SAMPLING AND DATA EVALUATION REQUIREMENTS FOR FISH AND BENTHIC MACROINVERTEBRATE COMMUNITIES

Wayne S. Davis and Thomas P. Simon
U.S. Environmental Protection Agency
Environmental Sciences Division
536 South Clark Street
Chicago, Illinois 60605

Abstract

During the planning of the Workshop, it was decided that the best way to facilitate exchange of the many technical and program/policy-related issues was to establish specific discussion groups of the major issues. From this breakout of groups, two aquatic life discussion groups emerged: benthic macroinvertebrates and fish. The intent of separating these two groups was not to discourage exchange between the two disciplines or establish adversarial positions, but to gather those actively working within the respective aquatic life groups in State and Federal programs for discussion of specific issues. The knowledge and professional experience of a qualified professional field biologist should be used to determine which group of organisms may be best utilized in the various environmental assessment projects. It is also realized that economic constraints sometimes necessitate implementation and operation of a less than ideal program. However, the experiences and knowledge shared at this Workshop convinced us that evaluation of both aquatic life groups is necessary. We do not advocate the use of one group over the other on a programmatic basis. We wish to leave this decision to the State and Federal field biologists.

Introduction

Recommendations from the two workgroups dealt primarily with Quality Assurance. There is a great need to develop and implement Data Quality Objectives, demonstrate reproducibility of results, and ensure that well-qualified biologists (fisheries and benthic) are preforming the sampling and subsequent taxonomic identifications, as well as data analysis and interpretation. Generic and specific recommendations for the benthos and fish community sampling and data evaluation requirements appear below. The following documents provided insight and language for some of the recommendations that appear in this report (Ohio EPA 1987a,b; Hellawell 1978; and Plafkin et al. 1987).

Sampling and Data Evaluation Requirements

The following recommendations apply to both the fish and benthos field programs, thus, they are incorporated together to eliminate redundancy. Bioassessments should be incorporated by the USEPA and State regulatory agencies into an integrated monitoring strategy that can accurately assess instream biological integrity use attainment and measure the success of pollution abatement programs.

The bioassessment program supported by USEPA and the State regulatory agencies should be based on using both fish and benthic macroinvertebrate community analysis. Frequently, analysis of biosurvey sampling results from both aquatic life groups yield the same water quality evaluations and thus corroborates one another.

However, when the results differ, it has been due to the tolerance of these groups to the various environmental stresses that may be reflected only by their trophic level and place in the food chain. Use of the two groups can integrate perturbations to the system via measurements of their structural and functional shifts.

Bioassessments should be used for surveillance, monitoring, and enforcement of water quality standards for point source discharges. Their use identifies synergistic and additive impacts. Small incremental impacts can be identified by quantitative shifts in the community structure and function even when the designated use is being attained.

Bioassessments should be used for screening areas impacted by non-point pollution sources. Once identified, these tools can determine the extent and severity of the impacts and be used to evaluate long-term trends. Results from previous biological surveys should be incorporated into each successive 305(b) report to identify stream segments impact by non-point sources. Whereas there are many surrogate methods for estimating point source impacts to the biota (chemical and bioassay), a direct measurement of the biological communities by biosurveys is the only practical method for assessing non-point source impacts.

Sampling and data evaluation requirements: One sampling event is adequate for screening purposes (Angermeier and Karr 1984) with a single exceedence of a narrative or numerical biocriterion adequate for initiating a control action. Control sites should be selected from upstream sites, for point source impact determination. If the upstream segment is impacted, a control site may be chosen from an adjacent stream of similar drainage area and ecoregion. The ecoregion concept (Larsen et al. 1986; Omernik 1987) may also be useful for watershed evaluation and use attainability categorization when the entire basin may be impacted.

Field sampling must be standardized to ensure reproducibility (OEPA 1987a; Plafkin et al. 1987), and carried out by professional field biologists who determine the appropriate habitats to be sampled and the types of sampling gear necessary. The biologist should participate in all aspects of the field studies from planning, data collection and interpretation, to report writing or at a minimum final document review. Long-term monitoring should be conducted by the discharger to evaluate the effectiveness of the control options.

When evaluating non-point source influences, deficiencies in baseline data should be identified and remediated. This activity should involve EPA interaction with other State, local, and Federal agencies such as U.S. Fish and Wildlife Service, U.S. Forestry Service, U.S. Geological Survey, State DNRs, and DECs. Future resource needs should be coordinated among the agencies to eliminate, or at least reduce, duplication of effort. Other actions include: support of technology transfer between States to enable the establishment of reference control sites for States or EPA regions which have common ecoregions; coordination of

basin/watershed studies by the Federal agencies to ensure complete evaluation of transboundary streams; coordination with the State and Regional Superfund groups who may be aware of data necessary to support the non-point source assessments.

