data that they already have; or
- participate in the larger discussion, help select indicators, provide supporting data; or
- develop their own set of indicators within a sustainability framework.

To build an indicators system based on water quality monitoring, there are four essential phases, each guided by a series of questions. These phases are:

1. Analyze your context;
2. Select your indicators;
3. Collect and manage your data; and
4. Bring your indicators to life.

AGRICULTURAL ISSUES PANEL

SESSION INFORMATION:

No individual papers were submitted for this session.

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As volunteer monitoring moves into the mainstream, it becomes more important to strengthen partnerships among volunteer monitoring programs and to reach out to other constituencies. Developing and strengthening partnerships can lead to improved efficiency and success in our efforts to protect and improve water quality. Having a diverse group of partners allows for a more holistic way of looking at our surrounding resources and deciding how to best utilize and protect them.

This panel was organized to help establish a dialogue between the volunteer monitor and the agriculture communities. Representatives from the Missouri Corn Growers, Texas Farm Bureau, and America's Clean Water Foundation participated in the panel and engaged in an open discussion with the audience. Each representative gave a brief presentation on the work their organization is doing and the connections that exist with volunteer monitoring groups. Following their presentations, panelists and audience members began to explore some of the issues and obstacles confronting the agricultural and volunteer monitoring communities. The discussion also yielded some ideas for overcoming these obstacles and building partnerships.

Each gave a brief presentation on the work their organization is doing and the connections that exist with volunteer monitoring groups. Following the presentations, panelists and participants began to explore some of the issues and obstacles confronting agriculture and volunteer monitoring:

- Agriculture and volunteer monitoring folks both cited lack of trust and cooperation as a key hindrance in establishing partnerships. The Farm Bureau representative suggested that each state volunteer coordinator contact that states' Farm Bureau Environmental Coordinator. Picking up the telephone to arrange a meeting could be the first step to building a mutually beneficial relationship.

- All agreed that in order to build trust, both groups should resist the urge to polarize communities. Emotionally-charged outreach tactics were cited as a commonly used tool (by both groups) to divide communities.

- One major concern of agricultural landowners is confidentiality of water quality information from specific locations. The farming community and the volunteer monitoring community may be able to work together to promote aggregated data, or other types of data that are of a quality that is acceptable to both groups.

At the close of the session it was apparent that this panel discussion had provided an important opportunity for the two groups to begin an open dialogue. In order for volunteer monitoring to be increasingly accepted and respected, it will be vital to keep open the lines of communication with a wide variety of partners– including those in the agricultural community.

EYE ON RECOVERY: MONITORING RESTORATION ACTIVITIES

SESSION INFORMATION:

Moderator:

Wenley Ferguson, Save the Bay (RI)

Presenters:

Leah Graff, Izaak Walton League of America
Volunteer Monitoring of Stream Restoration: Muddy Branch Case Study

Wenley Ferguson, Save the Bay (RI)
From Fill to Phragmites: How Community Groups Can Assess and Restore Their Tidal Marshes

Donna Meyers, Coastal Watershed Council
Helpful Hints: Designing a Complete Monitoring Plan for Your Restoration Project

Introduction to the Session:

Different definitions of restoration
1950s view of restoration involved "fixing" erosion problems by changing a natural system into a concrete channel with a sole purpose of moving water away from an area as quickly as possible. After realizing the ecological, economic and social problems that this method of dealing with streams caused, restoration has broadened to consider the biological, chemical, physical and cultural integrity of watersheds.

- Society for Ecological Restoration: "Ecological restoration is the process of assisting the recovery and management of ecological integrity. Ecological integrity includes a critical range of variability in biodiversity, ecological processes, and structures, regional and historical context, and sustainable cultural practices." [Not just the stream functions but also the human and cultural aspects]

- National Research Council: "Restoration is reestablishment of the structure and function of ecosystems. Ecological restoration is the process of returning an ecosystem as closely as possible to predisturbance conditions and functions." [Implies that ecosystems are naturally dynamic. Cannot recreate a system exactly. Restore the stream's self-sustaining, yet ever-changing (dynamic) nature.]

