United States
Environmental Protection
Agency

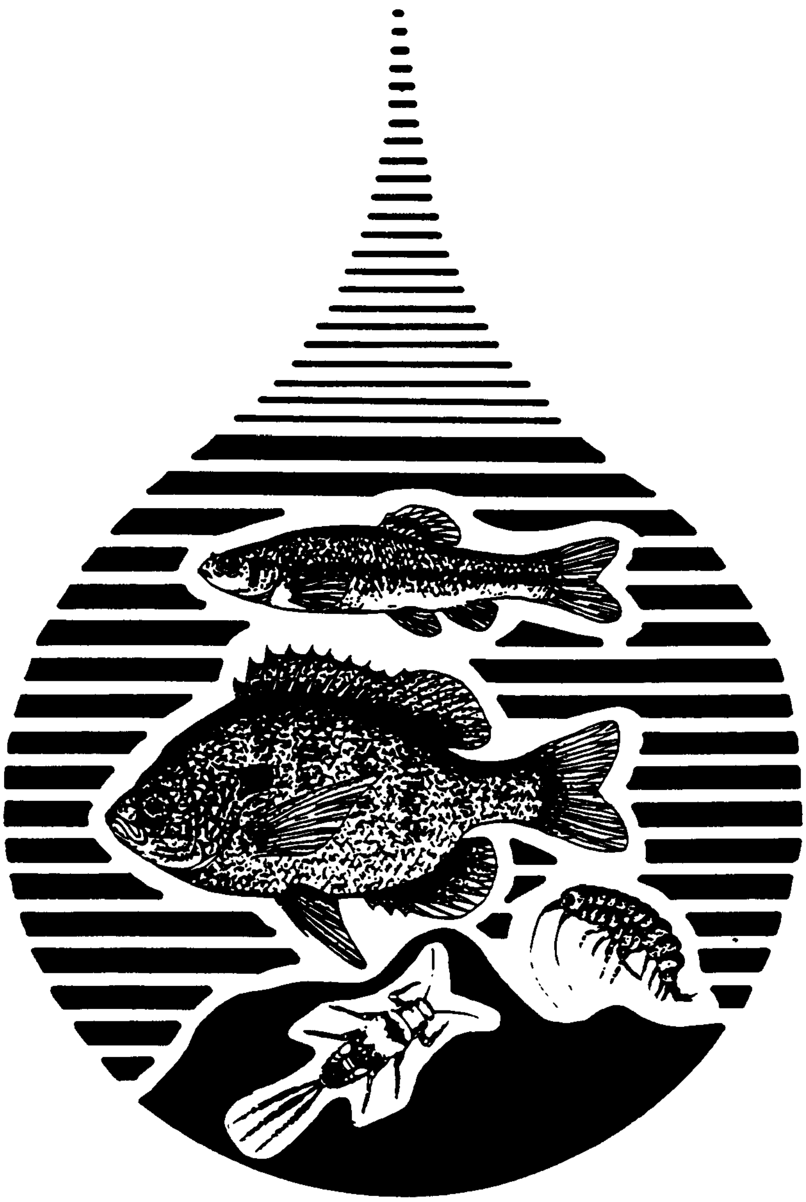
Region 5
230 South Dearborn Street
Chicago, Illinois 60604

EPA-905/9-89-007
October 1989

EPA

Proceedings of the 1989 Midwest Pollution Control Biologists Meeting

Chicago, Illinois
February 14-17, 1989



PROCEEDINGS OF THE 1989
POLLUTION CONTROL BIOLOGISTS MEETING

held in

CHICAGO, ILLINOIS

FEBRUARY 14-17, 1989

Edited by:

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Instream Biocriteria and Ecological Assessment Committee

Sponsored by:

U.S. Environmental Protection Agency
Assessment and Watershed Protection Division
Washington, D.C. 20460

U.S. Environmental Protection Agency, Region V
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Environmental Sciences Division
Chicago, IL 60604

NOTICE

When citing individual papers within this document:

Burton, G.A., B.L. Stemmer, P.E. Ross, and L.C. Burnett. 1989. Discrimination of sediment toxicity in freshwater harbors using a multitrophic level battery. pp. 71-84. In W.S. Davis and T.P. Simon (eds). Proceedings of the 1989 Midwest Pollution Control Biologists Meeting, Chicago, IL. USEPA Region V, Instream Biocriteria and Ecological Assessment Committee, Chicago, IL. EPA 905/9-89/007.

When citing this document:

Davis, W.S. and T.P. Simon (eds.). 1989. Proceedings of the 1989 Midwest Pollution Control Biologists Meeting, Chicago, IL. USEPA Region V, Instream Biocriteria and Ecological Assessment Committee, Chicago, IL. EPA 905/9-89/007.

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Cover: Cover design and illustration by Blaine D. Snyder of EA Engineering, Science, and Technology, Inc. Depicted is a fathead minnow, a bluegill, a gammarid amphipod, and an emphemerellid mayfly superimposed on a drop of water. This design was originally used for the Rapid Bioassessment Protocols program, directed by James Plafkin, USEPA, Assessment and Watershed Protection Division, Office of Water, Washington, D.C.

FORWARD

This meeting was held to facilitate the technical exchange of methods and ideas among midwestern pollution control biologists, and to provide a forum for both technical and social interactions. The success of regional biologist meetings in other parts of the country prompted USEPA Region V to initiate a meeting in the midwest, with the hope that other local groups would become interested in hosting a meeting annually in different States. We did not view this as an "EPA" meeting, we simply took advantage of an opportunity to start this process with generous support from EPA Headquarters and Region V.

Regional biologists meetings, including our first meeting in Chicago, gather professionals in various biological disciplines and responsibilities to communicate on broad water pollution assessment and control issues. These issues cross-cut membership and participation in professional societies and associations. This meeting started to increase interaction with local pollution control biologists that are members of the American Fisheries Society, North American Benthological Society, Water Pollution Control Federation, International Association for Great Lakes Research, North American Lake Management Society, Society for Environmental Toxicology and Chemistry, and many others. The success of these regional biologists meetings acknowledge that our water quality and environmental problems can only be solved by integrating the practices of several biological disciplines and being knowledgeable of each others professional and programmatic roles.

The responsibilities we have as pollution control biologists are increasing, but are also becoming better defined. As a result of the "National Workshop on Biological Monitoring and Criteria", USEPA is well into the development of a National Biocriteria Policy, including the production of technical and program guidance documents to support the policy. These documents should be finalized during 1990. The first major product from this overall effort was the publication of the "Rapid Bioassessment Protocols for Use in Streams and Rivers" which has brought attention to environmental managers throughout the nation of the biological tools available for water quality assessments. As a group, pollution control biologists will have greater impacts on the assessment and control of water quality at the Federal, State, and local levels. Although this first Midwest Pollution Control Biologist's Meeting did not include many private sector groups, we certainly expect all future meetings to welcome the participation of all professional pollution control biologists in the midwest.

We gratefully acknowledge the participation and assistance of the following individuals for supporting the Midwest Pollution Control Biologists Meeting, as well as producing this document: Valdas Adamkus, William H. Sanders III, Charles Sutfin, Jim Giattina, Noel Kohl, James Plafkin, Curtis Ross, Meg Kerr, David Charters, Deborah White, and Ed Drabkowski. The members of the Region V Instream Biocriteria and Ecological Assessment Committee are thanked for their role in coordinating and hosting this meeting: Thomas Simon, James Luey, Linda Holst, Allison Hiltner, Carole Braverman, Larry

Shepard, Denise Steurer, Charles Steiner, Max Anderson, Mardi Klevs, Glenn Warren, Bill Melville, John Schneider, and Walter Redmon. Special thanks to all the authors of this proceedings, especially our keynote speaker, Dr. James Karr whose knowledge and insight into the water quality issues we face set the tone for the meeting.

Wayne S. Davis
Local Meeting Coordinator and Host
Chairperson, Instream Biocriteria and Ecological
Assessment Committee

TABLE OF CONTENTS

Author	Title	Page
Davis	Forward	iii
Karr	Monitoring of Biological Integrity: An Evolving Approach to Assessment and Classification of Water Resources	1
Szczytko	Variability of Commonly Used Macroinvertebrate Community Metrics for Assessing Biomonitoring Data and Water Quality in Wisconsin Streams	12
Davis and Lubin	Statistical Validation of Ohio EPA's Invertebrate Community Index	23
Marshall, Stewart, and Baumann	Black Earth Creek: Use of Biological Methods to Identify Non-Point Source Threats to a Naturally Reproducing Trout Fishery	33
Simon	Rationale for a Family-Level Ichthyoplankton Index for Use in Evaluating Water Quality	41
Bascietto	Ecological Assessment at the EPA: Superfund Guidance and EPA's Ecological Risk Assessment Guidelines	66
Burton, Stemmer, Ross and Burnett	Discrimination of Sediment Toxicity in Freshwater Harbors Using a Multitrophic Level Test Battery	71
Kapustka and Linder	Hazardous Waste Site Characterization Utilizing In Situ and Laboratory Bioassessment Methods	85
Kerr	Overview of Citizen-Based Surface Water Monitoring	94
Sefton	Volunteer Monitoring Data Applications to Illinois Lake Management	100
Lathrop	A Naturalist's Key to Stream Macroinvertebrates for Citizen Monitoring Programs in the Midwest	107
Bostrom	The "Why" of Minnesota's Citizen Lake-Monitoring Program	119
Kopec	The Ohio Scenic Rivers Stream Quality Monitoring Program: Citizens in Action	123
Rumery	Wisconsin's Self-Help Lake Monitoring Program: An Assessment from 1989 to 1988	128
Davis	A Summary of the First Midwest Pollution Control Biologists Meeting	137

Monitoring of Biological Integrity: An Evolving Approach to the Assessment and Classification of Water Resources

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Abstract

The ability to sustain a balanced biological community is one of the best indicators of the potential for beneficial use of a water resource. While perception of biological degradation stimulated most current state and federal legislation on the quality of water resources, that biological focus was lost in the search for easily measured physical and chemical surrogates. Development of concepts like "antidegradation" and "use attainability" have strengthened the call for ambient biological monitoring. Further, the development of an operational definition of biological integrity and of ecologically sound tools to measure divergence from that societal goal have stimulated increased interest in ambient biological monitoring. The Index of Biotic Integrity has now been applied successfully throughout North America. Some modifications of metrics are necessary for application outside the midwest but its ecological foundations have been retained. The success of IBI has stimulated the development of similar approaches using benthic invertebrate communities. Expansion in the use of ambient biological monitoring is essential to the protection of water resources.

Keywords: Biological integrity, biological monitoring, IBI, water pollution, water resources.

Introduction

The assumption that surface waters were in existence to receive the discharges of human society was common until relatively recently. In 1965, for example, an Illinois water official noted "regardless of how one may feel about the discharge of waste products into surface waters, it is accepted as a universal practice and one which in Illinois is considered a legitimate use ofstream waters" (Evans 1965). While that philosophy has yet to be abandoned, the legal and regulatory environments have changed, both in terms of societal goals and in the nature of monitoring programs designed to protect water resources.

The Illinois water official quoted above subscribed to the phrase "dilution is the solution to pollution." Even after the concept of biotic integrity was first explicitly incorporated into federal water law (in PL 92-500, the Water Quality Act Amendments of 1972), point source effluents were the primary target of regulatory efforts. Implementation of the mandates of PL 92-500 narrowly focussed on chemical parameters, or when a biological perspective was used, the emphasis was on acute and later chronic effects of chemical pollutants from point sources. Concern for non-point sources increased after the mid-1970's but they were (and remain today) largely unsuccessful because of difficulties involved in applying point source approaches to diffuse non-point source problems.

Within this chemically oriented context, even the definition of pollutants generated controversy. In 1974, for example, I was challenged by agricultural scientists when I argued that sediments were a pollutant that must be brought under control if the quality of water resources was to be protected. They argued, to my dismay, that sediment must not be a pollutant because USEPA had not announced a criterion for maximum tolerable levels.

Fortunately, the 1980's have seen a major shift in philosophy with recognition of the inadequacy of that approach. A 1987 USEPA report entitled "Surface Water Monitoring: A Framework for Change" included among its recommendations the need to accelerate the development and application of promising biological monitoring techniques. The Water Quality Act of 1987 strengthened the call for ambient assessment to evaluate biological integrity. Biological integrity was recognized as a direct, comprehensive indicator of ecological conditions.

