National Nonpoint Source Monitoring Program

TechNOTES 5

Through the National Nonpoint Source Monitoring Program **(NNPSMP)**, states monitor and evaluate a subset of watershed projects funded by the Clean Water Act Section 319 Nonpoint Source Control Program.

The program has two major objectives:

1. To scientifically evaluate the effectiveness of watershed technologies designed to control nonpoint source pollution
2. To improve our understanding of nonpoint source pollution

NNPSMP Tech Notes is a series of publications that shares this unique research and monitoring effort. It offers guidance on data collection, implementation of pollution control technologies, and monitoring design, as well as case studies that illustrate principles in action.

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Using Biological and Habitat Monitoring Data to Plan Watershed Projects

Introduction

The goal of this Tech Note is to explore and promote the use of biological and habitat data in watershed planning and evaluation. The status and condition of resident aquatic biota are important to water quality assessment programs and to the overall goals of protecting and restoring surface waters. This document is not intended to provide complete instruction in the process of biomonitoring but rather to provide a foundation for understanding the important roles that biological and habitat information can play in watershed planning and management. The material provides information so that knowledgeable individuals and groups can work with professionals to develop effective biological/habitat monitoring efforts to help achieve the goals of their watershed project.

1.0 Overview of Watershed Planning Process

The watershed planning process used in this Tech Note can be organized into six major steps (USEPA 2005):

1. Build partnerships
2. Characterize the watershed to identify problems
3. Set goals and identify solutions
4. Design the implementation program
5. Implement the watershed plan
6. Measure progress and make adjustments

The U.S. Environmental Protection Agency (USEPA) has expanded on these basic planning steps and identified nine necessary elements of any watershed project using Clean Water Act section 319 funds to address nonpoint source (NPS) isssues, TMDLs

(Total Maximum Daily Loads), and watershed-based plans in support of TMDLs (USEPA 2003):

1. An identification of the causes and sources that will need to be controlled to achieve the load reductions and other watershed goals identified in the watershed-based plan;
2. An estimate of the load reductions expected for the management measures to be implemented;
3. A description of the NPS management measures (BMPs) that will be implemented to achieve the estimated load reductions and achieve other watershed goals of the plan;
4. An estimate of the cost and amounts of technical and financial assistance needed and/or the sources and authorities that will be relied upon to implement the plan;
5. An information/education component to help achieve project goals;
6. An expeditious schedule for implementing the management measures in the plan;
7. A description of interim, measurable milestones for determining whether NPS management measures or other control actions are being implemented;
8. A set of criteria for determining whether loading reductions and substantial progress are being achieved over time and, if not, the criteria for determining whether the plan or NPS TMDL needs to be revised; and
9. A monitoring component to evaluate the effectiveness of the implementation efforts over time, measured against the criteria established for the project.

Understanding the interrelationships among the physical, chemical, biological, and habitat characteristics of water resources and the management and use of land in the watershed is essential to fully restoring and protecting water quality. For example, a narrow focus on reducing chemical and physical pollutant loads in response to a watershed management plan, without recognition of the roles these pollutants play as ecological stressors could result in only partial success where load reduction targets are met but water quality goals as measured by biological and habitat criteria are not achieved. It is the fundamental linkage of physical, chemical, and biological dimensions of watersheds and water resources that forms the basis for much of the discussion that follows.

2.0 Overview of Biological and Habitat Monitoring

Biological data have been used for many years by state and local water quality agencies to evaluate the ecological health of aquatic ecosystems. This approach uses biological surveys and other direct measurements of resident aquatic biota to assess surface water conditions (Gibson et al. 1996). During surveys, data are generally collected on the physical habitat and specific biological assemblages such as plants, fish, and benthic macroinvertebrates.

The status and condition of resident aquatic biota are key indicators of water quality and can provide information that is distinct from momentary measurements of physical or chemical variables. Because the aquatic biota are continuously exposed to cumulative and multiple environmental factors in the environment, they reflect the overall condition of the waterbody and associated watershed. The character of the resident aquatic biota is the ultimate proof of attainment of designated aquatic life use support. For watershed planning, biological indicators and associated data are useful for ecological risk assessments relevant to management decisions related to correcting existing and preventing future problems.

