NOTICE TO USERS

All methods and procedures for the use of biological criteria contained and/or referred to in these volumes supercede those described in any previous Ohio EPA manuals, reports, policies, and publications dealing with biological evaluation, designation of aquatic life uses, or the evaluation of aquatic life use attainment. Users of these criteria and supporting field methods, data analyses, and study design should conform to that presented or referenced in these volumes (and subsequent revisions) to be applicable under the Ohio Water Quality Standards (WQS; OAC 3745-1).

Three volumes comprise the supporting documentation for setting and using biological criteria in Ohio. All three volumes are needed to use the biological criteria, implement the field and laboratory procedures, and understand the principles behind their development, use, and application. These volumes are:

Ohio Environmental Protection Agency. 1987. Biological criteria for the protection of aquatic life: Volume I. The role of biological data in water quality assessment. Division of Water Quality Monitoring and Assessment, Surface Water Section, Columbus, Ohio.

Ohio Environmental Protection Agency. 1987. Biological criteria for the protection of aquatic life: Volume II. Users manual for biological field assessment of Ohio surface waters. Division of Water Quality Monitoring and Assessment, Surface Water Section, Columbus, Ohio.

Ohio Environmental Protection Agency. 1987. Biological criteria for the protection of aquatic life: Volume III. Standardized biological field sampling and laboratory methods for assessing fish and macroinvertebrate communities. Division of Water Quality Monitoring and Assessment, Columbus, Ohio.

In addition, one other publication from the Stream Regionalization Project is recommended to all users:

Whittier, T.R., D.P. Larsen, R.M. Hughes, C.M. Rohm, A.L. Gallant, and J.M. Omernik. 1987. The Ohio stream regionalization project: a compendium of results. U.S. EPA - Environmental Res. Lab, Corvallis, OR. EPA/600/3-87/025. 66 pp.

These documents can be obtained by writing:

Ohio Environmental Protection Agency
Division of Water Quality Monitoring and Assessment
1800 WaterMark Drive, P.O. Box 1049
Columbus, Ohio 43266-0149

Other recommended and helpful literature is listed in the references of each volume.

ACKNOWLEDGMENTS

The members of the WQM&A, Surface Water Section biological field evaluation groups made significant contributions to this document and the development of biological criteria in general. This includes Ed Rankin (computer support and data analysis), Marc Smith, Roger Thoma, and Randy Sanders (Fish Evaluation Group), Jeff DeShon, Jack Freda, and Mike Bolton (Macroinvertebrate Evaluation Group), and Dennis Mishne (data processing support). Computer programming support was also provided by Charlie Staudt. Chris Yoder coordinated the assembling of the Users Manual. These are the principle authors and their efforts made the production of volume II possible.

This work is an outgrowth of the Stream Regionalization Project which was initiated in 1983. Dan Dudley, Ohio EPA, was the project officer and contributed to the overall success of the SRP program. Gary Martin and Pat Abrams, Ohio EPA, also provided invaluable management support that was necessary to accomplish the SRP program and produce the Users Manual and supporting documents. Bob Hughes, Northrop Services, Inc. formulated many of the initial concepts about ecoregions, the Stream Regionalization Project, and the integration of these ideas with biological assessment. He also provided detailed guidance, insights, and, along with Dave Miller, reviews of early drafts of the Users Manual. Phil Larsen and James Omernik of the U.S. EPA Freshwater Research Laboratory in Corvallis, Oregon also provided invaluable assistance and participation with the SRP program. Jim Luey and Wayne Davis (U.S. EPA, Region V) provided invaluable support and encouragement for the production of the Users Manual and the concept of biological criteria in general.

Persons providing timely reviews and helpful comments on the Users Manual and biological criteria concepts include Dan Dudley, Ray Beaumier, Dave Altfater, Paul Albeit, Bob Heitzman, and Bob Davic (all of Ohio EPA), Jim Luey (U.S. EPA, Region V), and Bob Hughes and Thom Whittier (Northrop Services, Inc.). Word processing support was provided by Mary Napier, Lisa Palsgrove, and Pam Jaques.