Simply put, if water resources are to be protected, a quantitative and ecologically sophisticated method is needed to monitor the biotic integrity of running waters. No non-biological techniques exist that can serve as a surrogate for the direct measurement of biological conditions in a stream. A principle impediment to the development of an ecological approach has been the dominance of water-pollution engineers in state and federal agencies. Because engineers, agriculturists, and biologists do not speak a common language, they could not agree on either common goals or approaches to attain those goals. Even biologists could not agree on approaches to biomonitoring, leaving water resource issues to other interests and expertise. Fortunately, an increasing number of water resource scientists and agencies recognize that an approach that mixes chemical criteria, whole effluent criteria, and biological criteria is essential to restore and maintain the quality of water resources.

Assessing Biotic Integrity

But more than the dominance of an engineering approach limited the incorporation of biological monitoring into water resource programs. Other limits were the lack of an easily defensible definition of biological integrity, lack of agreement on standardized field methods, and lack of indexes that could be generally applied in a wide range of water resource systems and that were successful "in measuring attainment of the biological integrity goals of the Clean Water Act" (Ohio EPA 1987). Finally, a major impediment to incorporation of biological monitoring was the misconception that biological monitoring is expensive relative to other approaches, an issue that has recently been put to rest, especially by studies conducted by Ohio EPA (Table 1).

I first recognized these problems in 1974-75 during my participation in a project designed to examine the role of agricultural non-point source pollution in the degradation of water resources (Morrison 1981). My colleagues and I first addressed the problem in that project (Karr and Schlosser 1977, Karr and Dudley 1977) and then began to generalize our results (Karr and Schlosser 1978, Karr and Dudley 1981), eventually leading to the development of an index of biotic integrity (IBI) using fish communities (Karr 1981). In retrospect, a critical component in that development was the challenge involved in working with an interdisciplinary team of water resource specialists. The challenging and questioning that

Table 1. Comparative cost analysis for sample collection, processing and analysis for evaluation of the quality of a water resource. Data from Ohio EPA, 1987.

Chemical/Physical Water Quality	
4 samples/site	$1,501
6 samples/site	$1,715
Bioassay	
Screening (Acute - 48 hour exposure)	$3,159
Definitive (LC50[a] and EC50[b] - 48 & 96 hour)	$5,901
Seven Day (acute and chronic effects - 7 day exposure single sample)	$8,538
Seven Day (as above but with composite sample collected daily)	$12,642
Macroinvertebrate Community	$ 699
Fish Community	
2 passes/site	$ 673
3 passes/site	$ 897

a - dose of toxicant that is lethal (fatal) to 50% of the organisms in the test conditions at a specified time.
b - concentration at which a specified effect is observed in 50% of organisms tested; e. g., hemorrhaging, dilation of pupils, stop swimming.

accompanied that effort forced me to think in more inclusive terms, both in the development of a broadly based index, and in the advocacy of such an index to diverse audiences.

Why IBI?

Biologists have advocated the need for direct biological assessment for over two decades and a variety of methodologies have been proposed (Worf 1980, Fausch et al. 1989). Laboratory studies of acute toxic effects dominated early work with the goal of establishing criteria for pollutants (USEPA 1976), an approach that was challenged by many (Thurston et al. 1979). Field monitoring of selected (indicator) taxa was also tried using fish (bluegill (Lepomis macrochirus), fathead minnow (Pimephales promelas) or some salmonids), benthic invertebrates, or diatoms. These approaches identified two important aspects of biological monitoring: The ability of individuals to survive stress from a toxic compound and the pollution tolerance of assemblages of species (communities). More or less independently, biologists responsible for sport and commercial fishery resources, dealt primarily with physical habitat degradation, and in western watersheds, with the problem of decreased flow.

The primary weakness of all of these methods is clear. Limits to the biological integrity of a water resource vary in space and time and none of these approaches can be used to identify all types of degradation. Sole focus on acute toxicity in the laboratory misses chronic effects in the field and the synergistic effects of combinations of chemical pollutants. A focus on community structure such as species composition of benthic invertebrates misses the opportunity to evaluate a wider array of aspects of biotic integrity such as individual health, sizes of populations of component species, or trophic structure of the community. Thus, I set out to develop a more comprehensive approach to the study of biotic integrity. The result of that effort was an index to assess biological conditions in a river or stream using fish communities and referred to as the Index of Biotic Integrity (IBI). IBI is a multiparameter index which uses attributes of fish communities to evaluate human effects on a stream and its watershed. Its use in a variety of contexts (effects of mine drainage, impacts of sewage effluent) and in a diversity of geographic areas demonstrate the utility of IBI (Karr et al. 1986, Steedman 1988, Miller et al. 1988, Fausch et al. 1989).

A number of advantages of IBI have been cited (Karr 1981, Karr et al. 1986, Miller et al. 1988, Fausch et al. 1989) including:

1) it is quantitative;
2) it gauges a stream against an expectation based on minimal disturbance in the region;
3) it reflects distinct attributes of biological systems;
4) there is no loss of information from constituent metrics when the overall index is determined;
5) professional judgement is incorporated in a systematic and ecologically sound manner.

IBI does not serve all of the needs of detailed biological monitoring (Karr et al. 1986, Fausch et al. 1989) and certainly cannot be advocated as a replacement for physical and chemical monitoring or toxicity testing. However, IBI, or some other biological monitoring, must be an essential part of all monitoring programs because it provides direct information about conditions at a sample site relative to a site with little or no human influences or to the expectation under a designated use classification. Finally, IBI illustrates a conceptual framework for the protection of biotic integrity of water resources.

What is IBI?

The index of biotic integrity was conceived to provide a broadly based and ecologically sound tool to evaluate the biological conditions in a stream. Twelve attributes (Table 2) of a fish community are rated in comparison to what would be expected at a relatively undisturbed site in a stream of similar size in the same region. The sum of those ratings provides an integrative and quantitative assessment of local biological integrity. Three groups of metrics are evaluated: species richness and composition, trophic composition, and fish abundance and condition. Each metric reflects the quality of components of the fish community that respond to different aspects of the aquatic system. Further, the metrics have differential sensitivity along the gradient from undisturbed to degraded. IBI is calculated for each site and it is possible to 1) evaluate current conditions at a site; 2) determine trends over time at a site with repeated sampling, or 3) compare sites from which data are collected more or less simultaneously. IBI (or modifications of IBI - see below) has now been used by about 30 states and provinces and several federal agencies. At least four states and the Tennessee Valley Authority have incorporated IBI into their standards and monitoring programs (Miller et al. 1988).

Evolution of IBI

IBI can and should change as more is learned about the dynamics of biological systems and the behavior of IBI as an index. Even in its current form, IBI does not incorporate aspects of a fish community that could be used to improve evaluations of water resources. Two such aspects are species composition within major taxa and relative health of individuals within populations of selected species. Both of these were mentioned by Karr (1981) but were not incorporated into the index because the information necessary to incorporate them was not easy to obtain, especially on historical data bases, the primary data available for initial development and testing of IBI. For example, a site with johnny darter (Etheostoma nigrum) and orange-throated darter (E. spectabile) is likely to be degraded relative to another site with banded (E. zonale) and slenderhead darters (Percina phoxocephala). One approach to scoring these situations (Hughes and Gammon 1987) is to give sites with a preponderance of species that indicate high quality a +. When IBI scores are totaled, two or three species richness metrics with a plus appended would be scored by adding one unit to IBI. Such differences could be incorporated into future IBI applications when relative rankings of several species as indicators of degradation are known. As another example, one could incorporate information on health of individual fish through metrics such as condition factor (K) where L is total length (mm) and W is weight (gms) $K = {}^{W}/L^3$. Some effort must be made to define a length class for determination of K. Alternatively, the age structure of the population might be used by examination of the weights and/or lengths of individuals of selected species or through reading of growth rings on scales. Use of either of these would improve the resolution of IBI evaluations, although the quantitative value obtained may not change much. They might be especially useful when sport fishery goals are established to supplement assessments of biotic integrity.

Adaptation of IBI to geographic regions outside the midwestern US where it was developed requires modification, deletion or replacement of selected IBI metrics. Miller et al. (1988) provide the most up-to-date review of changes needed to reflect regional differences in biological communities and fish distributions. The kind of flexibility illustrated by IBI results from an integrative framework with a strong ecological foundation. Areas as diverse as the streams of Colorado, New England, northern California, Oregon, southeast Canada, and Appalachia and estuaries in Louisiana have been evaluated with modifications of IBI.

In California, the principle attributes that must be accommodated are reduced species richness, high endemism among watersheds, absence of midwestern taxa such as darters and sunfish, and high salmonid abundances. Modifications in IBI needed for use in estuarine areas of Louisiana included variation in salinity regimes and estuary size. IBI metrics were chosen to reflect aspects of fish residency, presence of nearshore marine fishes and large freshwater fish, and a measure of seasonal variation in community structure. As in the adaptation of IBI to other regions, the principles established in IBI are used to develop metrics that are more meaningful in the estuarine environment. Other special considerations include the importance of stream gradient in Appalachia and geographic variation in tolerance rankings of some species. For example, the creek chub (Semotilus atromaculatus) varies appreciably in its tolerance of stream degradation and food habits from Colorado to Illinois to the New River drainage of Virginia.

Modifications adopted by Ohio EPA include the replacement of several of the original IBI metrics with alternates for analysis of conditions in large rivers. They propose replacement of darters with round-bodied suckers in large rivers sampled with boat-mounted electrofishing gear, an excellent suggestion in a situation where darters are likely to be undersampled. They have, in addition, field tested and evaluated many aspects of IBI. Anyone planning to use IBI should be familiar with the approach of Ohio EPA (1987).

Recent use of IBI by the Tennessee Valley Authority has demonstrated its value in assessing declining biotic integrity (TVA, unpulb. reports). In one case release of cold water limited fish communities and in another case low flow periods left much of the channel dry with degraded biotic integrity. In both cases, IBI detected this degradation when general reviews of habitat conditions did not alert biologists to problems of water resource degradation.

Perhaps the most innovative and comprehensive recent use of IBI is the work of Steedman (1988) in southern Ontario. He sampled fishes at 209 stream sites in 10 watersheds near Toronto. All are in tributaries on the northwestern shore of Lake Ontario. His 10 metric IBI included several adaptations to accommodate both cold- and warm-water reaches. He changed taxonomic metrics to include both sculpins and darters, salmonids and centrarchids, and suckers and catfishes. He found that within-year variation at sample sites on large rivers were generally within 8% (4 points out to 50) and most were within 2%. For between-year comparisons, more than 80% of sample sites varied among years by less than 10%. IBI was strongly associated with independently derived measures of watershed condition whether he used whole watershed IBI values or IBI values derived for individual stream reaches. He found that a threshold of degradation for Toronto area streams was reached when 75% of riparian vegetation was removed in areas with no urbanization. Conversely, a similar threshold existed with 0% removal of riparian vegetation at 55% urbanization. He noted that sites with both high urbanization and riparian destruction were unrepresented in his study. Thus, it was not possible to evaluate his model in that situation.

His analysis reminds me of a persistent but as yet unanswered question about the percent of riparian vegetation within a watershed that should be protected to improve water quality and biotic integrity (Karr and Schlosser 1978). His approach using IBI may in fact provide an indirect approach to answering that question. It deserves considerable study in a number of geographic areas.

Miller et al. (1988) encouraged modification of IBI to make it suitable for a wide range of geographical areas but they added two cautions. First, avoid idiosyncratic modifications unless they really improve the utility of the index (Angermeier and Karr 1986). Second, modifications of IBI should be undertaken only by experienced fish biologists familiar with the conceptual framework of IBI, local fish faunas, and watershed conditions. Finally, efforts should be made to develop IBI-type concepts for use in other environments such as lakes and terrestrial ecosystems.

Finally, the recent development of the ecoregion approach (Hughes et al. 1986, 1987) provides a useful tool that encompasses many of the regionalization goals that were not possible just a few years ago without great individual effort.

Assessment of Biotic Integrity with Invertebrates

Following development of IBI several efforts were made to develop biomonitoring approaches like IBI but using benthic invertebrates. The most extensively tested, integrative effort is the Invertebrate Community Index (ICI) developed by Ohio EPA (1987). ICI is a ten-metric index (Table 2) that emphasizes structural rather than functional aspects of community structure. Ohio EPA used this approach because of the "accepted historical use, simple derivation, and ease of interpretation." Metric 10 is scored based on a qualitative sample while metrics 1-9 are based on artificial substrate sampling.