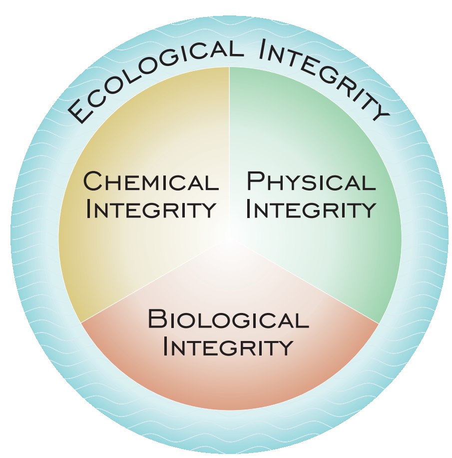
The physical habitat represents the set of environmental conditions and constraints that supports or limits a biological community and includes such features as the geomorphology of the waterbody, the riparian zone, physical and chemical constituents dissolved or suspended in the water, and substrate and refugia for aquatic organisms. Measuring the components of the physical habitat is important to understanding and interpreting biological data because habitat is a major influence on what kind of organisms can inhabit the system.

Several questions can be addressed with comprehensive biological and physical habitat data:

1. What is the condition of the aquatic resource?
2. Is the resource impaired or degraded?
3. If there is a problem, what are the stressors?
4. What is the biological potential upon mitigation or restoration?

2.1 Relationship Among Biological, Physical, and Chemical Monitoring

The concept of ecological integrity embraces the combination of biological, physical, and chemical integrity. These three broad components of an ecosystem are inseparable in understanding the functioning of a healthy waterbody. The condition of the aquatic biological community reflects the exposure to, frequency, and duration of single or cumulative stressors in the ecosystem. In watershed planning, ecological attributes of the biological community can be considered response indicators of the multitude of stressors.



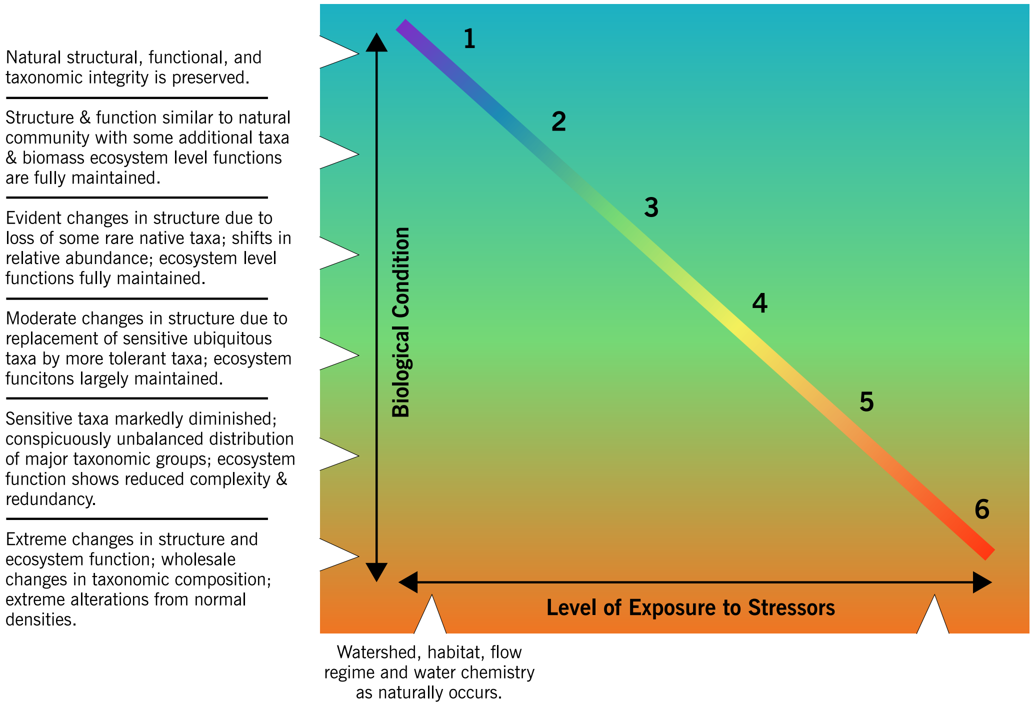


Figure 1. Biological condition gradient (BCG).

