

Chapter 1 - The Protection of Biological Integrity

1.1 Introduction

Biological monitoring is integral to the measurement of the total ecological health of a waterbody and is becoming increasingly important in water quality monitoring and assessment. Historically, most natural resource programs have measured individual pollutants in the water column and sediments. Although such programs have effectively monitored and controlled point source discharges of nutrients and contaminants, their efforts to assess total ecological integrity, measured by combined chemical, physical (including habitat), and biological attributes, have been limited. Many surface waters have continued to deteriorate from nonpoint pollution, habitat modification, and other impacts of human activities (Karr 1991). For example, in the United States, the total lake acreage that deteriorated in quality from 1972 to 1982 was four times the acreage that improved (Johnson 1989).

Around the country, various agencies use terms differently. This can lead to confusion when developing a guidance document intended for national use. Therefore, for the purposes of this document, the following terms are defined:

A biological survey (biosurvey) is the process of collecting and processing representative portions of a resident aquatic community to determine the community structure and function.

A biological assessment (bioassessment) is an evaluation of the biological condition of a waterbody that uses biosurveys and other direct measurements of resident biota in surface waters.

Biological monitoring (biomonitoring) is the use of a biological entity as a detector, and its response as a measure, to determine environmental conditions. Toxicity tests and biosurveys are common biomonitoring methods.

Biological criteria (biocriteria) are numeric values or narrative expressions that describe the reference biological condition of aquatic communities inhabiting waters of a given designated aquatic life use.

This document describes a set of protocols for biological assessment of lakes and reservoirs relevant to issues of ecological integrity. It is not intended to address human health concerns as these issues have been addressed in previous guidance documents. The protocols in this document are intended for use by local, state, tribal, and regional natural resource monitoring agencies, and they can be used in the implementation of biological criteria.

The document includes a general strategy for biocriteria development, identifies steps in the process, and provides technical guidance on how to complete each step, using the experience and knowledge of existing state, regional, and national surface water programs where appropriate. The protocols are tiered to allow flexibility in customizing individual monitoring programs according to the user's own requirements and available resources.

The multiple assemblage and multimetric assessment approach outlined here is designed to address elements and processes associated with community balance, trophic structure, and richness. This guidance is not intended to replace existing biological assessment or biocriteria programs. Rather, it can be used as a tool for developing new programs and/or enhancing current programs. Although not designed to “push the envelope” of lake bioassessment, this document was developed to provide methods that are technically credible, practical, and geared toward the genuine needs and resources of natural resource agencies.

1.2 The Concept of Biocriteria

Efforts to monitor human effects on waterbodies have ranged from 19th century physical observations of sediment and debris movement (Caper et al. 1983) to chemical metrics, currently the most commonly employed source of water quality criteria (USEPA 1992e). Investigators and resource managers, however, have long recognized that water column measurements reflect conditions only at the time of sampling.

As an important supplement to chemical sampling, biological measurements can reflect both current conditions and temporal changes in waterbodies, including the cumulative effects of successive disturbances. However, the development and widespread use of formal biological criteria have lagged behind chemical-specific, instream flow, and toxicity-based water quality criteria in waterbody management (USEPA 1985b, USEPA 1985c). Recent recommendations on monitoring strategies for aquatic resources have emphasized the need to accelerate the development of biological sampling as a regular part of surface water programs (USEPA 1987b, USEPA 1987c).

Biological criteria are benchmarks for water resource protection and management decision making. Expressed as numeric values or narrative expressions, they measure attainment of biological integrity. In turn, biological integrity describes the most robust aquatic community to be expected in a natural condition in a water resource relatively unaffected by human activities.

The development of biocriteria by natural resource agencies depends on the assessment of conditions at reference sites. Reference sites are not necessarily pristine, although they must exhibit only minimal impairment relative to the overall region of study. Based on biological sampling, or surveys, a bioassessment of multiple sites is done, resulting in values that represent the biological potential for waters in the region. The regional biological potential is then used to establish biocriteria. Biocriteria can then be used as a measuring stick for determining the status of test sites. The sites can be surveyed, scored, and compared to the established biocriteria.

Biocriteria supported by bioassessment serves several purposes in surface water programs. The use of biocriteria expands and improves water quality standards, helps identify impairment of beneficial uses, and helps set program priorities. The use of bioassessments to investigate impairment, evaluate the severity of problems, ascertain the causes of the problems, and determine appropriate remedial action is a step-by-step process. Decision criteria for ascertaining impairment are part of the implementation plan and the foundation for establishing biocriteria to determine beneficial use categories and

assess subsequent management efforts. This should be followed by continued monitoring, improving the resource quality with each cycle. (See Figure 1-1.)