As part of its effort to establish biological metrics USEPA has also supported development of a hierarchy of methods for biological monitoring using benthic invertebrates. Their Rapid Bioassessment Protocol III is most similar to the ICI but has only 8 metrics (Table 2). Both structural and functional metrics are included, a strength relative to ICI in my view. The method combines sampling invertebrates from a riffle/run habitat and from a grab sample of coarse particulate organic matter (CPOM) at each sampling site. A major weakness of Protocol III is the use of a 100 organism sample. First, the general survey approach might be criticized because of quality control problems and second, the selection of 100 organisms at random is likely to result in major biases among individuals doing the subsampling. Finally, I am not convinced that a 100 individual sample is sufficient to represent a complex community of invertebrates. I suspect that a method will ultimately be developed that is between the Ohio and USEPA approaches. A compromise should seek to reduce the time required in analyses using Ohio ICI and improve the quality control- problems inherent in the Protocol III approach.

The Future of IBI

IBI and a number of derivative approaches provide a powerful set of tools for the improvement of water resources and both state and federal agencies have demonstrated distinct shifts in the philosophy and approach to the improvement of

Table 2. Metrics used to assess biological integrity using fish or benthic invertebrate communities.

A. Index of Biotic Integrity (IBI) - After Karr 1981, Karr et al. 1986. Ratings of 5, 3, and 1 are assigned to each metric according to whether its value approximates, deviates somewhat from, or deviates strongly from the value expected at a comparable site that is relatively undisturbed.

Species richness and composition
1. Total number of fish species
2. Number and identity of darter species
3. Number and identity of sunfish species
4. Number and identity of sucker species
5. Number and identity of intolerant species
6. Proportion of individuals as green sunfish

Trophic composition
7. Proportion of individuals as omnivores
8. Proportion of individuals as insectivorous cyprinids
9. Proportion of individuals as piscivores (top carnivores)

Fish abundance and condition
10. Number of individuals in sample
11. Proportion of individuals as hybrids
12. Proportion of individuals with disease, tumors, fin damage, and skeletal anomalies

B. Invertebrate Community Index (ICI) - After Ohio EPA, 1987[a]. Ratings of 6, 4, 2, and 0 are assigned to each metric according to whether its value is comparable to exceptional, good, slightly deviates from a good, or strongly deviates from a good community.
1. Total number of taxa
2. Total number of mayfly taxa
3. Total number of caddisfly taxa
4. Total number of dipteran taxa
5. Percent mayfly composition
6. Percent caddisfly composition
7. Percent Tribe Tanytarsini midge composition
8. Percent other dipteran and non-insect composition
9. Percent tolerant organisms
10. Total number of qualitative EPT[c] taxa

C. Rapid Bioassessment Protocol III - After USEPA, unpublished[b]. Ratings of 6, 3, and 0 are given based on values of each of the metrics with 6 being high quality and 0 being a heavily degraded site.
1. Taxa richness
2. Family biotic index
3. Ratio of scraper/filtering collector
4. Ratio of EPT[c] and chironomid abundances
5. Percent contribution of dominant family
6. EPT[c] index
7. Community loss index
8. Ratio of shredders/total

a - Metrics 1-9 based on artificial substrate sampler; metric 10 based on qualitative stream sampling.
b - Metrics 1-7 based on qualitative riffle/run sample; Metric 8 based on leaf-pack (CPOM) sample.
c - EPT - Emphemeroptera, Plecoptera, and Trichoptera Taxa.

water resources. Monitoring and analysis of biotic conditions plays a central role in those changes. As a result, the opportunities for biologists to influence, even guide, decisions about water resources has never been greater.

The time is ripe to turn the tide on what I refer to as the fundamental fallacy in water resources management. That fallacy,"making clean water will solve water resource problems," with its focus on physical/chemical aspects of water systems has been both short-sighted and damaging to water resources.

The principle strength of IBI is that it provides a mechanism that illustrates the weaknesses of older approaches, while it provides a quantitative assessment based on sound ecological principles. When that value is combined with an expanded concept in the management of water resources, the prognosis for the future is especially gratifying. The end result, whether it is a new approach to stream classification or more enlightened approaches to define the goals of management of water resources, will go beyond what could be developed by any one organization/discipline.

A next level challenge will be the integration of classification/ evaluation systems. Important components must include recognition of the alternative factors that may be responsible for degradation and that the relative influence of these varies with human activity (see Fig. 1, Karr et al. 1986). In addition, stream systems may have differential sensitivity as a function of stream size and geographic region (e.g. flow volume in the west; toxic substances in urban areas; destruction of riparian zones, water table depression, and agricultural chemicals in agricultural areas; habitat structure including riparian zones everywhere).

However, it is important that water resource specialists move forward to use all the tools available today. We do not have the luxury of waiting until an ideal system is available. Inevitably, a number of indexes will provide for the most enlightened water resource management for the same reason that a multiparameter index like IBI is better than a simplistic approach such as measuring water quality or sampling only a single indicator species. For biological assessments, monitoring programs must include all levels from the individual to the ecosystem.

Significant progress has been made in recent years as evidenced by workshops and other programs sponsored by USEPA that have focussed on recovery of damaged ecosystems, development and implementation of biological monitoring, and major efforts to incorporate "good science" at all levels of water resource policy. These advances are tied to evolution of common understanding of the inherently biological nature of water resource problems and the importance of water as a natural resource to all components of society.

I close with one final point that might be considered obvious, but with an importance that warrants frequent repetition. The importance of maintaining a watershed perspective cannot be ignored because of the influences of the terrestrial environment on the water resources of a watershed and because of the connection across river sizes within that same watershed.

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Variability of Commonly Used Macroinvertebrate Community Metrics for Assessing Biomonitoring Data and Water Quality in Wisconsin Streams[1]

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Abstract

Six single and 6 paired community comparison metrics (including generic (BI) and family (FBI) level biotic indices, Ephemeroptera-Plecoptera-Trichoptera (EPT) index, Margalef's diversity index, generic and species richness measures, and similarity and distance metrics) were applied to biomonitoring data from selected Wisconsin streams to evaluate their variability and potential use in biomonitoring programs. The biomonitoring data were generated from biotic index samples as part of the WI Dept. of Natural Resources Nonpoint Source Biomonitoring Program. The database included a total of 250 samples with 5 replicates. The single metrics with the exception of the EPT exhibited less overall variation (measured as the coefficient of variation) among replicate samples than the community comparison metrics. The BI and FBI had the lowest variability among replicate samples of all metrics tested and appeared to offer the most reliable water quality determinations. The similarity and distance estimates between replicate samples varied widely (14 - 59%), offering conflicting estimates of the degree of similarity or dissimilarity depending on which metric was used. These community comparison metrics are not recommended at this time for use with biotic index samples to evaluate water quality changes.

Introduction

In 1979 the Wisconsin Department of Natural Resources (WDNR) began using the Hilsenhoff Biotic Index (HBI) (Hilsenhoff 1977, 1982, 1987) to evaluate stream water quality state-wide. A standardized protocol for sampling and laboratory procedures, as part of a quality assurance effort in biological monitoring was implemented by the WDNR in 1983 and statistical procedures for applying the HBI were developed (Narf et al. 1984). The HBI was originally designed to detect dissolved oxygen problems caused by organic loading of putrescible wastes, and it appears to work well for that purpose (Hilsenhoff 1977, 1982, 1987).

Other biotic indices similar to the HBI have also been used recently by other states and agencies as rapid bioassessment tools to evaluate stream water quality (Platts et al. 1983; Jones et al. 1981; Bode 1986, Shackleford 1988, and Fisk 1987). The wide acceptance and use of biotic indices by aquatic biologists has occurred in part, because of the ease in which they can be applied, and also because the organisms used are continually exposed throughout their aquatic life cycle to extremes in environmental conditions, and should

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1 Study supported in part by the Wisconsin Dept. Natural Resources grant #8406.

therefore, theoretically serve as effective barometers of environmental changes. Because of the above additional approaches to rapid bioassessment of lotic ecosystems have continued to utilize aquatic macroinvertebrates.

Recently other approaches utilizing different aspects of macroinvertebrate community structure have been used to evaluate stream water quality (Berkman et al. 1986, Bode 1986, Boyle et al. 1984, Courtemanch and Davies 1987, Johnson and Millie 1982, Moss et al. 1987, Ormerodad and Edwards 1987, Osborne and Davies 1987, Perkins 1983, Pratt et al. 1981, Rabeni and Gibbs 1980, Rabeni et al. 1985, and Shackleford 1988). These approaches have included similarity indices, diversity indices, species and generic richness, dominant species, Ephemeroptera-Plecoptera-Trichoptera index (EPT), coefficient of community loss index, percent contribution of major groups, field assessment and various ordination and clustering techniques. Applications of these techniques have sometimes produced highly variable, and conflicting results. Most aquatic biologists agree that additional testing and a better understanding of the inherent variability of these metrics are needed before they can be used in biomonitoring programs.

The main objective of this research was to compare the variability of 6 single and 6 community comparison macroinvertebrate metrics among replicate samples to determine their usefulness in Wisconsin's Nonpoint Source Biomonitoring Program (Bureau of Water Resources). Replicate variation is important since it can be considered a measure of "background or baseline noise" of the index resulting from sampling or processing inefficiencies related to gear design or operator variability. Paired comparisons between sites should include a correction factor for this inherent variation before determinations of water quality changes are made. This would essentially provide a corrected "zero point" for a specific study.

Methods and Materials

The Oconto River, a fifth order Lake Michigan tributary of Green Bay was the study area for this research project. Seven sampling stations were established by the WDNR between the towns of Gillett and Oconto in Oconto Co., WI (Fig. 1). Two dams (Oconto Falls and Mackickonae) were located within this study section.

The sampling design of this study was similar to the sampling and laboratory protocol of the NPS Biomonitoring Program to insure that results and metrics used in this study would be applicable to historical and future biotic index databases generated by the Department. Macroinvertebrate biotic index samples were taken by WDNR biologists according to the methods described by Hilsenhoff (1982) on May 17, August 8, and October 3, 1984, and June 5, and September 13, 1985. Seven sampling stations were established with wet and dry (sites which were periodically dry due to the amount of water released from the dams) sites (Fig. 1). A total of 290 samples (stations 1 and 7 did not have dry sites and stations 2 and 6 did not have dry samples taken for the first sampling period due to high water levels) were collected which included 5 replicate samples from each wet and dry site for each sampling period.

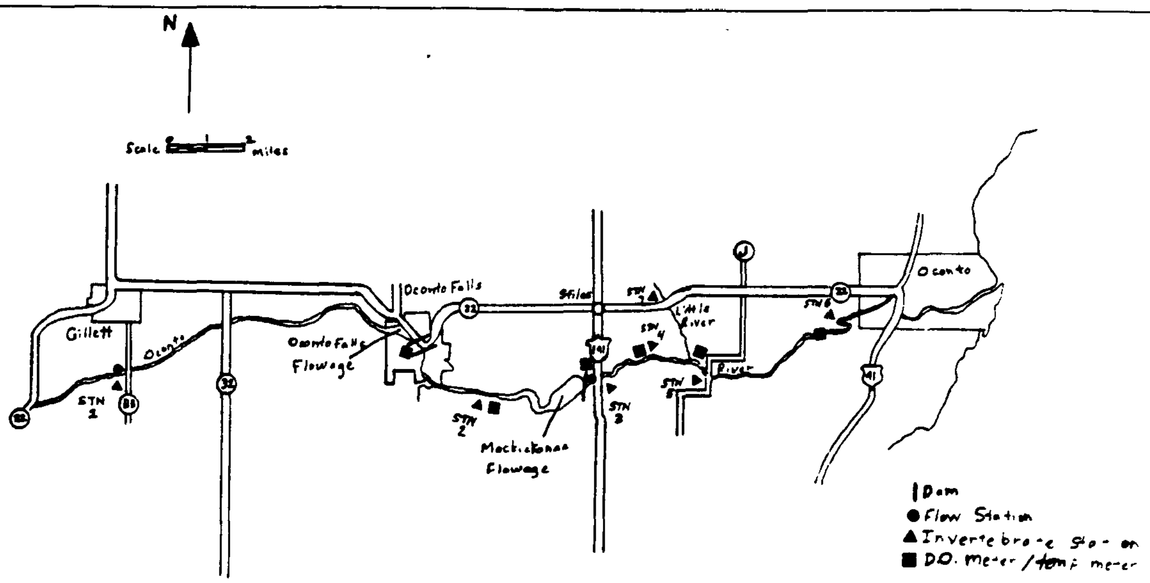


Figure 1. Sampling locations for biotic index samples on the Oconto River, Wisconsin (from Laura Herman, Lake Michigan District, Dept. of Natural Resources)

Samples were taken with a D-frame net and the entire sample was preserved in 70% isopropyl alcoholuntil sorted in the laboratory. In the laboratory each sample was subsampled by placing the entire sample in a transparent sorting tray with 2 inch., consecutively numbered grids etched on the bottom. The debris and macroinvertebrates were distributed as evenly as possible in the tray and grids were randomly selected using a random number table. All macroinvertebrates in each randomly selected grid were picked and placed in a sample jar for identification and grids were picked until at least 100 macroinvertebrates with biotic index values had been removed. The last grid was picked totally no matter how many macroinvertebrates were included in the subsample and all individuals picked were included in the database regardless of whether they had a tolerance value or not.