In a water body, a biological condition gradient (BCG) can be visualized that responds to a gradient of stressors (Figure 1). The horizontal axis represents exposure to any combination of stressors that affects the ecosystem; the response of a suitable biological indicator is used to track the overall biological condition, represented by the vertical axis. Anywhere along the BCG a condition can be identified based on specific ecological attributes that reflects the physical, chemical, and biological conditions of the waterbody. Because of this, watershed planning should encompass all three monitoring domains—biological, physical, and chemical.

The concept of the BCG is the underpinning to effectively implement biological and habitat assessments into watershed planning. Appropriate bioassessment adheres to basic critical technical elements that are addressed during design, methods development, and data interpretation (Barbour and Yoder 2007) (see Figure 2).

2.2 Elements of Survey Design for Bioassessment

The first five elements in Figure 2 comprise components of survey design. Bioassessments are best conducted under established and tested index periods. This optimizes the collection of information from an aquatic community that transitions through spawning, nursery, and emergence functions. Although perturbations in a watershed can occur at any time of the year, interpretation of biological data from index periods provides evidence of the severity of those perturbations. Watershed planning needs to incorporate an adequate spatial coverage of sites from which the biological and habitat measurements are taken. Over-extrapolating from too few sites in a watershed is a serious flaw in the design. Classification frameworks separate natural distinctions between waterbody types (Barbour et al. 1999), e.g., warmwater or coldwater streams; headwater streams, wadeable streams, nonwadeable streams, and large/great rivers, etc. Depending on the types of waterbody in your watershed, expectations for biological endpoints will vary. Ideally, BCGs are developed for each type of waterbody to most effectively define biological expectations. These expectations are the reference conditions critical to a survey and assessment design. Appropriate reference conditions are formulated based on non-biological criteria but that correspond to the higher biological condition levels on a BCG.

Key Technical Elements

Design	1. Index period 2. Spatial coverage 3. Natural classification 4. Criteria for reference sites 5. Reference conditions
Methods	6. Taxonomic Resolution 7. Sample collection 8. Sample processing 9. Data management
Interpretation	10. Ecological attributes 11. Biological endpoints 12. Diagnostic capability 13. Professional review

Figure 2. Critical elements of a bioassessment program.

2.3 Methods Development of a Bioassessment Program

Sample collection methods should be appropriate for the waterbody type and region of the country. The Rapid Bioassessment Protocols (RBPs) provide details on methods for the various assemblages (Barbour et al. 1999). Taxonomic resolution, i.e., the identification to family vs. genus vs. species, is key to a bioassessment program. While biological impairment can sometimes be detected by identifying organisms only to the family level, often the value of biological data for a causal analysis is diminished unless genus/species information is available. How the samples are processed—in the field or in the lab—can be critical to the quality of the data. The proper quality control checks need to be in place to ensure confidence in the results. An effective and efficient data management system for maintaining the data cannot be underestimated, as many condition assessments are hampered by improper and inadequate data management procedures.

2.4 Elements of Data Interpretation and Reporting

Understanding the pertinent ecological attributes of the biological assemblage is key to a bioassessment program and constitutes the foundation of the BCG. These attributes are often equated to biological metrics as a means of summarizing raw data into meaningful endpoints. Multiple metrics can be used to aggregate and convey the information available regarding the elements and processes of aquatic communities (Barbour et al. 1999) and address four primary categories: (1) **richness measures** for diversity or variety of the assemblage; (2) **composition measures** for identity and dominance of species present; (3) **tolerance measures** that characterize sensitivity to perturbation;

and (4) **trophic or habit measures** for information on feeding strategies. These metrics and ecological attributes can be aggregated into multimetric indices (e.g., Karr's *Index of Biotic Integrity* [IBI], see Karr et al. 1986) or into a predictive model, such as the *River Invertebrate Prediction and Classification System* [RIVPACS] where the observed taxonomic representation in a sample is compared to a calculated expected value. Barbour et al. (1999) present a more detailed discussion of these two approaches. Using ecological attributes or endpoints that provide diagnostic capability assists in identifying the causes of impairment. This capability is referred to as using biological response signatures that are associated to individual or multiple stressors (Yoder and Rankin 1995). Finally, any bioassessment program is strengthened if a professional review of the methods, calibration of endpoints, procedures for analysis and interpretation is conducted. The most robust review is from independent technical experts knowledgeable in bioassessment approaches and their application in water resource programs.