If discharger self-monitoring or consultant mediated monitoring is advised by the regulatory agency to support a decision, the following items must be satisfied: the methods used must comply with USEPA or State regulatory agency methods; a study plan must be approved by the regulatory agency; the regulatory agency will determine the level of effort necessary including, but not limited to, the number of study sites, location, taxonomic effort expended; and downstream sampling should include locations within the mixing zone if practicable, and at locations further downstream at discrete intervals to characterize the extent of impact.

Biosurveys should be routinely used to rank grant applications for environmental improvement (remediation) projects based on the potential for environmental improvement. This can be accomplished by comparing the extent and severity of degradation with the potential for biological improvement. The result would be a ranking of where the funds for building or upgrading treatment plants or implementation of Best Management Decisions will result in the greatest environmental benefits for the funds expended.

Fish Community Survey

Fish should be used for environmental assessments since: the taxonomy of fish is well established and allows professional field biologists to identify most species in the field, thus minimizing lab time and speeding data analysis; life histories and environmental tolerances are well documented in the scientific literature; fish comprise the upper trophic levels in aquatic ecosystems thus integrating lower trophic level energy transfer; species specific tolerances to environmental stresses result in measurable shifts in community structure and function; fish continuously inhabit the receiving waters and integrate the chemical, physical, and biological history of the waters that are not directly measured by chemical or short-term bioassays alone; most fish species have long life spans (3-10 years and frequently longer) and can reflect both past and recent environmental quality; assessment techniques now permit determination of the type of impact and incremental degrees using numerical evaluations that have meaning to non-biologists (e.g. Index of Biotic Integrity (Karr et al. 1987), Index of well-being (Gammon et al. 1981), Shannon diversity index, and others used in the State programs); and fish are a highly visible component of the aquatic community to the public sector.

An evaluation of habitat quality must be conducted in conjunction with the biological evaluation to account for ecoregional differences. A standardized quantitative habitat evaluation procedure should be developed.

Although sampling is not limited by season for the purposes of determining environmental impact, sampling should be conducted during the low-flow periods of summer and early fall (Angermeier and Karr

1986; Hilsenhoff 1987). This period generally coincides with the period of greatest environmental stress (e.g. high temperatures, lower DO, lower flow) and ease of sampling.

Larval fish, or young-of-the-year, not used in most indices (Fausch et al. 1984; Karr et al. 1986) should be collected and identified. Their presence should be included in a narrative discussion of the survey results until further indicies can account for impacts to the early life stages.

Sampling should be standardized to obtain a representative sample from each site. Either distance or time needs to be measured, depending on gear type to ensure that a sample is comparable.

The use of ecoregions to delineate and establish reference and control sites is strongly encouraged.

Benthic Macroinvertebrate Community Surveys

Benthic macroinvertebrates provide the impetus for environmental assessments based on the following: most benthos are sessile or have a limited migration pattern, thus they the are particularly well-suited for assessing site-specific impacts (upstream-downstream studies); benthic communities integrate the effects of short-term environmental variations since most species have a complex life cycle of two years or less, the sensitive life stages will respond quickly to stress; degraded stream conditions can often be detected with only a cursory examination of the benthos in the field since they are relatively easy to identify to the family levels for intolerant taxa; sampling is less strenuous than fish, requiring few biologists with inexpensive gear, and has no detrimental effect on the resident biota; benthos are a primary food source for important recreational and commercial fish, and reflect the lower trophic levels; many small streams of 1st and 2nd order naturally support a diverse macroinvertebrate fauna; most State regulatory agencies that routinely collect biosurvey data have benthic data available.

State and Regional training is needed on the use of the Rapid Bioassessment Protocols to further refine and evaluate these methods for geographical-specific uses. The Rapid Bioassessment Protocols should not replace the more extensive State program methods.

State programs represented at this Workshop demonstrated technically successful data generation for supporting water programs. At a minimum, data interpretation should include a decision tree, and should include a range that can be used to evaluate data for the decision process.

The use of artificial or natural substrates should be based on the data needs within a particular State program. Each method provides necessary information for program use and it may be preferable to use the different methods when encountering program or site-specific requirements.

Habitat sampling preference (e.g. riffle, run, pool, undercuts, CPOM) should be decided on a site-specific basis by the State program field biologist. The overall requirement of demonstrating reproducible results negates concern for this item.