The single community metrics used in this study included: Hilsenhoff (1987) biotic index (HBI); Hilsenhoff (1988) family biotic index; Ephemeroptera-Plecoptera-Trichoptera Index (EPT); species richness (SP); generic richness (GEN), and Margalef's (1957) diversity index (DIV). The community comparison metrics included: coefficient of community loss index (CCL) (Courtemanch & Davies 1987); coefficient of similarity index (CS) (Pinkham & Pearson 1976); Stander's similarity index (SIMI) (Stander 1970); percentage similarity (PS) (Whittaker 1952); coefficient of similarity (B) (Pinkham & Pearson 1976), and ecological distance (EDIS) (Rhodes et al. 1969).

A dBase III plus computer program was developed to compute each of the above metrics and to create databases of sample statistics. The variability among replicate samples was estimated for each metric using the coefficient of variation (CV) (standard deviation/mean), which is unit independent and therefore, allows comparisons of metrics with different values. The CV was determined for each set of 5 replicate samples.

Results and Discussion

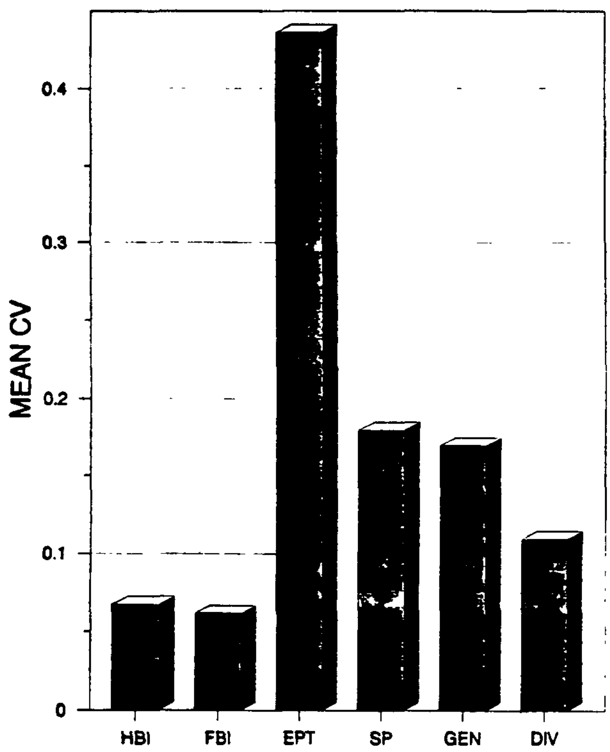
The FBI exhibited the lowest CV (0.062) among replicate samples (based on a mean of the 58 mean CV's for each set of 5 replicates for each sampling station, each sampling period and each wet and dry site) of all single metrics (Fig. 2). The FBI and HBI had lower variability among replicate samples than the other single metrics and the EPT had the greatest variability (0.436). Species and generic richness measures had similar levels of variability (0.170 - 0.180). This trend in variation was also evident when the wet and dry sites were separated, although all metrics were more variable at dry sites than wet sites (Fig. 3). This site difference in variability was probably related to the greater water level fluctuations at dry sites, and was not likely an anomaly of sampling error.

The greatest overall mean variation (CV = 0.210) of all single metrics combined (including wet and dry sites) occurred during sampling period 4 (June 5, 1985), although the variability (mean CV range = 0.143 - 0.210) was similar for each sampling period (Fig. 4). There was no obvious trend in variability due to sampling periods or seasonality, however wet sites generally had less variability (overall mean for all single metrics CV = 0.159) than dry sites (overall mean of all single metrics CV = 0.183). This same basic trend in variability was observed when wet and dry sites were split for sampling periods.

The CCL had the highest coefficient of variation (0.481) among replicate sample comparisons of all community comparison metrics (based on 580 paired comparisons of replicate samples - each set (N = 58) of 5 replicate samples had 10 rep comparisons) for combined wet and dry sites for all sample periods and stations (Fig. 5). The CCL also had the highest mean CV of wet (0.465) and dry (0.496) sites analyzed separately (Fig. 6). The EDIS had the lowest variation (CV = 0.180) of all community comparison metrics for combined wet and dry sites and also for wet (0.196) and dry (0.164) sites analyzed separately (Figs. 5 & 6). The SIMI and coefficient B metrics had similar variation and CS and PS variations were lower (Fig. 5). Generally the dry sites had greater variability than the wet sites except for EDIS metric which was similar to that discussed above for the single metrics (Fig. 6).

As in the single metrics discussed above there was no obvious trends for the community comparison metrics in variability due to sampling periods or seasonality. Sampling period 4 (June 5, 1985) had the greatest overall variation (mean CV = 0.306) of all community comparison metrics combined (including wet and dry sites), however the variability was similar (mean CV range = 0.264-0.306) for all sampling periods (Fig. 7).

The overall variability of the community comparison metrics was generally much higher than the variability of the single metrics with the exception of the EPT (mean CV = 0.432), which was most similar in variability to the CCL (mean CV = 0.481). This indicates that these metrics may not be appropriate to measure similarity or dissimilarity between sites using biotic index sampling methods.



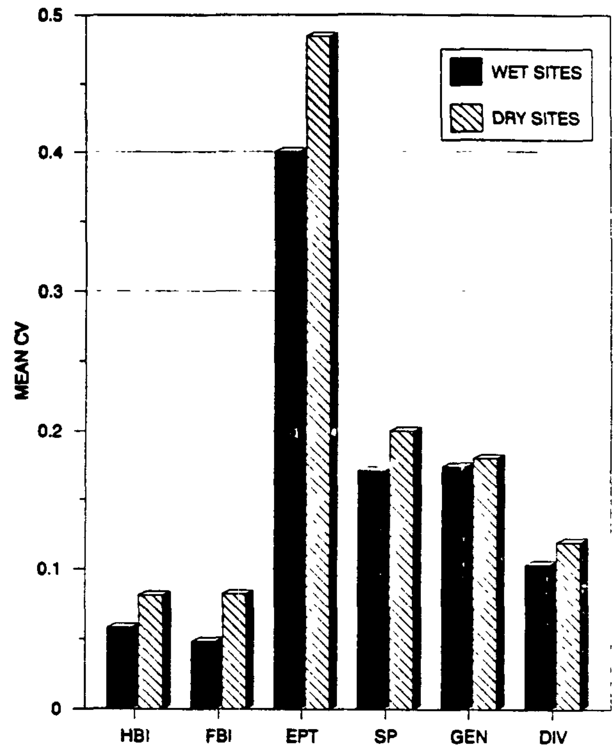
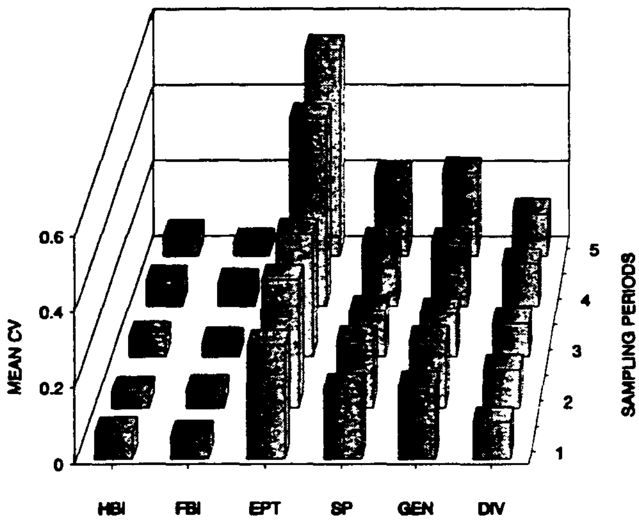


Fig. 2. Mean coefficient of variation (CV) of single metrics among repli-cate samples taken on the Oconto River (based on a mean of the 58 mean CV's for each set of 5 replicates for each sampling station and sampling period including wet and dry sites; HBI=Hilsenhoff biotic index, FBI=family biotic index, EPT=Ephemeroptera, Plecoptera, Trichoptera index, SP=species richness, GEN=generic richness, DIV=Margalef's diversity index).

Fig. 3. Mean Coefficient of variation (CV) of single metrics among replicate samples at wet and dry sites taken on the Oconto River (based on 35 mean CV's for wet sites and 23 for dry sites; stations 1 and 7 did not have dry sites, stations 2 and 6 did not have dry samples for the first sampling period; HBI= Hilsenhoff biotic index, FBI=family biotic index, EPT =Ephemeroptera, Plecoptera, Trichoptera index, SP=species richness, GEN=generic richness, DIV=Margalef's diversity index).



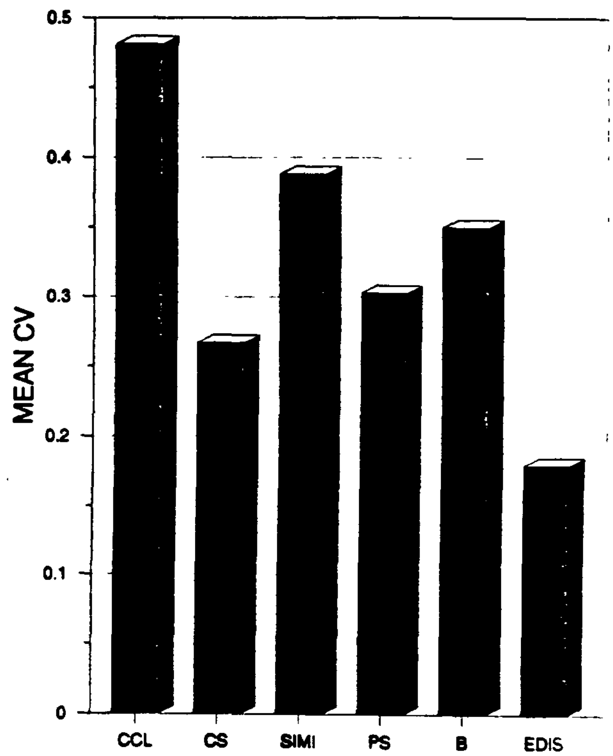


Fig. 4. Mean coefficient of variation (CV) of single metrics among replicate samples by sampling periods from the Oconto River (wet and dry sites and sampling stations combined; HBI = Hilsenhoff biotic index, FBI = family biotic index, EPT = Ephemeroptera, Plecoptera, Trichoptera index, SP = species richness, GEN = generic richness, DIV = Margalef's diversity index; sampling period 1 = May 17, 1984, 2 = August 10, 1984, 3 = October 3, 1984, 4 = June 5, 1985, 5 = September 13, 1985).

Fig. 5. Mean coefficient of variation (CV) of community comparison metrics among paired comparisons of replicate samples taken on the Oconto River (based on 580 comparisons of replicate samples - each set (N = 58) of replicate samples had 10 rep comparisons for each wet and dry site; CCL = coefficient of community loss, CS = coefficient of similarity, SIMI = Stander's similarity index, PS = percentage similarity, B = coefficient of similarity (B), EDIS = ecological distance measure).

The mean values of the 6 community comparison metrics for replicate comparisons (each set of 5 replicate samples had 10 comparisons for each sample period, sampling station and site) suggested that individual samples from a replicate set were more dissimilar than similar (Fig. 8). The mean CCL value for replicate samples was 0.649 + 0.279 for combined wet and dry sites and 0.640 + 0.291 for wet and 0.658 + 0.279 for dry sites (Figs. 8 & 9). These values imply that some change (benign or enriching effect) has occurred between the replicate samples, however they are close to the limit (> 0.8) where harmful damage to the community has occurred due to high displacement of indigenous taxa (Courtemanch and Davies 1987). Since there is significant overlap in the range of values Courtemanch and Davies (1987) provided for pristine and enriched sites it is difficult to determine what these numbers actually mean in terms of water quality changes. Clearly the CCL did show a fairly high level of background noise or variation within the 10 paired comparisons nested within each set of 5 replicate samples.