- Stream Corridor Restoration: Principles, Processes and Practices: "Restoration… is a holistic process not achieved through the isolated manipulation of individual elements… Restoration … includes a broad range of actions and measures designed to enable stream corridors to recover dynamic equilibrium and function at a self-sustaining level. The first and most critical step in implementing restoration is to, where possible, halt disturbance activities causing degradation or preventing recovery of the ecosystem. Restoration actions may range from passive approaches that involve removal or attenuation of chronic disturbance activities to active restoration that involves intervention and installation of measures to repair damages to the structure of stream corridors."

A Process

- Understand how the stream or wetland to be restored functions and recognize what is a healthy system verses a system that needs restoration. Remember that restoration can mean doing nothing!
- Set project goals.
- Look at the whole watershed and fix the causes of problems first.
- Stream example – fix stormwater issues first before installing a project to stop a bank from falling in. The amount of water the stream now carries will be the same, so worse erosion downstream or ripping out of the project will result.
- Wetland example – educate people to stop planting invasive exotic species on their property rather than just remove invasives from the adjacent wetland over and over again
- Fund raise
- Involve members of the community
- Develop a monitoring and maintenance strategy
- Conduct pre-project monitoring and site analysis
- Use monitoring information to design project
- Obtain permits
- Install project
- Conduct post-project monitoring and maintenance

The Role for Volunteers In Restoration

Many volunteer monitors get into restoration because they discover the stream or wetland is unhealthy through their monitoring efforts and want to do more than just turn over data to a state or local government entity. Volunteers can be involved in restoration in many ways:

- Through monitoring, they may realize a stream is in need of restoration and may start pushing for restoration work to be done.
- Participating as partners in a watershed assessment process
- Overseeing restoration work to make sure ecological goals are achieved
- Raising funds
- Installing some restoration device techniques
- Conducting on-going monitoring
- Maintaining the site

Always seek technical help throughout a project. Also, the more partners with a variety of backgrounds that can be involved in a project, the better the project will be.

How do you know if you have achieved restoration?

Trying to evaluate a restoration project based on one of the definitions above would be difficult and meaningless. For each project, goals need to be set that can be achieved given the constraints of time, money and land uses in the watershed. Goals also need to take project scale into account. Are you working on an entire watershed, or just a small stream segment?

Monitoring is vital both to measure project success and to make the project successful. Monitoring should take place before, during and after restoration projects. In addition, a reference site should be chosen and monitored for comparison to the restoration site. Monitoring during and after a project can reveal problems with the project that can be solved through maintenance. Therefore, it is important for monitors to communicate with the people responsible for maintaining the site.

Challenges?

As the attention of funders is shifting from monitoring to restoration, money often is not available for the monitoring or maintenance needed to make restoration projects successful. As restoration is an evolving science, solid monitoring data would benefit the entire field of restoration in addition to allowing groups to track the success of a particular project.

EYE ON RECOVERY: MONITORING RESTORATION ACTIVITIES

Volunteer Monitoring of Stream Restoration: Muddy Branch Case Study

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Stream Doctor™ Project

In 1994, the Izaak Walton League's Save Our Streams (SOS) Program developed a process for stream restoration that compares the stream to a sick patient, and the volunteer to the doctor taking care of the patient. The Stream Doctor™ Project suggests that the volunteer first examines and diagnoses the stream through monitoring, cures the stream through restoration, and provides long-term care through continued monitoring and maintenance. Save Our Streams started Stream Doctor™ as a way to direct the energy of enthusiastic stream monitors into taking action to repair the streams they discover to have poor water quality.

The Stream Doctor™ Project teaches citizens to restore streams through bioengineering. Bioengineering is a method of streambank restoration that involves regrading slopes and planting native vegetation in engineered patterns. The planting pattern adds structural stability to the slopes, which are strengthened by the root structures as the plants begin to grow. The vegetation then provides wildlife benefits, in-stream food and shelter, cools the water temperature, and keeps banks stable.