The use of physical habitat information in an integrated report is useful for aiding in the interpretation of the biology (Barbour and Stribling 1994). Because the habitat is the foundation for the structure and function of the aquatic community, treating the habitat data as a dependent variable is a useful technique. In addition, the habitat itself is a function of landuse, and habitat metrics or variables serve as response indicators in assessment.

3.0 Opportunities to Use Biological and Habitat Data in Watershed Project Planning

3.1 Building Partnerships

Biological and habitat data can be used effectively to build partnerships because they allow individuals to visualize problems better than can be done in many cases using chemical and physical data alone. While people may find it difficult to appreciate the significance of high nutrient levels, depressed dissolved oxygen concentrations, or elevated water temperatures, they can easily understand declining fishing success, depletion of prized fish species, fish advisories caused by mercury contamination, or outright fish kills. Rallying people around a cause requires that they understand the issues, and biological and habitat data can contribute much in that regard as evidenced by the role volunteer monitoring of benthic macroinvertebrates has played in increasing community involvement in local water quality issues.

Source: fieldandstreamblog.com

In addition to increasing awareness of local water quality problems, biological and habitat data can be important in setting project goals and indicators of progress. The Chesapeake

Bay Program, for example, reports Bay health to the general public using three data types: fish and shellfish populations, habitats and lower food web, and chemical/physical water quality variables (CBP 2008).

3.2 Characterizing Watersheds

Use of biological indicators to understand resource condition. The interpretation of biological data is grounded in the understanding of the condition of the resource that is expected under unperturbed or minimally disturbed scenarios—a condition termed as *reference condition*. Typically, a reference condition is regional and not local, so that natural variability in biological communities can be incorporated into the characterization of reference (Barbour et al. 1999). Once a reference condition is established, a *best attainable condition* can be described. This condition reflects the balance between a regional reference condition that may be outside of a watershed of interest and the best attainable condition given the level and intensity of land use modification and effectiveness of implemented or proposed BMPs to offset the influence of stressors. Understanding the connection between established reference conditions and selected indicators is an important component of using biological information. For example, a diverse warmwater fish fauna might be expected to occur in natural Midwestern streams. Any loss of species or reduced abundance of native species would be a deviation from this reference condition. From these scientific underpinnings, biological indicators can be used to determine the status and condition of the water resource.

Use of biological and habitat measures to identify causes and sources of problems in the watershed. Biosurvey techniques are best used for detecting aquatic life impairments and for assessing their relative severity. Once an impairment is detected, however, additional ecological data, such as chemical, hydrogeomorphology, land use, and perhaps ambient and/or whole effluent toxicity testing are helpful to identify the causative agent and its source, and to implement appropriate mitigation (USEPA 1991). The identification of stressors causing the problem indicated by ecological condition requires detective work, and the several types of data needed for a good analysis are not always available (USEPA 2000). The availability of rigorous biological data is useful in stressor identification because many biological response signatures are known (Yoder and Rankin 1995). For example, the benthic assemblage becomes dominated by filter feeders in nutrient rich waters; exposure to sublethal doses of toxic trace metals is known to cause lesions and tumors on fish. Teasing out specific stressors is a process of elimination and weight-of-evidence (see Figure 3). Sometimes, it is an iterative process whereby one stressor is eliminated and the data are re-evaluated. In all cases, having biological data enhances the evaluation and determination of actual problems and diagnosing those problems in watersheds.