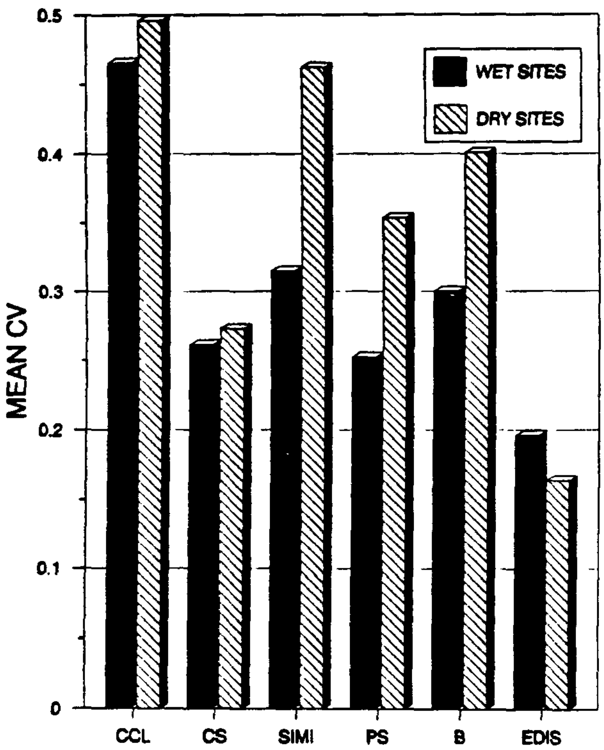
Similarity measurements of replicate samples ranged from approximately 12 - 54% for combined wet and dry sites, 14 - 59% for wet sites and 10 - 50% for dry sites (Figs. 8 & 9). The EDIS metric which is a distance measure generally indicated that replicate samples were more similar than the other metrics (combined sites - 54%, wet sites - 59%, dry sites - 50%) and the coefficient B metric showed the least similarity (combined sites-12%, wet sites - 14%, dry sites-10%). The CS and PS metrics generally had similar values and the SIMI values were slightly higher. Overall the wet sites were generally rated more similar than dry sites by all community comparison metrics except the CCL (Fig. 9).

Conclusions

The results of this research indicated that the single metrics, with the exception of the EPT exhibited less overall variation among replicate samples than the community comparison metrics. The high variability of the EPT was probably related to the fact that enumerations, rather than richness data were used to calculate the metric. Enumeration measures may not be appropriate with the biotic index sampling methodology used in this study. I recommend in the future that this index be computed as a simple generic richness estimate of Ephemeroptera, Plecoptera and Trichoptera.

Precision and variability are very important components in aquatic biomonitoring programs. Indices may not indicate that a change has or has not occurred in macroinvertebrate communities if the variability (CV) of the index does not provide reproducible values. These metrics may have desirable theoretical foundations and would have potential value in interpreting change in macroinvertebrate community structure, but they should not be used in aquatic biomonitoring programs because the results are unreliable. Quantitative approaches, including enumeration measures such as some of the similarity metrics used in this study, do not appear to be useful in biomonitoring programs which employ kick net samples due to the high degree of replicate variability.

The wide range of similarity estimates for replicate samples found in this study raises some serious questions concerning the use of these metrics in biomonitoring



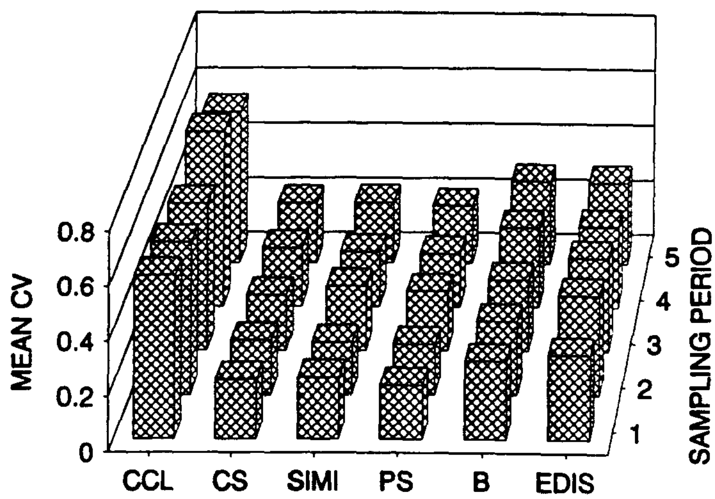


Fig. 6. Mean coefficient of variation (CV) of community comparison metrics among paired comparisons of replicate samples taken on the Oconto River (based on 35 comparisons for wet sites and 23 comparisons for dry sites, each set of replicate samples had 10 rep comparisons for each sampling date at each station; CCL=coefficient of community loss, CS=coefficient of similarity, SIMI=Stander's similarity index, PS=percentage similarity, B=coefficient of similarity (B), EDIS=ecological distance measure).

Fig. 7. Mean coefficient of variation (CV) of community comparison metrics among replicate samples by sampling periods from the Oconto River (wet and dry sites and sampling stations combined; CCL = coefficient of community loss, CS = coefficient of similarity, SIMI = Stander's similarity index, PS = percentage similarity, B=coefficient of similarity (B), EDIS = ecological distance measure; sampling period 1 = May 17, 1984, 2 = August 10, 1984, 3 = October 3, 1984, 4 = June 5, 1985, 5 = September 13, 1985).

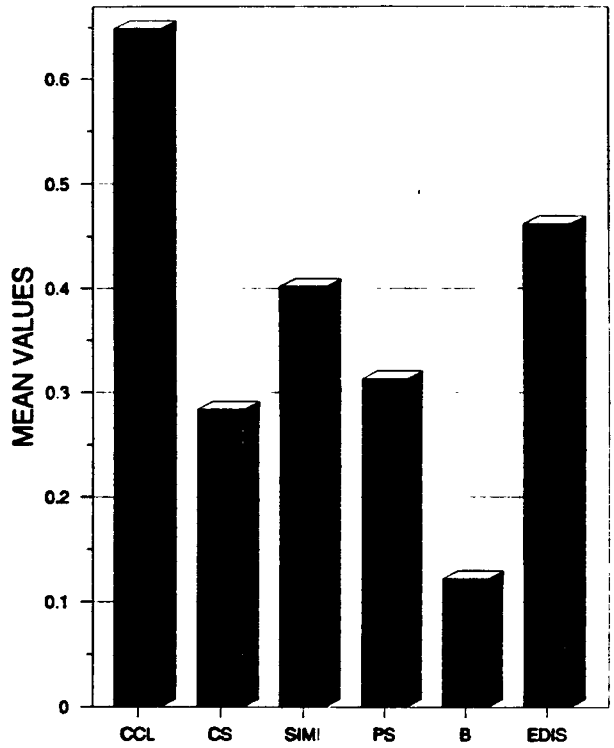


Fig. 8. Mean values of community comparison metrics for replicate samples taken on the Oconto River (based on 580 comparisons of replicate samples including all sites, sampling stations and sampling periods-each set (N=58) of replicate samples had 10 rep comparisons for each wet and dry site; CCL=coefficient of community loss, CS=coefficient of similarity, SIMI=Stander's similarity index, PS =percentage similarity, B= coefficient of similarity (B), EDIS=ecological distance measure).

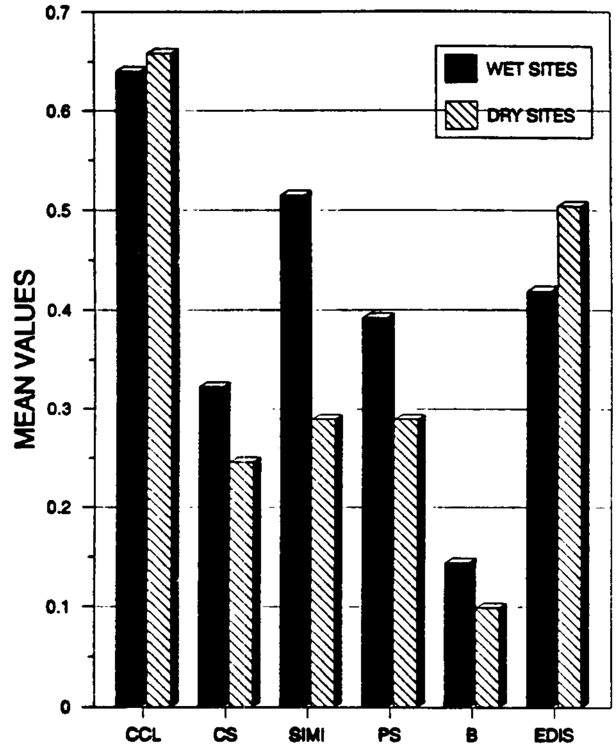


Fig. 9. Mean values of community comparison metrics of replicate samples taken at wet and dry sites on the Oconto River (based on 350 comparisons of wet sites and 230 comparisons of dry sites); CCL = coefficient of community loss, CS = coefficient of similarity, SIMI = Stander's similarity index, PS = percentage similarity, B = coefficient of similarity (B), EDIS = ecological distance measure).

programs. All metrics except the EDIS suggested that replicate samples were more dissimilar than similar and the degree of dissimilarity was variable depending on the metric used. In this study replicate samples were taken by thesame person at the same time and place and therefore we can assume that operator error was consistent for all samples. The similarity estimates between replicate samples should reflect the inherent error associated with the sampling design (laboratory error was reduced in this study since the entire sample was sorted and used to calculate the biotic index, and one person did most of the sorting and identification). These estimates must be subtracted from all other non-replicate comparisons to zero each index. If these estimates of variability (generally >45%) are subtracted from other comparisons to zero the index there would be no basis for comparison. The community comparison metrics used in this study are therefore not recommended to estimate similarity of BI samples due to the high variability of estimates among replicate samples, the wide range of similarity estimates based on what metric is used, and the general lack of understanding of what values from different metrics actually mean in terms of similarity or dissimilarity. Additional research is needed to resolve these questions before we can understand how these metrics behave in relation to water quality changes.

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Statistical Validation of Ohio EPA's Invertebrate Community Index.

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Abstract

This discussion presents the results of a statistical review of the newly developed Invertebrate Community Index (ICI) used by the Ohio Environmental Protection Agency (OEPA) to develop instream biological criteria. The statistical tools used for this analyses included a simple ranking program, correlation analyses, and factor analysis using the principle components technique via the Statistical Analysis System (SAS). The conclusions from our review are: (1) the ten metrics which comprise the ICI seem to be valid empirical indicators of water quality, (2) the identified 95th percentile distribution factors for drainage area relationships are appropriate, (3) the ICI metrics are minimally interrelated and therefore are not redundant, (4) the use of equal weights for the metrics is not optimal, and (5) the results obtained via the factor analysis-derived scale are similar to the results obtained by the ICI metrics scale for both the 232 reference sites and 431 ambient sites. It appears that the ICI is quite acceptable for their stated use. In general, we could not find any substantial fault with the ICI nor could we significantly improve upon the index.

Key Words: ICI, benthos, biocriteria, Ohio EPA, statistics, reference sites

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Background

The Clean Water Act (CWA), as amended in 1987, requires assessments of the nation's waterways with respect to designated use attainment, including those for aquatic life as indicated in Sections 304(1), 305(b), and 391 of the CWA. In recent years, the national shift in water quality management from general basin surveys to water quality-based controls through wasteload allocations (WLAs) and water quality-based effluent limitations (WQBELs) has necessitated a change in the way field biologists related their results to "decision-makers" and the public.

The Ohio Environmental Protection Agency (OEPA) bases the attainment of designated uses for aquatic life on direct measurements of the indigenous benthic macroinvertebrate and fish community structure and function. The development and the success of the Index of Biotic Integrity (IBI) for fish communities prompted the OEPA to assess whether a similar index was feasible for benthic macroinvertebrates. Using common and intuitive measures of the benthic community used by OEPA to reflect water quality, a basis for the Invertebrate Community Index (ICI) was established. After minor modifications and intensive testing and evaluation, the ICI has become a routinely used index in Ohio and part of the State's proposed biological water quality criteria (OEPA 1987a). Since the development of the ICI, less complex, similarly structured indices have been applied throughout the country (Plafkin et al. 1989; Shakelford 1988). However, none of these indices appear to have been rigorously statistically tested to verify their many assumptions and results.

Description of the Invertebrate Community Index

OEPA collected artificial and natural substrate data from 232 reference sites (least impacted sites) to develop the biocriteria, and used data from 431 ambient sites to test the ICI (OEPA 1987a,b; Whittier et al. 1987). The ICI is derived by summing scores of 0, 2, 4 or 6, which were assigned to each metric based upon its percentile relationship of the 232 sites as well as its relationship with drainage area. The ten invertebrate community metrics are:

1. Total number of taxa.
2. Total number of mayfly taxa.
3. Total number of caddisfly taxa.
4. Total number of dipteran taxa.
5. Percent mayfly composition.
6. Percent caddisfly composition.
7. Percent tribe Tanytarsini midge composition.
8. Percent other dipteran and non-insect composition.
9. Percent tolerant organisms.
10. Total number of qualitative EPT (Ephemeroptera-Plecoptera-Trichoptera) taxa.