Restoration of Muddy Branch

Through monitoring workshops held at the League's national headquarters in Gaithersburg, Maryland, SOS volunteers discovered that Muddy Branch, the creek that runs through the League's property, has poor water quality and severely eroded banks. Muddy Branch is a tributary of the Potomac River, which runs into the Chesapeake Bay. For a long time, Save Our Streams used slides of the steep, barren banks of Muddy Branch as an example of the types of problems that can addressed by volunteers through bioengineering.

SOS saw the League's national headquarters as a perfect opportunity to restore a stream, educate the public, and develop a case study of stream restoration and ecological property management. The League received funding from the Environmental Protection Agency's 5-Star Restoration Challenge Program, AT&T, Philip Morris Companies Inc., and National Fish and Wildlife Foundation. The funding covered equipment, materials, and staff time to restore about 400 linear feet of streambank, to educate 60 people in stream restoration techniques, and to provide a volunteer work-day for another 60 people.

The League's partners in this project included the Montgomery County Department of Environmental Protection, City of Gaithersburg, Montgomery County Conservation Corps, Wildlife Habitat Council, and the Izaak Walton League's Maryland Division. Working closely with these partners brought many benefits to the project. At the first meeting, the partners were asked what benefits they would receive from participating in the project and what assets they could offer the project. All of the partners made generous in-kind donations of staff time and provided helpful technical and networking assistance. In addition, the City of Gaithersburg donated plants and other restoration materials while the Montgomery County Conservation Corps lent equipment, as well as labor, to the project. Both the county and city had surveyed and evaluated the Muddy Branch watershed and prioritized site for restoration. This data helped complement the macroinvertebrate data gathered by SOS volunteers.

Stream Restoration Workshops and Project Installation

The three-day restoration workshop introduces watershed and stream ecology and dynamics, how to recognize potential problems, the advantages of bioengineering as an alternative to traditional structural engineering in stream channels, and how to plan a restoration project. Participants also learn about the importance of monitoring and maintenance to the long-term success of projects. Uses of a variety of monitoring techniques are explored. Participants learn a variety of stream restoration techniques using bioengineering. In teams, participants complete a site inventory and analysis, and design a restoration plan using monitoring and background data provided. On the last day, participants install a restoration project, incorporating elements from the plans they designed in teams.

Over the course of two workshops and two volunteer workdays, more than 400 linear feet of streambank were restored. Bioengineering techniques used included live pole cuttings, regrading banks and creating terraces, fascine bundles, erosion control fabric, brush layering, and brush mattressing. Container plants of wetland emergents, floodplain trees, and shrubs rounded out the project.

Challenges and Lessons Learned

Although Save Our Streams advocates taking a watershed approach to restoration, the Muddy Branch project site was selected because it was on the League's property. The county and city had identified the portion of Muddy Branch where the project is located to be in need of restoration, but a watershed wide assessment was not used to determine the specific site location. SOS did start the restoration work with the segment furthest upstream on the League's property and worked downstream. Also, SOS is waiting to attempt restoration of some of the more degraded downstream segments until some storm water issues are addressed by the city.

The project would benefit from additional planning to assist local volunteers in setting up a regular monitoring and maintenance schedule. The volunteers will need some direction. SOS plans to remedy this problem by holding special monitoring and maintenance workshops on the property for the local volunteers.

During the first three-day restoration training workshop, participants accomplished much of the pre-project monitoring. The second workshop eliminated most of the hands-on monitoring because, in the limited time, participants wanted to focus more on restoration techniques. For the second three-day restoration training workshop, SOS included brief monitoring demonstrations, and provided necessary monitoring data and background information on the site in notebooks to help participants design appropriate stream restoration techniques as part of their team exercises. This change in workshop format means that the project will rely more heavily on the monitoring and maintenance efforts of the local volunteers.

Another monitoring challenge is that it can be difficult to teach workshop participants how to use monitoring data directly for design. Some of the data that is more significant to the design process for stream restoration includes stream flow, stream classification, channel morphology and other data not often collected by volunteers. Monitoring macroinvertebrates is important– especially if a restoration goal is water quality or improved habitat– but macroinvertebrate data does not address which specific design elements should be included in a project to prevent bank erosion.