USEPA's *Causal Analysis/Diagnosis Decision Information System* (CADDIS) is an online application based on the stressor identification process depicted in Figure 3. An online Guide organizes the process into five steps (USEPA 2008). If probable causes of identified water quality problems can be identified with a high degree of confidence using this process, then the next steps may include allocating the contributions of different sources of the cause and developing and implementing management options. Accurate and defensible identification of the cause is the key that directs management efforts toward finding solutions that have the best chance for improving biological condition.

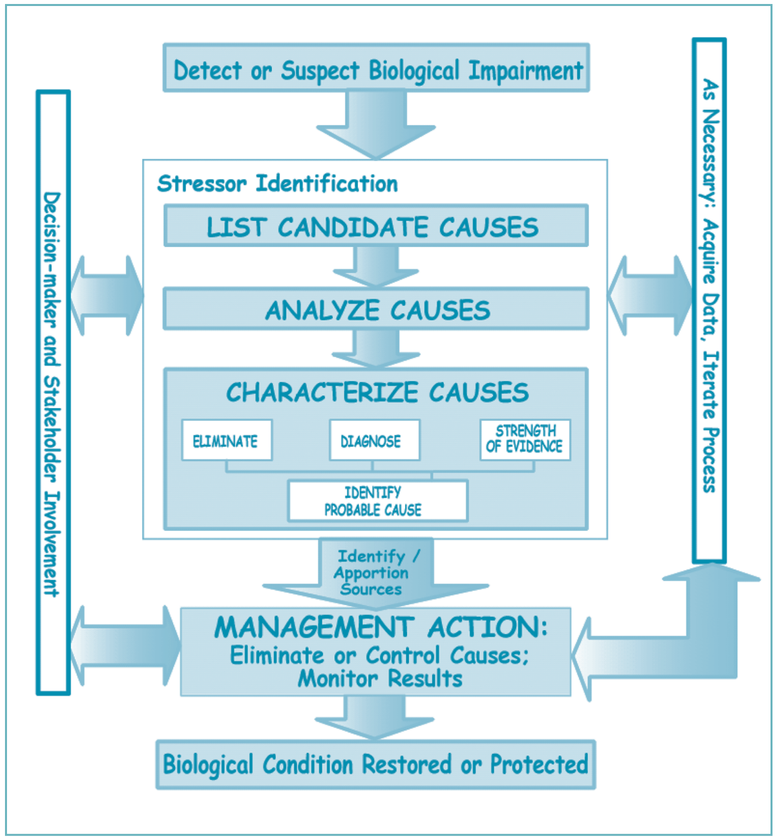


Figure 3. Stressor identification process.

Physical habitat data from an appropriate spatial design are useful to determine if there has been any habitat alteration within the watershed, and particularly upstream or upriver from noted perturbations. The structure of the physical habitat (as an aquatic organism sees the habitat) is critical for maintaining refugia, nursery and spawning areas, feeding regimes, etc., which, in turn, are required to maintain a stable ecosystem. As habitat degrades, direct effects from runoff, erosion, and sedimentation can be compounded and escalated as the streams/rivers flow downstream. Where physical habitat quality at a test site is similar to that of a reference, detected impacts can be attributed to water quality factors (i.e., chemical contamination) or other stressors (Barbour et al. 1999).

Stressor Identification Training Modules

Two stressor identification modules originally developed as part of USEPA's 2003 National Biocriteria Workshop are available online at *www.epa.gov/waterscience/biocriteria/modules/*.

The SI 101 course contains several presentations on the principles of the stressor identification process and a case study: *www.epa.gov/waterscience/biocriteria/modules/#si101*.

Use of biological and habitat data to identify information gaps. Biological and habitat surveys are often used as screening tools to identify the need for more intensive data gathering to fill information gaps regarding watershed condition. Depending on the sampling design, biological surveys can be planned to occur as an initial data gathering technique or to target areas where other types of data suggest a problem exists. For example, if fish sampling reveals the presence of lesions or tumors indicative of metals pollution, investigators can then explore potential metals sources and measure metals levels in the watershed. Having a robust data set of ecological information provides a true characterization of the condition of the surface waters within a watershed.