Table of Contents

Table of Contents (continued)

Table of Contents (continued)

Procedure No. WQMA-SWS-6 Date Issued 11/02/87
Revision No. 1 " Effective 11/02/87

Biological Criteria for the Protection of Aquatic Life: Volume II. Users Manual for Biological Field Assessment of Ohio Surface Waters

SECTION 1: INTRODUCTION

Background

A principal objective of the Clean Water Act (CWA) is to restore and maintain the biological integrity of surface waters. Although this objective is fundamentally "biological" in nature the specific methods by which regulatory agencies are attempting to reach this objective are predominated by such non-biological measures as chemical/physical water quality (Karr et al. 1986). The rationale for this process is well known - chemical criteria developed through toxicological studies of representative aquatic organisms serve as surrogates for measuring the attainment of the biological objectives of the CWA. Whole effluent toxicity testing offers an improvement over a strictly chemical approach, but itself lacks the ability to broadly assess ecosystem effects, particularly physical and non-toxic chemical impacts. The presumption is that improvements in chemical water quality will be followed by a restoration of biological integrity. Although this type of approach may give the impression of empirical validity and legal defensibility it does not directly measure the ecological health and well-being of surface waters. Recent information shows that other factors (e.g. excessive sediment) in addition to chemical water quality are responsible for the continuing decline of surface water resources in a majority of cases (Judy et al. 1984). Because biological integrity is affected by these factors in addition to chemical water quality, controlling chemical discharges alone does not in itself assure the restoration of biological integrity (Karr et al. 1986).

Ohio Water Quality Standards (OAC 3745-1) are designed to provide a basis for protecting and restoring surface waters for a variety of uses, including the protection and propagation of aquatic life. Aquatic life protection criteria consist of tiered aquatic life uses which are defined in OAC 3745-1-07. These include Warmwater Habitat (WWH), Exceptional Warmwater Habitat (EWH), Cold Water Habitat (CWH), Seasonal Salmonid Habitat (SSH), and Limited Resource Waters (Modified Warmwater Habitat will be proposed). Each of these use designations have been qualitatively defined in general ecological terms in the WQS and chemical-numeric criteria are assigned on a parameter-by-parameter or narrative basis. In addition to this Ohio EPA has specifically defined the WWH, EWH, and CWH use designations based on measurable characteristics of instream fish and macroinvertebrate communities (Ohio EPA 1984).

Since 1980 Ohio EPA has used measurable characteristics of instream fish and macroinvertebrate communities (expressed as numerical and narrative biological criteria) to quantitatively determine use attainment/non-attainment in flowing waters. Examples of this use are the derivation of water quality-based effluent limits (formerly the CWQR process), the biennial 305b water quality report, and the Priority Water Quality Area-Municipal Project Priority List (PWQA-MPPL) system. Other recent uses of this evaluation technique include evaluation of dredge and fill projects (i.e. 401 certification), nonpoint source profiles, validation of effluent toxicity test results, and the discovery of previously unknown or poorly understood environmental problems.

The Biological Basis for Determining Use Attainment/Non-Attainment

Aquatic life use attainment has traditionally been determined on a chemical basis. This was accomplished by collecting water samples, conducting chemical analysis, and comparing results with water quality criteria. If exceedences of specific chemical criteria were observed it was then assumed that the designated use was not being attained. However, it has been our experience that this approach has some significant shortcomings particularly when chemical results are compared to the response of the resident biota. Biological measures have indicated non-attainment when chemical WQS were not exceeded and visa versa. These "conflicts" occur for several reasons the most important of which are the design of most chemical sampling programs, "inadequacies" of the criteria themselves, and the fact that the biota respond to non-chemical perturbations of the environment. Some substances (e.g. sediment, nutrients) which are common constituents of both point and nonpoint sources exert their negative effects by means other than toxicity. These substances are generally not included in water quality criteria guidance documents because there is no toxicity basis for developing a water quality criterion. Thus it has not been possible to develop threshold response levels for aquatic life comparable to the chronic and acute toxicity thresholds that are routinely developed for substances that do exert their negative effects by toxicity. Other substances that are highly toxic may not be included in WQS because data to develop a criterion is lacking. In partial response to this problem Section 308 of the Water Quality Act of 1987 directs U.S. EPA to develop biological evaluation techniques as an alternative to the pollutant-by-pollutant approach for toxic chemicals. This volume presents an approach toward fulfilling this mandate.