Future Involvement of Volunteers in Restoration Projects

Through the Stream Doctor™ Project, Save Our Streams plans to involve volunteers in multiple aspects of restoration projects. Volunteers could play a key role in assessing watersheds to: prioritize sites for restoration; monitor sites before, during and after project installation; conduct project maintenance; install bioengineering techniques; and perform some aspects of project design.

EYE ON RECOVERY: MONITORING RESTORATION ACTIVITIES

From Fill to Phragmites: How Community Groups can Assess and Restore their Tidal Marshes

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Background
Community groups and volunteers can play an integral role in every stage of a restoration project from identifying human impacts to a salt marsh to conducting pre and post restoration monitoring. Save The Bay developed a tool volunteers can use to assess the restoration potential of degraded salt marshes called the Narragansett Bay Method. This assessment method is a quantitative and qualitative tool for characterizing the health of both tidal and formerly tidal marshes. The assessment method was designed to be used by interested citizens, land trusts, neighborhood organizations and town boards. The protocol focuses on easily identifiable impacts to a salt marsh and its buffer. Save The Bay adapted the method from the New Hampshire Audubon Society's Coastal Method. The goal of the salt marsh assessment is to:

- evaluate relative health of salt marshes,
- build stewardship for salt marsh protection and restoration,
- provide important baseline information for future restoration efforts,
- identify areas that need land protection measures, and
- help local communities plan pro-active salt marsh restoration projects.

The assessment method is not meant to fully determine the technical or economic feasibility of restoring a particular salt marsh. Rather, it is a useful tool for building a base of local knowledge about the current health of a marsh to determine, in a preliminary way, a site's potential for successful restoration. The method also helps identify salt marshes that are healthy but may be threatened by development adjacent to a marsh.

The protocol focused on easily identifiable impacts to salt marshes and their associated upland buffer. To conduct the assessment, volunteers used aerial photographs and GIS maps to assist them in identifying human impacts to a salt marsh and to map both activities in and adjacent to a marsh. The volunteers also ground-truthed both the GIS maps and aerial photographs. Volunteers identified salt marsh impacts such as:

- extent coverage of *Phragmites australis*
- the condition and size of the upland salt marsh buffer
- presence of tidal restrictions such as roads or railroads
- presence of fill material
- extent and condition of mosquito ditching
- land use surrounding the marsh
- land ownership of the salt marsh
- artificial structures on the marsh i.e. raised walkways, docks, boats
- evidence of cutting of salt marsh or buffer plants

A critical aspect of the salt marsh assessments was to ensure high QA/QC of the evaluations. As a first step, volunteers attended a day-long training session that included both a field and classroom component. Save The Bay staff reviewed completed evaluations and assigned each a "credibility" rating. Staff consulted with volunteers to clarify data sheets and conducted site visits to verify volunteer findings.

A benefit to involving community volunteers in the salt marsh assessment is that citizens provide valuable information about the history of a marsh. For example, local knowledge is key to identifying what, how and when disturbances occurred to the marsh or what plants and animals used to be found in the marsh. Community involvement is also crucial to ensure that local residents are both educated and aware of the benefits and value of restoration.

Based upon the salt marsh assessments, Save The Bay created a list of potential salt marsh restoration projects and shared those results with Rhode Island's Coastal Habitation Restoration team and state legislators to build support for a state fund for coastal habitat restoration. Currently, Save The Bay is collaborating with a variety of local and state partners on the planning, design and implementation of these restoration projects. By linking individuals, communities, scientists and decision makers together, the Narragansett Bay method created a solid foundation for planning locally defined and initiated salt marsh restoration projects.

Volunteer Monitoring: A Critical Component of Salt Marsh Restoration Projects

As a follow up to the salt marsh restoration assessment, volunteer monitors can gather important data that can be used in determining whether a salt marsh is in need of restoration. Such activities include:

- conducting tidal surveys,
- staking the edge of the *Phragmites* to determine if the *Phragmites* is expanding, and
- monitoring salinity levels up and downstream of a tidal restriction to determine the severity of the restriction.

Restoration Monitoring

Volunteers can assist in the long-term monitoring of a restoration project's success. Monitoring should be conducted for a minimum of five years and ideally up to ten years to track a restoration project's success. Due to the length of time associated with post restoration monitoring, it is important to establish a realistic monitoring program that can be easily conducted by volunteers from year to year. For example, permanent photo stations are a simple yet effective way to monitor long-term changes in the marsh, specifically the coverage, height and density of *Phragmites* or other invasive plants.