3.3 Setting Goals and Identifying Solutions

As discussed above, a reference condition can be used to set the best attainable condition for the watershed. When anchored to a BCG, the reference condition can be used for a benchmark of biological potential and for restoration goals. Values for ecological attributes associated with this condition can also be used to set both overall and intermediate project goals. The range of the biological condition gradient can be subdivided into categories corresponding to various levels of impairment. Priorities can be set on mitigation plans and BMPs, based on the severity of impact, or the best likelihood for restoration and recovery. For state and tribal programs having tiered aquatic life uses that correspond to the BCG as a foundation, identifying attainment of designated uses and potential solutions to portions of the watershed in non-attainment can follow a prescriptive process with biological condition as the ultimate arbiter of recovery.

Goals for land treatment and pollutant source control could be based at least in part on results of a stressor identification process that leads to identification of causes and potential sources of pollution or degradation in the watershed. If sufficient research has been done to form relationships between stressors and biological indicators, it may be possible to develop project goals that incorporate these relationships. For example, a sub-objective to protect the number of native fish species could be set based on the relationship to sedimentation and benthic oxygen depletion. Implementation of BMPs would then be directed to reducing sedimentation from upstream erosion and increasing benthic dissolved oxygen levels to the point where native species respond sufficiently for measurable improvement of water quality and achievement of the sub-objective.

3.4 Designing the Implementation Program

Implementation of land treatment in watersheds typically involves an identification of the BMPs to be implemented based on the problems being addressed or prevented, BMP locations, implementation mechanisms, and an implementation schedule. BMP selection and design are driven by the need to achieve water quality and land treatment objectives set for the project. Again, knowledge of linkages among biological indicators, habitat indicators, and stressors is essential to selecting and designing BMPs that will get the job done. Stressor identification leads to a better understanding of the causes and sources of problems measured with biological indicators, making it more likely that BMPs can be targeted to the sources and activities at those sources that must be controlled to solve the problem. This formal approach to identifying causes and sources can also help to identify causal relationships that are otherwise not immediately apparent and prevent biases in the planning effort.

Research has demonstrated many links between land management and ecological conditions in a water body. Habitat degradation, for example, can result from land disturbance in a watershed; an increase in stream nutrient levels may dramatically alter the character and type of macroinvertebrate community. Ecological condition is also known to be affected by invasive exotic species or removal of riparian zone vegetation. These known or probable linkages can be helpful to frame the discussion regarding the BMP implementation plan. Much is unknown at this time about the subtle relationships among stressors and biological and habitat indicators, however, so it is prudent to consider the full range of potential stressors whenever developing a BMP implementation plan. Such a process is used by the U.S. Department of Agriculture-Natural Resources Conservation Service (NRCS) to develop a Resource Management System, which is a combination of conservation practices and resource management activities for the treatment of all identified resource concerns for soil, water, air, plants, animals, and humans that meets or exceeds the quality criteria in the FOTG (Field Office Technical Guide) for resource sustainability (USDA 2007).

To illustrate, a screening level analysis using a biological survey may reveal obvious and possibly some subtle problems in a stream system. Data may show that fish assemblages are lacking in diversity or numbers, and a closer look at species richness and abundance metrics indicates potential siltation, habitat alteration, or even toxicity problems in the watershed. In this case, multiple stressors of both a chemical and physical nature are probable causal agents. The Stressor Identification Process is implemented to ascertain the most appropriate mitigation measures. With these multiple stressors, it could be that BMPs are selected that stabilize the riparian area, provide improved habitat, and reduce discharge of toxic materials to the stream without addressing the need to provide a better flow regime, with the end result being a healthier watershed, but one that still fails to support a fish community normally expected in such a watershed. Monitoring the effectiveness of BMPs is crucial to detect whether prescribed recovery is occurring, and in this particular watershed, additional investigation is needed to determine why an improvement in the fish assemblage is not attained.

Delineation of critical areas based on biological and habitat data is similar to the process based on chemical/physical monitoring data in that a reasonable starting point is to assume that the portion of the watershed draining into the area where impacts are detected contains the critical areas. Critical area delineation is further refined based on other important factors such as lag time, source magnitude, and the potential for improved management at suspected sources. When considering biological communities, however, it is also very important to consider the health of the source population for recolonization and recovery. If only a portion of the watershed is impaired, then it is likely to recover more rapidly than in a watershed that is completely disturbed, and colonization from outside of the watershed is the primary source.