Sampling in the mixing zone and downstream of the mixing zone is

Table 1. The comparative ability and "power" of various chemical, physical, and biological assessment techniques to measure or indicate key components of factors affecting biological integrity of surface waters (D - directly measures; I - indirectly measures; S - strongly reflects; C - casual relationship). Modified from Ohio EPA (1987).

Factors/Components	Level 1&2 Exposure Assess.[1]	Level 3 Exposure Assess.[2]	Toxicity (acute)	Toxicity (chronic)	Physical Assessment	Ambient Biological Evaluation
I. CHEMICAL WATER QUALITY						
Conventional substances	D	D	I	I	-	S
Heavy metals	D	D	I	I	-	S
Toxic organics	-	D	I	I	-	S
Static interactions	S	S	I	I	-	N/A
Dynamic interactions	-	I	-	I	-	S
II. ENERGY DYNAMICS						
1° and 2° dynamics	C	I	-	-	-	I
Nutrient cycling	C	I	-	-	-	I
Organic inputs	-	C	-	-	-	I
III. HABITAT QUALITY						
Substrate	-	-	-	-	D	S
Water velocity	-	-	-	-	D	S
Instream cover	-	-	-	-	D	S
Channel integrity	-	-	-	-	D	S
Riparian buffer	-	-	-	-	D	S
Habitat diversity	-	-	-	-	D	S
IV. FLOW REGIME						
Low Extremes	I	I	-	-	-	S
High Extremes	-	-	-	-	-	S
Temporal cycles	-	C	-	-	C	S
Volume	D	D	-	-	D	S
V. BIOTIC RESPONSES						
Acute effects	I	I	D	D	-	S
Chronic effects	I	I	I	S	-	S
Abundance, biomass	-	-	-	-	-	D
Structural	-	-	-	-	-	D
Functional	-	-	-	-	-	D
Disease, etc.	-	-	C	C	-	D
Tolerances	-	-	-	-	-	D
Competition	-	-	-	-	-	S
Reproduction	-	-	-	S	-	S
Predation	-	-	-	-	-	S
Growth	-	C	-	S	-	D

[1] primarily models for oxygen demanding substances and simple mass-balance dilution calculations for other substances; steady-state conditions assumed.
[2] applications ranging from probabalistic dilution to dynamic fate-assessment models.

recommended to evaluate effluent toxicity and associated impacts.

Benthic invertebrates should be collected during the latter period of the season(s) which demonstrate a stable base-flow (normal flow) and temperature regime. Seasonality and low-flow sampling have been important issues raised by critics of the use of biosurveys in the regulatory programs. We recommend that it is not necessary to sample during 7Q10 conditions because not only do the biological communities integrate the ecosystem effects over a long period of time, the populations are most stable and easily collected at the base-flow allowing for a more accurate assessment.

Benthic surveys are recommended for instances where significant toxicity is measured by effluent toxicity tests. If the biosurvey does not support the toxicity evaluation, the information must be reevaluated using a "weight of evidence" decision (USEPA 1988). If the biosurveys indicate a potential toxicity problem with a discharge, an effluent toxicity test is recommended.

The use of functional feeding groups to indicate use impairment due to toxics or conventional pollutants should be further

evaluated, in addition to the utilization of in situ bioassays (e.g. caged fish, clams, leaf-packs) for use in toxicity bioassessment.

The utilization of riparian vegetation as a potential instream assessment tool should also be evaluated.

The EPA biological field methods manual (USEPA 1973) should be updated.

Program Development and Management

Transdisciplinary definitions need to be established for the following terms to eliminate potential confusion over appropriate usage and terminology: biosurvey, biomonitoring, bioassessment, bioassay, biosurveillance, and biotic integrity. Standard definitions may be required for additional terms.

We recommend the use of the term "bioassessment" to broadly encompass the other terms identified. The terms survey (short time period) and surveillance (continued systematic surveys) generally apply to the instream communities (fish and benthos). Toxicity test, or bioassay, are the preferred terms to represent the exposure of test populations in a laboratory setting to ambient water or effluent discharges. In situ toxicity tests, or bioasssays, utilize placement of test organisms in the ambient water or effluent discharges for known exposure periods. Biological monitoring is surveillance conducted to ensure instream standards, or effluent permits, are being met using either the instream community or toxicity tests.