Monitoring plans should incorporate methods that are replicable and that are most important to measuring the success of restoration goals. Pre and post restoration monitoring can include:

- establishing vegetative transects,
- sampling soil salinity using PVC wells,
- recording height, density and percent cover of vegetation,
- observing wildlife and
- establishing photo stations.

For further reference, states such as New Hampshire, Connecticut and New York have established pre and post restoration monitoring guidelines for state and federal funded projects.

EYE ON RECOVERY: MONITORING RESTORATION ACTIVITIES

Helpful Hints: Designing a Complete Monitoring Plan for Your Restoration Project

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Background
Over the last twenty years there has been increased interest in environmental restoration at the local, state and federal levels. Restoration management is reflected in almost all approaches to improving aquatic and riparian habitats. Restoration management takes many forms and can include riparian habitat enhancement, wetlands enhancement, streambank stabilization techniques, alternative floodplain management, and targeted eradication of exotic species. Restoration can be broadly classified as (1) natural or passive restoration or (2) active restoration (Natural Research Council, New Strategies for America's Watersheds, 1999). Natural or passive restoration happens when the watershed is allowed to recover naturally and anthropogenic impediments to that recovery are removed (ie., removing grazing cattle from stream areas). Active restoration incorporates practices designed to fill an ecological void or accelerate natural recovery (ie., putting large woody debris in streams).

All restoration types (whether passive or active) require improved scientific knowledge and predictive capabilities to reach their full benefit. Scientific knowledge and data are still often lacking for many decisions regarding restoration activities. Specifically, there is a lack of pre- and post-monitoring data for the majority of restoration projects that are implemented on the ground. Gathering data for restoration projects is extremely important and critical to the increasing knowledge base on restoration effectiveness in aquatic ecosystems.

This presentation advocates for a new role for volunteer monitoring programs: restoration effectiveness monitoring. The discussion will include suggestions for designing and implementing accurate physical, biological and habitat monitoring both before restoration occurs and following construction of a restoration project. Two case studies from the Central Coast of California will be used:

- Arana Creek Restoration Project: A project involving streambank stabilization along a 300 foot section of a small urbanized stream. Additional elements include extension of an existing fish ladder to stabilize streambed elevation and removal of exotic species in the riparian corridor.

- Gazos Creek Restoration Project: A project involving in-stream habitat restoration along a 3 mile section of a pristine coastal stream. Project goals are to restore in-stream spawning, rearing and cover areas for coho salmon and steelhead trout. Restoration was mandated by the Environmental Protection Agency following a Clean Water Act violation by the local public works agency.

Monitoring Elements for Restoration Projects

Arana Creek Project	Gazos Creek Project
Vegetation survey – On-site exotic species mapped – On-site native species mapped	Stream Geomorphology – Longitudinal profiles – Cross-sections
Fisheries habitat – Stream channel morphology – In-stream habitat characteristics – Canopy cover – Large woody debris survey – Pool, riffle, run habitat measured	Fisheries habitat – Pebble counts – Embeddedness
Stream Geomorphology – Longitudinal profiles – Cross sections	Benthic Macroinvertebrates
Benthic Macroinvertebrates	Water quality and temperature

Elements of a Restoration Monitoring Plan

- Design your monitoring plan concurrently with your restoration plan
- The monitoring plan needs to address the key elements of the restoration project at a variety of time scales
- The monitoring plan should be designed to determine whether your restoration objectives were met
- Monitor the right indicators to determine success
- Identify what to monitor and consider:
    - Cost effectiveness
    - Repeatability
    - Adaptability
    - Quantitative vs. qualitative data
    - Quality assurance
- Detail how you will respond to you findings
- Plan for the long term (1-5 years)

DATA MANAGEMENT IN ACTION 1: STORET AND EXCEL-BASED DEMOS

SESSION INFORMATION:

Moderator:

Ken Cooke, Kentucky Waterwatch

Presenters:

Elizabeth Herron, University of Rhode Island– Watershed Watch
Excel-Based Data Management

Marty McComb, USEPA Region 8
(no paper submitted)

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DATA MANAGEMENT IN ACTION 1: STORET AND EXCEL-BASED DEMOS

Excel-Based Data Management

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Volunteer monitoring programs collect a tremendous amount of useful data – but we aren't always sure how best to handle that information. There are many options, from just storing paper data sheets in boxes (not a great method – especially if you want someone to actually DO something with the info), to having "professionals" manage our data in high tech databases, and all points in between.