4.0 What to Consider When Selecting and Implementing Biological/Habitat Data Collection

- **Understand waterbody classification/types and take advantage of classification systems developed in your area (where available).** It is important to determine the types of waterbodies in your watershed and how different waterbody types relate to different biological expectations and therefore different endpoints.
- **Take advantage of reference condition work developed for your area.** It is unlikely that you will have a sufficient range of conditions to truly develop reference conditions in your watershed. Consult with your state environmental agency for information on their biomonitoring program.
- **Make use of state-specific or eco-regionally refined indices whenever possible.** These are typically more appropriate and provide more information than broad-scale or general indices from a textbook. The more regionally refined your data collection and assessment approach can be, the more useful your data will be to your watershed project.
- **Fully understand what the biological indicators you are using mean and what they do not mean, and, therefore, what they can and cannot do.** Some metrics, for example are designed to look at sediment-related issues, while others may be more responsive to chemical stressors.
- **Select and use methods that are appropriate to the biological indices you have chosen.** If you are using a state-developed index, failure to use similar methods, equipment, and taxonomic resolution will result in data that are not comparable.
- **Be sure to collect a core set of physical, chemical, and habitat data to complement your biological data.** Such data may be critical to identifying stressors and determining sources of impairment. To the extent that similar data are also being collected by states or other organizations in your area using similar methods, your data will be more comparable and enhance interpretation.

5.0 Examples of Use of Biological and Habitat Data in a Watershed Project Planning Process

Example 1: Sometimes, habitat and biological data alone are sufficient to both characterize a problem and suggest the solution. In the Upper Grand Ronde Basin (Oregon), loss of spawning habitat and elevated stream temperatures (due to loss of riparian vegetation) caused a decline in trout populations over the past 30 years, leading to a National Nonpoint Source Monitoring Program (NNPSMP) project aimed at restoration of the fishery. Biological surveys and habitat assessments were used to design restoration efforts focused directly on the stream and riparian zone. Riparian fencing, channel reintroduction to an historic wet meadow meander pattern, extensive riparian planting, and creation of off-channel pond habitats were successful in restoring both temperature regimes and trout population (Whitney and Hafele 2006). Investigators also concluded that livestock exclusion by itself was not enough to recover sensitive aquatic life if stream channel and habitat conditions remained degraded.

The Vermont Rapid Habitat Assessment

The Vermont Agency of Natural Resources is developing a new process-based rapid habitat assessment (RHA) that links the processes that form and maintain physical river habitat with processes that support the life cycle requirements of aquatic plants, macroinvertebrates, and fish. The RHA protocol has been developed with the ultimate goal of linking the assessment of physical and biological components in flowing waters.

The RHA includes eight physical habitat attributes—Woody Debris Cover, Bed Substrate Cover, Scour and Depositional Features, Channel Morphology, Hydrologic Characteristics, Connectivity, River Banks, and Riparian Area. Indicator data are collected to score each parameter, and then a final score is produced to investigate deviations from an expected reference condition. The RHA has been stratified by stream types that include riffle-pool (dune-ripple), step-pool (cascade, bedrock), plane bed, and braided (alluvial fan) to account for expected differences in physical processes and the associated reference habitat condition.

When added to the Agency's Stream Geomorphic Assessment protocols, the RHA will permit scientists to look at the health of rivers and streams based on a joint assessment of geomorphic condition and physical habitat quality at spatial and temporal scales previously looked at in very few analyses. Such information can be used for a variety of applications such as identifying opportunities for restoration and protection projects, supporting biomonitoring data to establish causation, and guiding river corridor planning.