To resolve some of the stated shortcomings of a strictly chemical approach to defining aquatic life use impairment we introduce the use of biological criteria to determine the magnitude and severity of environmental degradation directly. This approach has some important advantages:

1. Some organism groups, particularly fish and macroinvertebrates, inhabit the receiving waters continuously or for most of their life cycle and as such are a reflection of the past chemical, physical, and biological history of the receiving waters (includes healthy, not transient communities). Hence they are continuous monitors of the quality of the aquatic environment.

2. Resident biological communities are integrators of the prevailing and past chemical, physical, and biological history of the receiving waters, i.e. they reflect the dynamic interactions of stream flow, pollutant loadings, habitat, toxicity, and chemical quality that are not comprehensively measured by chemical or short-term bioassay results alone.

3. Many fish species and invertebrate groups have life spans of several years (2-10 yrs. and longer), thus the condition of the biota is an indication of both past and recent environmental conditions. Biological surveys need not be conducted under absolute "worst case" conditions to provide a comprehensive and meaningful evaluation of use attainment/non-attainment.

4. Biological assessment techniques have progressed to the point that incremental degrees and types of degradation can be determined and presented as numerical evaluations (e.g. Index of Biotic Integrity, Invertebrate Community Index, etc.) that have practical relevance.

5. Biological community condition portrays the results of water quality management efforts in direct terms, i.e. increases and decreases in community health (as reflected by biological community structure and function) are a meaningful measure of regulatory program progress.

6. Biological assessments at the sub-community level (e.g. fish, macroinvertebrates) are a workable, affordable, and cost-effective monitoring activity for state regulatory agencies (Ohio EPA 1986).

The condition of the aquatic community as revealed by the above mentioned measures is the integrated result of the chemical, physical, and biological processes in the receiving waters. This condition can be viewed as an "ecological endpoint" much the same way that lethality is the endpoint of an acute toxicity test. Since this endpoint can be quantified in measurable terms, criteria can be established that represent direct measures of use attainment/non-attainment. Finally, biological community data (particularly for fish and macroinvertebrates) are reasonably obtainable. Rapid advances in field sampling and laboratory techniques over the past 10 years make routine biological field monitoring a workable concept for regulating surface water quality. A recent Ohio EPA analysis of program costs shows that obtaining biological field data is cost competitive with chemical and bioassay evaluations (Ohio EPA 1986).

Biological Criteria

Ohio EPA has used numerical and narrative biological criteria based on fish and macroinvertebrates for quantitatively determining aquatic life use attainment/non-attainment since 1980. For fish the Index of Well-Being (Gammon 1976; Gammon 1980; Gammon et al. 1981) was the principal basis for determining use attainment. For macroinvertebrates a system of narrative criteria were used which are based on specific macroinvertebrate community characteristics (DeShon et al. 1980). These criteria and analyses are termed "structural" in that they are based on community aspects such as diversity, numbers, and biomass. More recently measures that incorporate community "function" (i.e. feeding strategy, environmental tolerance, disease symptoms) have been incorporated into the program. For fish the Index of Well-Being is retained in a modified form (Appendix C) and the Index of Biotic Integrity (IBI; Karr 1981; Karr et al. 1986) is added. For macroinvertebrates the Invertebrate Community Index (ICI) will supplant the narrative evaluations. These are not merely diversity indices and should not be equated to or confused with the more traditional information theory based indices (e.g. Shannon index) or species richness. Although these structural attributes are included, they are one component along with metrics that measure community production, function, tolerance, and reproduction. This provides for a rigorous, ecologically oriented approach to assessing aquatic community health and well-being. The rationale, development, and application of these indices is discussed in detail later in this document.

The application of these methods and criteria have been tested over a wide range of surface water body sizes and types, and a wide range of physical and chemical conditions in Ohio and elsewhere. More than 330 rivers and streams covering more than 5,300 stream miles have been biologically evaluated by Ohio EPA since 1979. This has included impact assessments for more than 700 point source discharges, a wide variety of nonpoint source influences, combined sewer overflow and stormwater discharges, sewage plant bypasses, accidental spills, and previously unknown or unregulated discharges.