In this session one of those midpoints was shown– the URI Watershed Watch Excel based data files. This system relies on many of the useful features of Excel (multiple worksheets within one workbook file, the ability to connect between workbook files, the ability to perform calculations and statistics, graphing, etc.) to fairly effectively manage a large multi-year data set for upwards of 100 monitoring stations. While Excel does have a variety of very useful features, it does have some very real limitations, especially in being able to easily pull out specific information from the larger data set. For this reason, URI Watershed Watch will be adding an Access database component to its data management tool bag. Excel will still be used as the day to day data entry system, with the Access database being used to store all fully proofed and calculated data. If you decide you'd like to use Excel, Excel for Dummies and similar books are a good place to start.

When deciding upon how your program will manage its data some specific questions to ask IN ADVANCE are:

- what will the data be used for? (will you need weekly results, monthly averages only?)
- can you identify specific questions that might be asked? (ways the data set might be queried in the future)
- who will be handling the data? (what technical ability or support will be required)
- how much data will your program be generating? (small datasets may not require as sophisticated a system for effective data management).

If possible, have this discussion with the potential data users, or a technical advisory committee. Most importantly, get your data into some sort of a system NOW. The longer you wait, and the more those data sheets pile up, the harder it will be to get going. Also, remember to always check your work for data entry errors, and to keep those paper copies in a safe place. You never know when some information that didn't get entered (or entered correctly) might prove useful down the road.

Some additional resources:

- http://www.epa.gov/OWOW/monitoring/volunteer/spring95/index.html
- http://www.paradiesproductions.com/volsite/html/examples.html

ADVANCING YOUR STREAM MACROINVERTEBRATE MONITORING

SESSION INFORMATION:

No individual papers were submitted for this overview and discussion session

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The purpose of this workshop was to explore advanced methods for monitoring benthic macroinvertebrates in streams, and the implications for volunteer monitoring programs.

The Context
From the Clean Water Act of 1972:

> *The objective of this Act is to restore and maintain the chemical, physical, and biological integrity of the Nation's Waters.*

The CWA contained this national objective, but was notably sketchy on what it meant. Over the past 30 years, biologists have defined biological integrity in various ways. I like this definition, based on that of James Karr and others:

> Biological integrity is achieved under conditions that support communities of organisms such that these communities:

- have the full range of structure and functions
- result from natural evolutionary and bio-geographical processes
- are expected in areas with minimal impacts from modern human society

Biological integrity is essentially what we are trying to assess when we monitor benthic macroinvertebrates. Most biologists use the following approach:

- Assess reference ("least impaired") conditions
- Assess stresses placed on natural conditions by humans
- Assess response of the watershed to the stresses
- Monitor the response of the watershed ecosystem over time to our attempts to reduce the stresses

The Process
Monitoring benthic macroinvertebrates involves 5 basic steps:

1. Design a study
2. Collect the critters
3. Process the samples
4. Identify the samples
5. Summarize and interpret the results

Within each of these steps, there are myriad options and levels of rigor possible. We'll explore these options in the following sections.

Step 1: Designing a Study
This involves framing study questions and then deciding

- what kind of study you will carry out
- what will be your data quality objectives
- how, where, and when you will collect and analyze samples
- how you will analyze the results

As you move from basic to rigorous monitoring, your goals are to increase the extent to which your samples represent what actually lives in the stream, and to minimize the extent to which your sampling and analysis introduces variability into your results. So, your monitoring strategy should be designed to meet the needs of your program, to maximize representativeness and to minimize variability. Advanced monitoring programs do this in a number of ways:

- They carefully select reference and study sites, and classify them into homogeneous groups.
- They standardize the level of effort involved with sampling the critters, to reduce differences in abundance caused by inconsistent sampling techniques.