Figure 1-1. Interdependence of Environmental Monitoring and Environmental Criteria.

1.3 Uses of Bioassessments and Biocriteria

By directly measuring the condition of the water resource at a site, surveys and assessments of resident biota are an important foundation in the derivation and maintenance of biocriteria and, thus, are a critical tool for natural resource agencies in protecting the quality of water resources. Biocriteria, in conjunction with surveys of aquatic assemblages, are useful for a variety of purposes including:

- Problem screening and identification, through the early detection of problems that other methods might fail to uncover or might underestimate.
- Assessing the effectiveness of implemented water resource management practices.
- Determining attainment of designated aquatic life uses.
- Refining aquatic life uses categories.
- Identifying impact sources

Applications of bioassessments and biocriteria to specific USEPA, state, local, tribal, and regional management programs (such as under Clean Water Act sections 303, 305(b), 314, 319) are discussed in Chapter 2 of this document.

1.3.1 Screening and Identifying Problems

Monitoring of the resident biota can be used to identify and rank problem areas for further attention and dedication of resources. It can also serve as an early warning system to identify problems and to ensure against continued degradation. Biological assessments can be used to establish priorities for remedial actions. Screening can be done on an individual lake to establish management priorities. Screening can also be used as a tool on a regional or statewide basis to determine programmatic priorities. For example, regional screening could determine whether nutrient controls, sediment controls, or toxic elimination should have the highest priority for improving regional surface water quality.

1.3.2 Assessing Effectiveness of Management Practices

Bioassessments can be used to track the effectiveness of remediation measures. In managing nonpoint source pollution, the natural resource agency may initiate cooperative land use programs in a given area or install best management practices (BMPs) to improve the water resource. Both Nonpoint Source (NPS) and Clean Lakes Programs require monitoring of BMPs. Before-and-after bioassessments compared to the biocriteria “benchmark” make it possible to objectively evaluate the relative success of management by assessing actual biological community changes.

While other management uses of biocriteria include reviewing the adequacy of NPDES permits, biocriteria are not recommended at this time for inclusion as NPDES permit limits. Rather, they are ideal for assessing the adequacy of the permit to protect the resident biota. This can be done by comparing biosurvey results at the test site to the criteria established for that waterbody. Failure to meet the criteria suggests that the waterbody is not meeting its aquatic life use. One possible explanation is that the permit is not protective enough for the use class.

Monitoring the status and condition of resident communities over time is important to assess trends in the quality of the biota, whether to guard against further degradation or to measure relative improvement as a result of mitigation. Several natural resource agencies have established monitoring stations for conducting periodic biosurveys in streams as part of their biomonitoring programs. Very few natural resource agencies have initiated biological assessment for compliance monitoring in lakes.

1.3.3 Refining Aquatic Life Uses

Both classification and definition of designated uses of lakes and reservoirs are important in the planning, development, and use of biocriteria. Historical data from existing state efforts such as surface water classification and Clean Lakes Programs, along with additional field efforts, aid completion of these key planning steps. Information obtained through biological surveys can be used to explicitly describe each designated use.

A designated use is a classification designated in state water quality standards for each waterbody or segment that defines the optimal purpose for that waterbody regardless of attainment status. The designated uses for lakes and reservoirs are usually defined by individual natural resource agencies and include such uses as drinking water, aquatic life, recreational use, industrial use, and agricultural use.

Use attainability - The potential for a waterbody to meet, reach, or develop to its optimal purpose or designated use.

Aquatic life uses - Classifications specified in state water quality standards for each waterbody or segment relating to the level of protection afforded to the resident biological community by the state agency.

General information on use designation can be found in Biological Criteria: National Program Guidance for Surface Waters (USEPA 1990a). Specific technical guidance for conducting use-attainability analyses is provided in Technical Support Manual:

Waterbody Surveys and Assessments for Conducting Use Attainability Analyses (USEPA 1984).

Designated uses of waterbodies are formulated on, and in turn influence, the level of protection afforded the aquatic resource. Natural resource agencies establish standards appropriate to the protection of specific designated uses. For example, the designation outstanding waters is sometimes assigned to waterways which are located in undisturbed or minimally influenced watersheds and are characterized by aquatic communities that are deemed to be as naturally occurs (USEPA 1990a). Alternatively, other use designations may reflect preexisting land use patterns that prevent attainment of the highest quality waters. However, an observed downward trend does not justify lowered use designation.