Each metric was evaluated for its relationship to drainage area by plotting the values for each metric by drainage area and visually interpreting the data. Once the individual metric distributions for each of the drainage areas were developed, the metrics scores were created based on a percentile method. The 95th percentile values (reflecting exceptional water quality) for each metric were identified. Each score was adjusted for a drainage area range of values, according to the drainage area relationship with the metric. Once the upper 95th percentile line was established, the four scoring categories (excellent, good, fair, and poor) were derived by sectioning the remaining data below the 95th percentile line into four parts. In some cases this was done by equal partitioning, and in others it was modified by professional judgement and known ecological principals (Ohio EPA 1987b). The ICI was derived by adding the scores of the ten individual metrics, assuming an equal weight associated with each metric. Thus, each metric was assumed to be equally as important in influencing the final ICI.

OEPA conducted a simple validation of the ICI using 431 "test" or ambient site data. These sites were evaluated for water quality before the ICI was developed and categorized as either excellent, good, fair, or poor. OEPA (1987b) reported that there was excellent agreement between the ICI values and the prior water quality classifications.

Objectives

Based upon a review of the ICI documentation (OEPA 1987a,b,c), the following objectives of this review were determined:

1. Professionally evaluate the reasonableness of the use and derivation of the invertebrate community measurements used to establish the ten metrics.
2. Determine if the drainage area relationships visually interpreted by OEPA for the ten metrics are reasonable.
3. Determine if any of the ten ICI metrics are interrelated and, thus, provide redundant information.
4. Determine if the assumption of equal weights for each metric was optimal.

5. Evaluate the overall accuracy of the ICI.

Data and Statistical Procedures

The data used to statistically evaluate the ICI were the original data used by the OEPA to develop the ICI and biocriteria (OEPA 1987a; Whittier et al. 1987). The procedures used to achieve each study objective are as follows. Professional judgement and a review of literature were applied to evaluate the reasonableness of the ICI(objective 1). The determination of the reasonableness of the drainage area relationships was achieved via comparisons of actual rankings with the OEPA visually interpreted results (objective 2). The interrelationships among the ICI metrics was determined via correlation analysis (objective 3). The determination of whether or not linear weights are optimal also was accomplished via factor analysis (objective 4). The overall accuracy of the ICI (objective 5) was assessed by correlating the OEPA results with those derived via factor analysis (results obtained via the utilization of empirically determined weights). The discussion that follows describes the analysis procedures. The drainage area size categories evaluated in this study were (1) less than 10 square miles, (2) 10 to 100 square miles, (3) 101 to 1000 square miles, and (4) more than 1000 square miles.

Correlation Analysis

The correlation analysis coefficients were computed using the Statistical Analysis System (SAS) software package (SAS 1985; Steel and Torrie 1960; Tabachnick and Fidell 1983). Correlation coefficients indicate the strength of associations among pairs of metrics. The correlation coefficient (r) equals:

$$r = SS_{xy}/(SS_{xx}SS_{yy})^{-2} \qquad (1)$$

where:

$SS_{xy} = SUMX_iY_i - (SUMX_i)(SUMY_i)/n$
$SS_{xx} = SUMX_i^2 - (SUMX_i^2)/n$
$SS_{yy} = SUMY_i^2 - (SUMY_i^2)/n$

Factor Analysis

Factor analysis (Harmon 1976; SAS 1985) was used to determine the appropriate weights for each of the ten metrics and to create "new" ICI scores. The new scores were computed by multiplying the standardized metric values by the factor analysis determined weights. These weights indicate the relative empirically determined contribution of each of the metrics to measuring water quality. Principal components analysis was the selected factor analysis technique because the evaluation required summarizing the interrelationships (correlations) among the metrics via independent factors. The basic principal components model is shown below:

$$Z = a_{n1}F_1 + a_{n2}F_2 + \ldots + a_{nj}F_n \qquad (2)$$

where:

Z = standardized ICI score;
a_{nj} = contribution (weights) for each of the n metrics;
F_n = factors.

Each factor equals:

$$Fn = SUM(a_{nj}/ n)Z_n \qquad (3)$$

where:

n = eigenvalues or the sum of the weights for each of the factors.

Due to the independence of the factors, the resulting scale is the sum of the factor weights multiplied by the corresponding standardized

ICI metric values. In addition to the rationale previously discussed, principal components analysis was selected because the technique does not require particular data distributions. Like the correlation analysis, the factor analysis was done via SAS.

Ranking Procedures

The comparison of the OEPA visual evaluation with the actual data distributions for each of the ICI metrics involved two steps. The first step used the SAS ranking procedure to order the information for each of the indicators. The SAS listing included the actual data values as well as the percentile rankings. The second step used SAS to determine the 95th percentile values for each of the metrics to compare with the corresponding visually determined values. These analytical steps were done for each of the drainage size categories.

Results and Discussion

The results and ensuing discussions are presented by study objective.

Professionally evaluate the reasonableness and derivation of the invertebrate community measurements used to reflect the metrics.

The ICI is basically composed of two types of metrics: richness measures (metrics 1,2,3,4, and 10) and enumerations (metrics 5,6,7,8, and 9). Richness measures are based on the presence or absence of selected taxa. Commonly used measures include the total number of taxa (metric 1) and the number of EPT (Ephemeroptera, Plecoptera, and Trichoptera) taxa. Resh (1988) showed that richness measures tend to be highly accurate with low variability.

The ICI further utilizes the EPT concept by including the mayflies and caddisflies as separate metrics (metrics 2 and 3). Since stoneflies are not abundant during summer in Ohio (Ohio EPA 1987b), there was no justification to give them equal weight and were therefore not included as a separate metrics. The ICI did include the full EPT measure from the natural substrate (metric 10). The other richness measure (metric 4) was based on the number of Dipteran taxa since the Diptera are generally present in even the most toxic conditions with increased representation in good conditions. This metric was justified by the need to be able to address a wide variety of water quality conditions. Overall, the five richness metrics appear to have been adequately justified.

The enumeration metrics focus on the numerical abundances of selected taxa in relationship to the total number of individuals collected at a site. The percentages of mayflies (metric 5) and caddisflies (metric 6) were used since their numerical abundances were observed to rapidly change with water quality conditions (OEPA 1987b). OEPA found that mayflies were much more sensitive to water quality changes than were caddisflies, but that the caddisflies provided an intermediate indicator between the use of mayflies and metrics 8 and 9. Through Ohio EPA's extensive studies, they found that the abundance of Chironomidae belonging to the Tribe Tanytarsini (metric 7) was positively related to higher water quality. The relative pollution intolerance of Tanytarsini midges has also been noted by Hilsenhoff (1982, 1987) and Simpson and Bode (1980).

The last two metrics are the only two that have a negative relationhip with the ICI and water quality. The percent of the "other" dipterans (non Tanytarsini midges) and non-insects (oligochaetes, crustaceans, gastropods, etc.) is metric 8. This metric was chosen because Dipterans are present in even the most polluted areas, and tend to predominant under such conditions. Hart and Fuller (1974), Pennack (1978), Hilsenhoff (1982, 1987) all support the observation that the Dipterans and other non-insect tend to predominate under poor water quality conditions.

The other "negative" metric is the percent tolerant organisms (metric 9). OEPA developed a list of organisms tolerant to a wide variety of perturbations, with the majority of the list devoted to non-Tanytarsini midges. The other tolerant organisms include oligochaetes, limpets, and the pouch snail. This metric is consistent with the literature regarding the pollution tolerances of these organisms (Bode and Simpson 1982; Hilsenhoff 1982, 1987; Howmiller and Scott 1977; Krieger 1984; Pennack 1978; Saether 1979; Simpson and Bode 1982). Further supportive documentation can be found in Beck (1977), Davis and Lathrop (1989), Fitchko (1986), Rae (1989), and Wiederholm (1984).

Each one of the ICI metrics presented above are consistent with common methods used to evaluate water quality. OEPA biologists developed these metrics based upon the information they have collected throughout the years of conducting such assessments. The ICI reflects the state-of-the-art for benthic assessments within Ohio, and complements the many other tools available for use including biotic indices, similarity indices, and rapid assessment methods.

Variability in both the ICI and each metric was determined using the coefficient of variation (C.V.). A summary of the metric values for the reference and ambient sites appears in Tables 1 and 2 along with the C.V. for each metric. In general, it appears that there is fairly low spatial variability with the ICI for both the reference and ambient sites. As expected, there is greater variability among the ambient sites than the reference sites. Also, the metrics with the greater variability are the enumeration measurements since their natural ranges are much greater and populations within a community tend to respond quickly to water quality changes. Temporal variability was not examined in this study, but since OEPA has a summer sampling program with restrictions on conditions when the sample can occur, temporal variability should be somewhat controlled.

<u>Determine if the drainage area relationships visually determined are reasonable.</u>

Data distributions derived via SAS ranking procedures for each of the drainage area size categories were used to determine whether or not the OEPA utilized appropriate percentile values. The rankings yielded 95th percentile results similar to the results visually determined by OEPA (Table 3). Therefore, the ranking results supported the accuracy of the original visual results.

<u>Determine if any of the metrics are interrelated and, thus, provide redundant information.</u>

The SAS-derived correlations among the pairs of metrics were uniformly low (Table 4). The highest individual coefficient is approximately 0.73 (R square = 0.53). The majority of the

Table 1. ICI metric values for reference sites (n=232).

Metric	Mean	C.V.
# Taxa	35.57	19.51
# Mayflies	6.86	34.52
# Caddisflies	3.78	61.14
# Diptera	15.52	30.95
% Mayflies	23.13	72.60
% Caddisflies	10.84	120.89
% Tanytarsini	23.43	78.80
% Dipterans[1]	40.79	52.05
% Tolerant	10.22	109.93
EPT	3.78	42.83
ICI	40.96	20.51

[1]and non-insects

Table 2. ICI metric values for ambient sites (n=431).

Metric	Mean	C.V.
# Taxa	28.79	32.82
# Mayflies	4.52	65.35
# Caddisflies	3.04	89.48
# Diptera	12.87	37.17
% Mayflies	15.96	109.24
% Caddisflies	10.93	142.39
% Tanytarsini	12.95	119.92
% Dipterans[1]	58.76	53.42
% Tolerant	23.27	121.84
EPT	6.32	68.40
ICI	29.47	53.72

[1]and non-insects

Table 3.ICI metric 95th percentiles.

	Drainage Area (mi^2)[1]			
Metric	A	B	C	D
# Taxa	36	48	47	39
# Mayflies	7	10	10	10
# Caddisflies	6	5	8	8
# Diptera	19	24	22	14
% Mayflies	43	58	53	54
% Caddisflies	51	23	39	57
% Tanytarsini	21	52	68	47
% Dipterans2	84	82	72	56
% Tolerant	33	25	1	2
EPT	11	15	19	17

[1]A=<10; B=11-100; C=101-1000;D=>1000
[2]Other dipterans and non-insects.

coefficients were less than 0.5, indicating that there was minimal intercorrelation (and redundancy) among the majority of the metrics.

Determine if the use of linear equal weights was appropriate.

The principal components analysis resulted in unequal weights, demonstrating that the use of equal weights is not optimal. The alternative weights are shown in Table 5.

Evaluate the overall accuracy of the ICI to develop biocriteria.

The evaluation of the overall accuracy of the ICI required the determination of whether or not the original results closely corresponded with those using the factor analysis derived weights (assumed to be the more optimal values). The factor analysis scale used for comparative purposes was created using only the substantial weights (metrics with low weights). The basic idea was that if the correlations among the pairs of original (OEPA) and the factor analysis derived scores were high, there is substantial similarity among the results. The correlation analysis without exception yielded high correlations among the OEPA original results and the factor analysis derived results. Table 6 presents results using the entire

Table 4. Correlations among the ICI metrics.

	Metric Number[1]									
Metric	1	2	3	4	5	6	7	8	9	10
# Taxa	*	.39	.29	.33	.04	-.12	.01	.01	.25	-.10
# Mayflies	.39	*	.29	-.06	.32	.04	.14	-.40	-.15	.02
# Caddisflies	.29	.29	*	-.26	-.09	.50	.31	-.44	-.23	.12
# Diptera	.73	-.06	-.26	*	.04	-.37	-.17	.33	.45	-.16
% Mayflies	.04	.32	-.09	.01	*	.04	-.38	-.52	-.05	-.03
% Caddisflies	-.12	.04	.50	-.37	.04	*	-.20	-.38	-.22	.09
% Tanytarsini	.01	.14	.31	-.17	-.38	-.20	*	.43	-.19	.19
% Dipterans[2]	.01	-.41	-.44	.33	-.52	-.38	-.43	*	.32	-.18
% Tolerant	.25	-.15	-.23	.45	-.05	-.22	-.19	.32	*	-.20
EPT	-.10	.02	.12	-.16	-.03	.09	.19	-.18	-.20	*

1Numbered metrics are ordered as in vertical list.
2Other dipterans and non-insects.