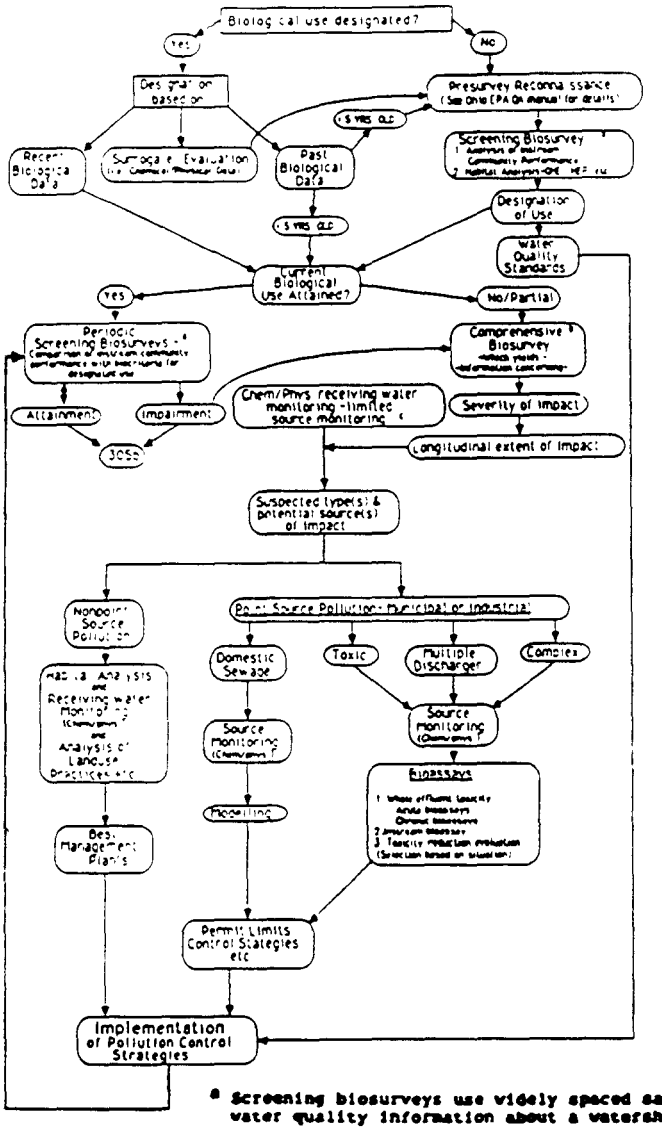
A successful biological assessment strategy to provide the information necessary to make correct regulatory decisions requires a knowledge and understanding of the strengths and weaknesses of each environmental tool employed. Table 1 depicts the ability of various chemical, physical, and biological assessment techniques to measure the key factors affecting the biological integrity of the surface waters. The relative use of each of these techniques, and their relative costs, should be carefully evaluated prior to any field sampling effort.

Bioassessments should be incorporated by the USEPA and State regulatory agencies into an integrated monitoring strategy that can accurately assess instream biological integrity and measure the success of pollution abatement programs. One method for utilizing biosurveys is presented in Figure 1, which is a conceptual framework implemented by one of the State regulatory agencies. The most important point of this framework is that when decisions are made on aquatic life use attainability and attainment, those decisions should be largely based on a direct determination of the aquatic community structure and function.

A technical support or guidance document should be developed by USEPA to identify how the biological criteria are implemented into the variety of regulatory and nonregulatory programs.

The data evaluation techniques currently employed in State programs should be the basis for establishing minimum data evaluation methods for new programs.

Education of State and Federal pollution control officials should be focused on the advantages and



[a] Screening biosurveys use widely spaced sampling sites to obtain general water quality information about a watershed.

[b] Comprehensive biosurveys require numerous sampling sites to document severity and extent of impacts. Sampling occurs at reference sites, sites up and downstream from point sources, and areas of expected changes in water quality.

[c] Biological communities react predictably to various water quality problems (e.g., toxicity, D.O. sags, siltation). As a result, biosurveys indicate the type of impact, and when coupled with receiving water monitoring provide greater resolution of the source(s) and type(s) of impacts

Fig. 1. A conceptual framework for assessing ambient biological performance and the success of implemented pollution control strategies (Ohio EPA 1987).

uses of biosurveys in the water programs. Education of regulatory agency biologists on the appropriate uses of biosurveys should be supported by USEPA Headquarters through Office of Research and Development (ORD) training. Education of the public and awareness of the biological ecosystem components are needed to

urge legislators to initiate corrective programs through a citizens monitoring network.

The cost effectiveness of biosurveys for assessments has been demonstrated by the State of Ohio. Other States and regulatory agencies need to corroborate this finding to gain a more widespread acceptance of using biosurveys.

The use of automated databases and computer programs should be encouraged through Federal negotiations with States on their monitoring programs. The use of BIOS for storage and retrieval is highly recommended, and funding should be made available to support PC-based data manipulation software which would permit a free exchange of data between the States and the USEPA. Resources should also be allocated for a rigorous evaluation of the ERAPT program (Dawson and Hellenthal 1985).

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