1.3.4 Determining Attainment of Designated Use

Biological surveys and criteria are fundamental tools for assessing aquatic life use impairment. State water quality standards exist to define and protect designated uses conducive to overall water resource enhancement and preservation. Current biomonitoring tools used to judge nonattainment are not well-formulated in many instances. Consequently, many natural resource agencies rely exclusively or primarily on chemical-specific criteria to evaluate use impairment.

Biocriteria provide the only direct assessment of resource condition, and they are sensitive to a broader range of human influences on the watershed than are chemical criteria alone (Karr 1991, USEPA 1991b). By including biocriteria, a natural resource agency gains a much more complete assessment of the condition of the water resource. Biocriteria relate directly to biological resource condition rather than surrogate concentrations of particular pollutants. Cumulative impacts on the biota can be measured, revealing synergistic degradation that may occur even though all specific permit conditions may be met. Similarly, this measure of the biotic community often reveals the sum total of effects over the entire year, not just at one point in time.

1.3.5 Identifying Causes of Impairment

The concept of measuring the attributes of aquatic communities in unimpacted areas for biocriteria was first developed for stream systems (Index of Biotic Integrity [IBI], Karr et al. 1986; Invertebrate Community Index [ICI], Ohio EPA 1987; Rapid Bioassessment Protocol [RBP], USEPA 1989b) Observed deviations from the unimpacted conditions are assumed to be indicative of impairment. Human-induced alterations affect biological integrity through their effects on five major classes of factors important to the aquatic biota (adapted from Karr et al. 1986):

- Energy base.
- Chemical constituents.
- Habitat structure.
- Hydrologic regimen.
- Biotic interactions.

These factors influence the aquatic biota and can adversely affect elements and processes that normally occur in a lake or reservoir. By specifically designing a survey to include all five of these elements, it is possible to address causality when a lake fails to meet its biocriteria. Such information will assist in diagnosing impaired sites and determining management actions, for example, distinguishing between impacts from toxic substances and disruption of habitat.

1.4 Other Biocriteria Reference Documents

USEPA has developed technical guidance documents for implementing biocriteria in response to biocriteria development issues including legislative authority, steps in developing biocriteria, and the application of biocriteria to surface water management (USEPA 1990a). A reference guide to the technical literature pertaining to biocriteria has been developed to provide support interest from natural resource agencies (Table 1-1). This reference guide contains cross-references to technical papers that present concepts, approaches, and procedures necessary to implement habitat evaluations and biological surveys in the development and use of biocriteria.

In December 1990, a symposium on biological criteria provided a forum for discussing technical issues and guidance for the various waterbody types of the Nation's surface waters. The proceedings at this conference are presented in USEPA (1991b). The Agency has also developed guidance to help natural resource agencies initiate narrative biological criteria (USEPA 1992e).

Recently, the Agency issued a technical guidance document for biocriteria use in streams and small rivers (USEPA 1996a). Much of the approach and many of the issues addressed by the stream document serve as a template for developing biocriteria for other waterbody types, including lakes.

Table 1-1. Biocriteria reference documents

Title	Document Citation
<i>Biological Criteria: National Program Guidance for Surface Waters.</i>	USEPA 1990. EPA-440/5-90-004. U.S. Environmental Protection Agency, Washington, DC
<i>Biological Assessment Methods, Biocriteria, and Biological Indicators: Bibliography of Selected Technical, Policy, and Regulatory Literature</i>	USEPA 1996. EPA-230-3-96-001. Office of Policy, Planning, and Evaluation, U.S. Environmental Protection Agency, Washington, DC
<i>Biological Criteria: Research and Regulation. Proceedings of a Symposium.</i>	USEPA 1991. EPA-440/5-91-005. U.S. Environmental Protection Agency, Office of Water, Health and Ecological Criteria Division, Washington, DC
<i>Procedures for Initiating Narrative Biological Criteria.</i>	USEPA 1992. EPA-822-3-92-002. U.S. Environmental Protection Agency, Office of Science and Technology, Washington, DC
<i>Biological Criteria: Technical Guidance for Streams and Small Rivers.</i>	USEPA 1996. EPA-822-3-96-001. U.S. Environmental Protection Agency, Office of Science and Technology, Washington, DC
<i>Summary of State Biological Assessment Programs for Streams and Rivers</i>	USEPA 1996. EPA-230-3-96-007. Office of Policy, Planning and Evaluation, U.S. Environmental Protection Agency, Washington, DC