Following field testing and pilot studies conducted in 2007, the RHA is expected to be released in spring, 2008.

http://www.vtwaterquality.org/rivers.htm

Example 2: In other cases, however, habitat and biological data by themselves may not be enough to guide successful restoration if other factors play a role in causing the problem. The Waukegan River (Illinois) NNPSMP project documented biological impairment with fish, macroinvertebrate, and habitat surveys, as well as visual observations of eroding streambanks and high storm flows. The project sought to restore the fishery through a combination of biotechnical streambank stabilization measures and in-stream structures such as lunkers and improved pool and riffle sequences. Although habitat improvements were clearly documented and some small early improvements in fish numbers and several biological indices were noted, the project did not achieve the hoped-for improvements in the fish community (White et al. 2003). Project staff attributed this shortfall to a failure to address extremes in flow regime from the highly urbanized watershed or to other pollutants such as toxics that were not revealed in habitat and biological surveys. The project would have benefited from a more complete stressor identification process. This outcome illustrates the importance of combining both habitat/biological and physical/chemical data to develop a full understanding of the problem as the basis for designing a successful treatment plan.

Example 3: Biological data should be integrated with other data when identifying causes of impairment. Human activities such as mining, logging, agriculture, and residential development have degraded biological conditions in many streams of West Virginia. Using benthic macroinvertebrates as biological indicators of stream health, the West Virginia Department of Environmental Protection (WVDEP) identified streams across the state that do not meet aquatic life use designations: these streams are considered to be biologically impaired. TMDLs are required for all streams that are classified as biologically impaired, and the TMDL process mandates that stressors to the biological community are identified so that pollutants can be controlled within each watershed. Using EPA's stressor identification guidance (USEPA 2000) to identify and rank physical, chemical, and biological stressors that may have impaired the aquatic community in Clear Fork of Coal River, candidate causes were identified. Watershed characteristics such as land use and soils, plus point-source inventories, site observations, and other lines of evidence were included in these analyses to help identify stressor sources. The strongest inferences were when the biological predictive model agreed with watershed-exclusive observations of stressor measures.

Definitions

Assemblage – an association of interacting populations of organisms in a given waterbody, for example, fish assemblage or a benthic macroinvertebrate assemblage

Benthic macroinvertebrates – animals without backbones, living in or on the sediments, of a size large enough to be seen by the unaided eye and which can be retained by a U.S. Standard No. 30 sieve (28 meshes per inch, 0.595 mm openings). Also referred to as benthos, infauna, or macrobenthos.

Bioassessment – a survey and evaluation of the condition of the aquatic resource using organisms.

Community – the aggregate of assemblages that inhabit an ecosystem. In this case, the aquatic community includes benthic macroinvertebrates, fish, algae, plankton, submerged aquatic vegetation, etc.

Ecological Integrity – the condition of an unimpaired ecosystem as measured by combined chemical, physical (including habitat), and biological attributes.

Habitat – all aspects of physical and chemical constituents that support aquatic life.

Index Period – A consistent seasonal time frame for sampling that minimizes between-year variability while optimizing accessibility of the target assemblages and maximizes efficiency of sampling crews and gear. Ideally, the optimal index period corresponds to recruitment cycles of the organisms (based on reproduction, emergence, growth, and migration patterns).

Multmetric Index – data structure that combines indicators, or metrics, into a single value. Each metric is tested and calibrated to a scale and transformed into a unitless score prior to being aggregated into a multimetric index. Both an index, and metrics, are useful in assessing and diagnosing ecological condition.

Reference Conditions – the set of selected measurements or conditions of unimpaired or minimally impaired waterbodies characteristic of a waterbody type in a region.

RIVPACS – a predictive method developed for use in the United Kingdom to assess water quality using a comparison of observed biological species distributions to those expected to occur based on a model derived from reference data.

Stressors – physical, chemical, and biological factors that adversely affect aquatic organisms.

Additional Resources

Hilsenhoff Biotic Index (HBI)
http://www.uwsp.edu/cnr/research/gshepard/History/History.htm
(accessed February 13, 2008)

Index of Biotic Integrity (IBI)
http://www.epa.gov/bioindicators/html/ibi-hist.html
(accessed February 13, 2008)

Qualitative Habitat Evaluation Index (QHEI)
http://www.epa.state.oh.us/dsw/bioassess/BioCriteriaProtAqLife.html
(accessed February 13, 2008)

Volunteer monitoring
http://www.epa.gov/owow/monitoring/volunteer/

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