Evaluating Biological Integrity

The term "biological integrity" originates from the Water Pollution Control Act amendments of 1972 (PL 92-500) and has been carried in subsequent revisions (PL 95-217; PL 100-1). Early attempts to define biological integrity in ways that it could be used to measure attainment of legislative goals were inconclusive (Ballentine and Guarrie 1975). These efforts to define biological integrity focused on the definition of some pristine condition that exists in few, if any, ecosystems in the conterminous United States. Hughes et al. (1982) concluded that biological integrity, when defined as some pristine condition, is difficult to precisely define and assess. The pristine definition of biological integrity was considered a conceptual goal towards which pollution abatement efforts should strive, although current, past, and future water and land uses may prevent its full realization.

For the purposes of the Ohio Water Quality Standards (WQS) biological integrity is practically defined as the ability of an aquatic ecosystem to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of the best natural habitats within a region (Karr and Dudley 1981). This is consistent with the recommendations of Hughes et al. (1982) and Karr et al. (1986). Thus the methods by which the following biological criteria have been established reflect this definition.

Biological definition of use attainment/non-attainment is made possible by monitoring aquatic communities directly. This is accomplished by standardized, quantitative sampling techniques which are described in the Ohio EPA Manual of Surveillance Methods and Quality Assurance Practices (Ohio EPA 1987a). Management decisions based on biological criteria must be made with the involvement of an aquatic biologist familiar with the specific methods, indices, and criteria being used (Karr et al. 1986). A sound familiarity with the regional fauna is also needed to ensure evaluations that are ecologically sound. Careful sampling is a necessity and requires the involvement of trained personnel who are able to contend with the site specific characteristics of different surface water bodies. Finally, taxonomic expertise must be adequate to accomplish organism identifications to the required level (Ohio EPA 1987a). Karr et al. (1986) provide additional cautions associated with using and interpreting biological data. These are general guidelines and cautions - more specific details are given later in this manual and in the Ohio EPA quality assurance manual (Ohio EPA 1987a).

Six criteria that biological monitoring programs should satisfy have been defined (Herricks and Schaeffer 1985). These requirements and how the Ohio EPA approach satisfies them are:

1. The measures used must be biological: The IBI, modified I_{wb}, and ICI are based soley on biological community attributes.

2. The measures must be interpretable at several trophic levels or provide a connection to other organisms not directly involved in the monitoring: The ecological diversity of each of the three indices and the inclusion of two organism groups that have species which function at different trophic levels satisfies this requirement.

3. The measure must be sensitive to the environmental conditions being monitored: The inherently "broad" ability of fish and macroinvertebrates to reflect and integrate a wide variety of environmental stresses (see Ohio EPA 1987b; Table 2, Figures 1 and 5) and the "redundancy" of the IBI and ICI metrics themselves satisfy this requirement.

4. The response range (i.e. sensitivity) of the measure must be suitable for the intended application: The biological indices and organism groups used by Ohio EPA have been demonstrated to have a high degree of sensitivity to even small, subtle changes in the environment and a wide variety of environmental disturbance types (Ohio EPA 1987b). One example is the ability to discern community differences between streams of the same use designation.

5. The measure must be reproducible and precise within defined and acceptable limits for data collected over space and time: Both the fish and macroinvertebrate sampling methods and evaluation indices have been shown to have consistent, reproducible expectations within acceptable limits (Appendices B-D). Carefully following prescribed field and laboratory methods is a prerequisite to meeting this requirement.

6. Variability of the measure(s) must be low: The variability inherent to each of the three biological indices being proposed has been shown to be quite low and within acceptable limits at relatively undisturbed sites. Variation between samples clearly increases with environmental disturbance (Appendices B-D). Satisfying this requirement involves understanding the nature of variability that may come from sampling frequency or seasonal influences.

Karr et al. (1986) evaluated the applicability of the IBI based on fish to these criteria and found that it satisfied the six requirements. The use of two additional indices and one additional organism group by Ohio EPA further satisfies these demands. Several of these requirements, particularly numbers 5 and 6, are addressed later in this manual.

The choice of both fish and macroinvertebrates as the routine organism groups to monitor was made because both groups have been widely used in water pollution investigations and there is an abundance of information concerning their life history, distribution, and environmental tolerances. The need to use both groups is apparent in the ecological differences between them, differences that tend to be complementary in an environmental evaluation. The value of having both groups showing the same general indication (i.e. confirmation) is important. Apparent differences in the responses of these two groups has usually led to the definition of problems which would have gone unnoticed or unresolved in the absence of information from either organism group.