Table 5. Factor analysis scale weights.

Metric	Factor 1	Factor 2	Factor 3	Factor 4
# Taxa	-.08456	.45265	.14775	.15932
# Mayflies	.14139	.33058	-.04850	-.18673
# Caddisflies	.23157	.17111	.19786	.41300
# Diptera	-.25057	.29023	.06976	.02050
% Mayflies	.06978	.18929	-.52270	-.28908
% Caddisflies	.20729	-.03090	-.16980	.59147
% Tanytarsini	.14237	.02690	.50169	-.31282
% Dipterans[1]	-.28677	-.16418	.09452	.19557
% Tolerant	.22392	.11371	.00090	.13188
EPT	.12308	.06188	.15082	-.18614

1Other dipterans and non-insects.

data set as well as each of the drainage area size categories.

Table 6. Correlations among ICI and factor analysis scales at the reference sites.

Drainage Area (mi^2)	n	r	r-square
All	232	.972	.945
<10	7	.903	.815
11-100	97	.978	.956
101-1000	107	.969	.939
>1000	21	.971	.943

To determine whether the ICI developed for the reference sites would be applicable to the ambient sites, correlations were studied between the ICI metrics calculated for the 431 ambient sites and the factor-derived scores for the same ambient sites using the factor scales from the reference sites. As expected, due to the greater variability among the ambient sites, lower correlations were found with the ambient site data than with the reference site data (Table 7).

Table 7. Correlations among ICI and Factor Analysis Scales

All	431	.914	.835
<10	17	.825	.681
11-100	151	.926	.857
101-1000	213	.917	.841
>1000	50	.813	.661

However, these correlations were still relatively high with the exception of the drainage areas greater than 1000 square miles. We feel that the ICI can be adequately applied to non-reference sites, as recommended by OEPA (1987b).

Therefore, it may be concluded that the presented OEPA results are acceptable and the OEPA scale is accurate. Since the factor-derived scale and OEPA-derived scales yielded similar results, it does not appear as though the use of equal weights detracted from the ICI.

Summary and Conclusions

In summary, the following was concluded:

1. The metrics which comprise the Invertebrate Community Index (ICI) seem to be valid empirical indicators of water quality;

2. OEPA employed appropriate 95th percentile distribution factors;

3. The individual ICI metrics are minimally interrelated;

4. The use of equal weights is not optimal, but is acceptable; and,

5. The factor analysis derived and the OEPA scales yielded similar results;

6. Consequently, both the overall accuracy and adequacy of the OEPA developed ICI were determined to be acceptable.

Even though the results of the OEPA effort were found to be reasonable, factor analysis should be used to develop empirically based weights rather than relying on the assumption of equality. Similarity among the OEPA and factor analysis scale scores was observed for both the reference and ambient site data. In general, we feel that OEPA has done an excellent job in documenting the ICI and in preparing an extraordinary index for the State of Ohio.

Acknowledgements

We gratefully acknowledge the assistance received from Jeff DeShon at the Ohio EPA for providing the data used for this study, reviewing this article, and clarifying some of the procedures used in the ICI development. This document does not necessarily reflect the opinions of the U.S. Environmental Protection Agency.

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Black Earth Creek: Use of Biological Methods to Identify Non-Point Source Threats to a Naturally Reproducing Trout Fishery

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Abstract

Black Earth Creek Watershed is one of 32 nonpoint source program priority watershed projects in Wisconsin. The identification of impaired uses is an important component of each watershed project. A variety of biological methods were used to appraise threats to the naturally reproducing Brown Trout fishery in Black Earth Creek. The water resources appraisal found dissolved oxygen levels not meeting standards during storm events; sedimentation degrading fish habitat; excessive aquatic vegetation; aquatic insect populations dominated by sediment tolerant species; and a stressed fish population.

Introduction

In 1985, a committee involving several Wisconsin DNR programs, USGS, and University of Wisconsin was organized to assess the water quality and fishery of Black Earth Creek. Black Earth Creek is a locally famous trout stream in the backyard of Wisconsin's second largest city and supports up to 1,800 adult wild Brown trout per mile. The assessment committee addressed the concerns of local Trout Unlimited members, other long-time anglers and users of Black Earth Creek who perceived declining water quality in the stream. A monitoring strategy was designed to characterize water quality and document impacts of point and nonpoint sources on the stream. Strong public interest and support among various public agencies eventually lead to the selection of Black Earth Creek as a Priority Watershed for controlling nonpoint source pollution. Under the Wisconsin Nonpoint Source Water Pollution Abatement Program, the original diagnostic study evolved into a project of stream protection and rehabilitation. Presently, monitoring continues and focuses on documenting success of the project.

Location

The Black Earth Creek watershed is located in south central Wisconsin, just west of Madison the state capital. The watershed encompasses 106 square miles of mostly hilly farmland and includes three small communities. In addition to Black Earth Creek, two other streams are classified and managed trout fisheries. Three more small streams support low trout numbers but mostly forage fish populations. Another small stream displays poor water quality and supports aquatic communities tolerant of organic pollution. Only one small natural lake occurs in the watershed which is on the fringe of a glaciated region to the east and unglaciated "driftless" area to the west. Along its 21 mile length, Black Earth Creek is divided into different fishery zones. The eastern headwaters section exhibits relatively low flow and supports mostly forage fish. The middle trout fishery section begins at an area of significant groundwater discharge which is the "lifeblood" of the trout stream. Lower Black Earth Creek has a diverse warm water fishery supporting species that migrate upstream from the Wisconsin River but also trout in the colder months.

Assessment Techniques

Monitoring and assessment involved a two-phased approach. Phase one, appraisal monitoring characterized stream habitats and water quality throughout the watershed. Appraisal monitoring helped prioritize management needs and identify stream segments for intensive evaluation monitoring, the second monitoring phase. Evaluation monitoring will focus on specific stream segments to closely assess water quality trends before and after implementation of land use management. Along with evaluation monitoring, the appraisal monitoring techniques will be duplicated at the end of the project to help document nonpoint source control effectiveness.

Appraisal Monitoring

Initially, appraisal monitoring focused on the managed trout water section of Black Earth Creek to characterize general water quality trends. Within that reach, USGS operated four gaging stations to continuously monitor dissolved oxygen, temperature and flow. BOD, suspended solids and nutrients were frequently sampled as well. Water Resources Management graduate students UW-Madison also participated on the Black Earth Creek Assessment committee when they selected the trout stream a "water resources management workshop" in 1985. The graduate students provided valuable information while getting experience at assessing water resources conditions and stream use potential. As part of the project, the students performed habitat assessments, conducted user surveys, and reviewed historical information on fisheries, water quality and land use. This information was compiled in a Institute for Environmental Studies Report.

DNR expanded appraisal monitoring to include more of Black Earth Creek and other streams in the water shed. Throughout the water shed, monitoring was aimed at assessing the impacts of channel strengthening, eroding cropland, over-pasturing and animal waste management problems. In Black Earth Creek, we also looked at potential impacts of construction erosion, a poorly designed and operated landfill, a wastewater treatment plant and a gravel mining operation. Appraisal monitoring involved a number of sampling techniques. Stream habitats were evaluated using standardized habitat rating forms and were supplemented with photographs. Population densities and size structure of trout were estimated in the managed trout streams. Fish populations were also monitored in small streams (not intensively managed by Fish Management) using a backpack stream shocker. Macrophotography supplemented fish preservation and laboratory identification of minnow species which could not be identified in the field.

A D-frame net was used to sample macroinvertebrate populations and the (HBI) Biotic Index, developed Hilsenhoff at UW-Madison, was calculate for each semi-quantitative sample. The index is based on varying tolerances of macroinvertebrate species to organic pollution. HBI values range from 0-10; 0 indicating most intolerant macroinvertebrates and 10 indicating most tolerant macroinvertebrates. Table 1 lists the HBI water quality scale calculated from macroinvertebrate communities. The HBI has been used in Wisconsin since 1978 and effectively demonstrated impacts of moderate to significant conventional pollutants on streams. Dissolved oxygen and temperature measurements supplemented biological information collected from each stream. Water column samples were tested for conventional pollutants below specific targets suspected of degrading water quality.

In addition to D-frame "bug" samples, quantitative suber samples were taken at five sites along Black Earth Creek to assess macroinvertebrates habitat preference and provide a closer look at macroinvertebrate community structure. Quantitative samples compared macroinvertebrates in substrates covered with aquatic plants to macroinvertebrates inhabiting bare substrates were part of a broader picture to assess the value of abundant aquatic plants in Black Earth Creek.

Appraisal Results

USGS reported that major runoff events had degraded the water quality in Black Earth Creek. Following a February 1985 warm spell and rainfall. BOD_5 concentrations reached 21mg/l. During a major storm in July 1985, dissolved oxygen levels dropped to 3mg/l which is below the minimum standard for trout streams (6 mg/l). Although Black Earth Creek displayed poor water quality during a few major storms, the HBI (a relatively long-term water quality indicator) reflected fair to good water in Black Earth Creek and most of the water shed streams. Brewery Creek, a small tributary of Black Earth Creek, is the only stream that displays poor water quality based on the HBI. The HBI reflected the dominance of _Asellus intermedius_ which is very tolerant of organic pollution. USGS provided further evidence of the poor water quality in Brewery Creek when BOD_5 concentrations reached 37 mg/l during the February 1985 thaw. High BOD concentrations were the result of animal waste management problems in the Brewery Creek Sub-watershed.

With the exception of Brewery Creek, HBIs indicated that water quality was not a limiting factor for benthic communities. Instead, habitat degradation caused by agricultural land use had a greater impact on aquatic invertebrates but is not and HBI measurement. Macroinvertebrates communities in most of the streams exhibited low diversity and were dominated by Chironomids, intolerant of severe organic pollution, and by _Gammarus pseudolimnius_ which indicates good water quality. These macroinvertebrates appear to have a high tolerance to siltation.

Consistent with macroinvertebrates sampling throughout the watershed, HBI's did not indicate significant pollution below the landfill, gravel mining operation or Cross Plains wastewater treatment plant. The landfill was closed in 1988 after volatile organic compounds were found in local private wells. Prior to closure however, leachate had reached the stream in a few instances. Except for relatively high COD concentrations in a drainage ditch below the landfill, appraisal monitoring techniques indicated no significant pollution. Concern was expressed by anglers that leachate may contain toxic contaminants that bioaccumulate in trout. As a public relations gesture, trout were tested for PCBs and other possible contaminants. Fortunately none were found, yet concerns are still being raised over the long-term impacts of a leaking landfill site.

During the '60's and early '70's, inadequate wastewater treatment at the Cross Plains plant reduced water quality in the Black Earth Creek trout stream and occasionally caused fish kills. As recently as 1985, a treatment plant upset caused high BOD concentrations to reach the stream. Since that time, mechanical problems in the plant have been corrected and effluent quality has been good.

Two potential impacts of gravel mining operations were identified during the watershed appraisal. First, impact of surface withdrawal from a quarry into Black Earth Creek during mid-summer increased by three degrees centigrade. Temperatures reached the upper limits for trout survival in lower sections of the trout stream. As a recourse,, the WPDES discharge permit has been temperature-dissolved oxygen profiled, withdrawal of water for 15 feet depth will maintain maximum discharge temperatures below 60°F. The other concern was the impact of gravel mining operations on ground water flow and springs which are the "life blood" of the trout stream. The groundwater issue was beyond the scope of the appraisal but will soon be addressed with a groundwater mapping effort.

Erosion from construction and development was identified as a problem, particularly in the Brewery Creek sub-watershed. Impacts of runoff and sedimentation could not be distinguished from agricultural sources, which occur throughout the watershed.

Figure 1 is a watershed map containing HBI data, with management and water resources objectives for each subwatershed.

Evaluation Monitoring

Evaluation monitoring techniques and locations were identified as part of the water resources appraisal. Appraisal monitoring identified Brewery Creek as a major source of sediment and enrichment in Black Earth Creek. The segment below Brewery Creek was selected for intensive evaluation monitoring because most of the stream reach contains substantial deposits of silt, abundant aquatic plants and benthic community dominated by Chironomids and Oligochaetes. A major focus of the evaluation monitoring is to map and quantify silt deposits and evaluate habitat loss for macroinvertebrates and trout. Aquatic plants will be mapped and numerous diel dissolved oxygen measurements will be taken to assess respiration of abundant plants. During June 1988, early morning dissolved oxygen concentrations dropped to 3.2 mg/l and a substantial trout kill occurred. It was the first documented fish kill caused by aquatic plant respiration in Black Earth Creek.