- They test metrics and use multi-metric indices to measure relevant attributes of the biota.

Step 2: Collecting the Critters

There are a number of well-tested and documented ways to collect macroinvertebrates:

Grabbing Them Off the Bottom
- Frame Nets
- Seines
- Surbers or Hess Samplers

Colonizing Artificial Substrates
- Rock Baskets
- Multi-plate Samplers

There are advantages and disadvantages to each approach and piece of equipment. Grabbing them off the bottom produces samples that better represent what actually lives there, but sampling technique can vary considerably. Using artificial substrates rigorously standardizes the collection area, but may not represent the natural habitat. Some studies use both to assess the impact of water quality versus habitat.

Advanced programs standardize the level of effort involved with sampling by standardizing the *area* or *time* of collection. In my experience, standardizing area works better than time for volunteer programs, with multiple people collecting samples. They increase representativeness by collecting replicate samples, sometimes consisting of a composite of several collection spots.

Step 3: Processing the Samples

Samples may be either processed entirely in the field, or preserved and processed in a lab. The two key decisions are:

1. Will you process the samples entirely in the field, or preserve them and bring them back to a lab?

2. Will you identify the whole samples, or a subsample?

Advanced programs preserve the whole samples in the field, and bring them back to a lab for processing. There's a lot of debate about whether to identify the whole sample or a part of it (subsample) and, if just a part, how much? The idea is to avoid having to identify thousands of critters in the whole sample by identifying a representative subsample. The trick is assuring that the subsample is representative. Most advanced programs identify the entire sample and, if they subsample, use a constant proportion and at least 300 organisms.

Step 4: Identifying the Samples

The key decision here is what taxonomic level to identify the critters to. Most volunteer groups identify orders, while some identify families. Most advanced programs identify genera and species. What they gain is greater sensitivity to changes in the stream's biota. In addition, some of the common metrics (biotic index, functional feeding groups) gain a finer resolution, since they were originally developed for species level data.

Genus and species level identification is very difficult for people who don't do it every day. For that reason, family is likely the lowest consistent level for most volunteer programs. However, some groups have developed subfamily groups of genera and species to refine the metrics, without having to identify individual species.

Step 5: Summarizing and Interpreting the Results

Benthic macroinvertebrate data are summarized using *metrics*. These are measures of attributes of the community. Most advanced programs use metrics in the following groups:

- Abundance

- Taxa Richness (EPT and Total)
- Pollution Tolerance
- Feeding Ecology
- Community Composition

Metrics in each of these groups are tested regionally to assure that they respond in a predictable way to specific stressors. The metrics that work are used in one of three ways:

1. *Metrics Are Analyzed Separately:* In this approach, one or more individual metrics are used to assess the biological condition. Results for these metrics are compared with those at an actual reference site, or to expected results based on a reference site database.

2. *Metrics Are Analyzed As A Single Score (Multi-metric Index):* A set of metrics is selected which responds in a predictable way to impairment. Results for each metric are scored and aggregated into a single score (or index). This score is compared with scores for an actual reference site or to a theoretical score (as in biocriteria) to determine impairment. Examples: EPA's Rapid Bioassessment Protocol, Karr's Benthic Index of Biotic Integrity.

3. *Metrics Are Analyzed Using Multivariate Statistics:* This approach consists of various statistical models that predict the benthic macroinvertebrate metrics results that would be expected to occur at a test site in the absence of environmental stress. Impairment is determined by comparing the metrics' results, predicted to occur at the test site, with those actually collected at sites with environmental stressors. The power of this approach is that it allows you to look at, and integrate, a number of variables at the same time to determine which stressor(s) seems to be having the greatest effect on the community.

If you live in a state with *biocriteria*, they may guide your data interpretation and be used instead of an actual reference site. Biocriteria are narrative or numeric expressions that describe the biological integrity of "natural" (unimpaired) aquatic communities living in waters of a given aquatic life use. They are used to determine whether a water body supports its designated aquatic life use under the Federal Clean Water Act.