Quantitative macroinvertebrates samples will be taken to assess community change and coincide habitat assessment. Long-term trout fishermen believe a greater diversity of aquatic insects, including numerous mayflies and daccisflies, inhabited the stream prior to recent habitat degradation. Assuming habitat will be improved, quantitative sampling should reflect a community shift from Chironomids and Oligochaestes to insects that trout fishermen consider "quality hatches".

Semi-quantitative sampling, used for the HBI may not accurately depict community structure. Table 2 contains preliminary comparison of quantitative surber samples to semi-quantitative D-frame samples. Over a

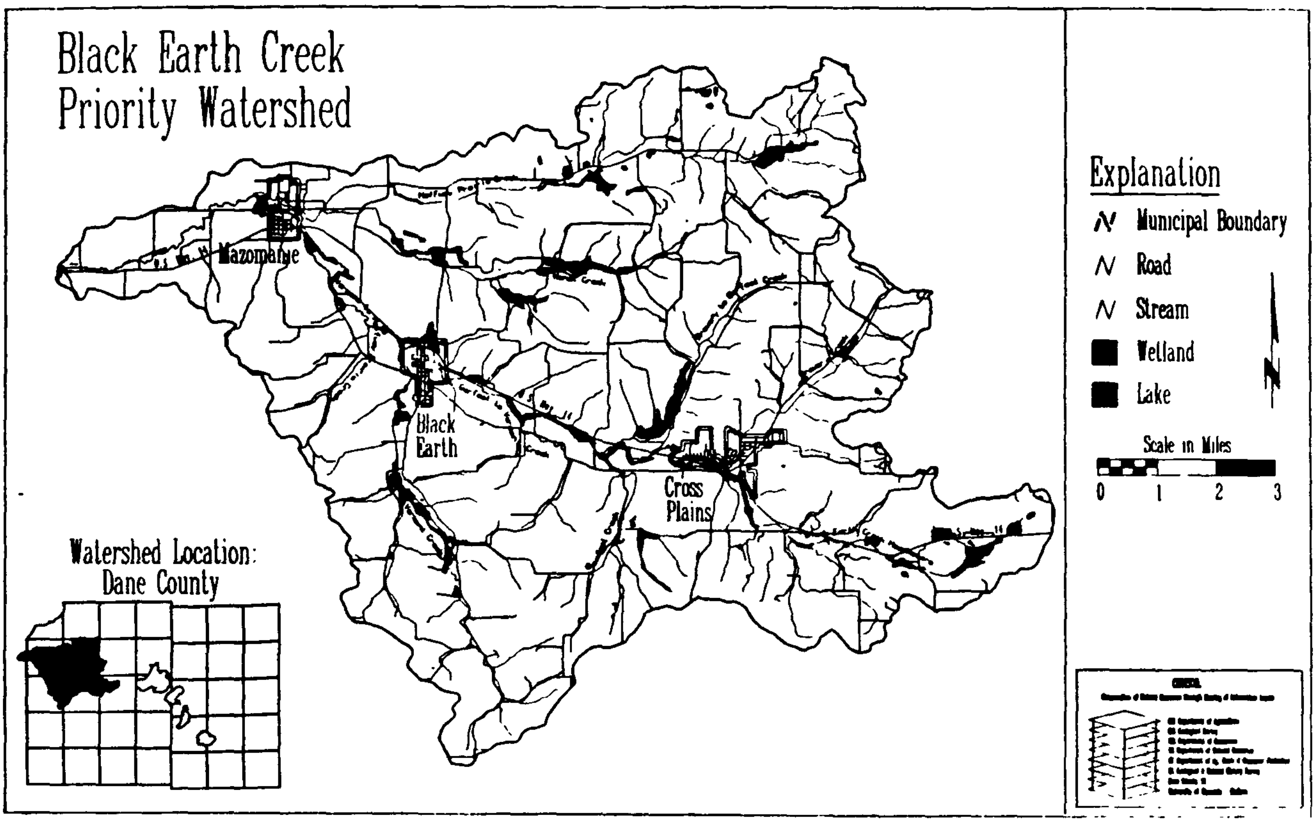

Figure 1. Black Earth Creek Priority Watershed.

Table 1. A description of the Hilsenhoff (1987) Biotic Index.

Biotic Index	Water Quality	Degree of Organic Pollution
0.00-3.5	Excellent	No apparent pollution
3.51-4.5	Very Good	Possible slight pollution
4.51-5.5	Good	Some organic pollution
5.51-6.5	Fair	Fairly significant pollution
6.51-7.5	Fairly Poor	Significant organic pollution
7.51-8.5	Poor	Very significant pollution
8.51-10.0	Very Poor	Severe organic pollution

Table 2. Surber and D-frame H.B.I. and percent Chironomid data (4/85).

Non-Vegetative Substrates		Vegetative Substrates		Both Substrates	
Surber	%Chironomids	Surber	%Chironomids	Surber	%Chironomids
2.61	51	2.55	62	2.71	18
3.4	89	3.15	95	3.0	63
3.08	89	3.13	87	3.4	48
3.04	95	3.59	84	2.96	38
3.14	91	3.44	92	3.19	61

range of vegetative and bare substrates, all D-frame samples had significantly lower percentages of Chironomids and may indicate for bias larger macroinvertebrates.

Estimates of trout population density and size structure and will dovetail macroinvertebrate sampling and habitat assessment. The combined evaluation monitoring techniques will ultimately characterize stream ecology before and after implementation of nonpoint source pollution controls in the Brewery Creek Sub-watershed and at planned management sits in Black Earth Creek. Below are more detailed summaries of methodology used for evaluation monitoring.

Intensive Habitat Assessment

Within the 3/4 mile reach below Brewery Creek, sediment depths and macrophyte cover will be measured along several transect sites will be marked for resampling biennially until completion of the project in 1995. A top settling rod will be driven into the sediment for measurement of silt accumulation. Silt measurements are taken at two foot intervals along the cross section and stream widths vary from 20 to 50 feet. Percent macrophyte cover is estimated in each two foot segment across the transect. The habitat assessment is performed during peak growing season, usually in July and early August.

Macroinvertebrate Sampling

Quantitative macroinvertebrates samples will be taken at several transects along the study reach during the three sampling periods at the beginning, approximate midway point and completion of the project. The primary focus is to characterize benthic community structure and community change as habitat changes. A hess sampler is used for quantitative sampling at two to three points along a transect. depending on stream width. Because of the labor involved in quantitative assessment, most of the laboratory sorting and identification stops at the Family level. However, subsamples will be removed for further identification and HBI calculation. Although habitat is the primary focus of the macroinvertebrate study, HBI sampling will continue because it is a standard water quality measurement tool in Wisconsin. Quantitative sampling will identify major community groups for comparison of total numbers and percentages of Chironomids and Oligochaetes to Ephemeroptera and Tricoptera. Other indices may be used as they are tested and approved. Dr. Stanley W. Szcythko, at UW Stevens point is currently evaluating new stream metrics techniques for use in Wisconsin.

Assessment of Trout Density and Size Structure

Mark and recapture population estimates will be conducted for brown trout (Salmo trutta) in the 0.75 mile stretch below the mouth of Brewery Creek. These estimates will be conducted during spring 1989 and 1990. Results will be compared to future estimates after land use practices and habitat improvement have been completed., An attempt will also be made to relate these results to previous estimates for the same stream stretch prior to construction erosion in the Brewery Creek sub-watershed.

Because trout size structure is an important consideration, all population estimates will be based on summation of size group estimates., This analysis will allow the evaluation of size structure trends through time.

Habitat Improvement Demonstration Sites

Since the project is a joint effort involving Fisheries and Water Resources Management programs, the three primary evaluation techniques will also be used to demonstrate the effectiveness of instream habitat improvement. Monitoring will be flexible to accommodate new demonstration sites as they are selected.

Dissolved Oxygen - Temperature

Diel dissolved oxygen and temperature monitoring will occur in study reach below Brewery Creek and throughout the Black Earth Creek trout stream. The sampling will occur biennially during the peak growing season to further assess impacts of abundant aquatic plants and determine how frequently D.O. levels drop below water quality standards. A YSI Model 57 dissolved oxygen-temperature meter with automated data logger is the primary instrument used. The equipment will be in place up to one week during mid to late summer.

Appraisal Monitoring Techniques

Appraisal monitoring discussed earlier in this report will be duplicated on smaller streams not intensively monitored. General habitat assessment, HBI and IBI sampling will be repeated midway and at the completion of the project to document overall changes of watershed conditions and success of the Priority Watershed Project.

Summary

In nonpoint source Priority Watersheds across the state, Water Resource Appraisals characterize water resource conditions and potential problems. Evaluation monitoring specifically focuses on documenting water quality changes before and after implementation of nonpoint source pollution controls. The specific appraisal and evaluation monitoring techniques will vary somewhat across the depending on water shed characteristics and evaluator preference. The monitoring strategy of this project reflect water resources issues and problems unique to the Black Earth Creek watershed.

The Black Earth Creek Priority Watershed Project has been a cooperative effort involving several environmental and conservation programs. Protecting water resources and assessing the effectiveness of nonpoint source pollution abatement and habitat rehabilitation are the primary goals of the project. A number of support technical reports were prepared during the Appraisal phase which helped identify specific management and water resources objectives to meet these goals.

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Rationale for a Family-Level Ichthyoplankton Index for Use in Evaluating Water Quality

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Abstract

Based on recommendations by proponents of the Index of Biotic Integrity (IBI), the early life stages of fishes are usually not included in evaluations of water quality. High initial larval mortality, differing gear-type vulnerability, and the lack of taxonomic expertise has precluded field biologists from considering them in their analyses. The literature demonstrates that the egg and larval stages of development are the sensitive period in all species of fishes. Recruitment failure, contamination of pool and nursery habitats, poor sediment quality, and discovery of reproductive failure at chronic levels of exposure would be advantageous in protecting aquatic resources. The use of a qualitative collection method with a family-level taxonomic approach will facilitate use without complicating logistics and level of effort. The index is based on three components: taxonomy, reproductive guild, and abundance and deformity.

Introduction

The early life history stages of fishes are recognized as the most sensitive and vulnerable life stage (Blaxter 1974; Moser et. al 1984). The Clean Water Act of 1972, section 316(b), inadvertently prompted large-scale monitoring and research in the ecology and taxonomy of ichthyoplankton. Documentation of perturbations brought about by large-scale water withdrawal for hydroelectric, industrial cooling, and navigation impacts have met with limited success. The ability to document trends without identifying most taxa to species has caused doubt as to the relevance or resolution abilities of using ichthyoplankton. The seasonal and taxonomic difficulties has all but reduced the usefulness of ichthyoplankton except for game or commercial species management. Finally, high yearly fluctuations in species density often dampens population effects.

Even though there is reluctance to conduct further ichthyoplankton studies detailed enough to answer water quality questions, investigators have furthered knowledge on the early life stages of fishes. A recent explosion in the amount and types of literature includes documentation of nursery habitats (Goodyear et al. 1982), ecological early life history notes (Wallus 1986; Wallus and Buchanan 1989; Simon and Wallus 1989), taxonomic studies of regionally important systems (Auer 1982; Holland and Huston 1983; Wallus et al. 1989), and toxicological studies using early life history stages (Norberg and Mount 1983; Birge et al. 1985; Simon 1989).

The purpose of the current study is to present an alternative for the use of ichthyoplankton data for determining water quality. Water quality managers could use this information to document reproduction, nursery habitats, and backwater habitats not conventionally surveyed during routine adult fish or macroinvertebrate collection. The format and structure of the ichthyoplankton index (I^2) is modeled after the index of biotic integrity (IBI) using a family-level approach. Since the proponents of the IBI recommend against use of larval and juvenile stages in their analyses (Angermeier and Karr 1984; Karr et al. 1986), the I^2 can be an additional use of data collected during a routine adult sampling event. Current knowledge on the identification of most freshwater faunas are limited, however, a listing of appropriate references are included in Table 1.

Methods and Materials

Sampling Requirements. The objectives of the I^2 are to provide a rapid screening method using a single collection event to determine effects of water quality on reproduction and the early life stages of fishes. Collection of a representative sample of ichthyoplankton requires a variety of gear types, and geographical, spatial and temporal considerations. The greater the stream complexity, the greater the distance needed to be sampled, e.g. a second order stream should be surveyed approximately 100 m, while a good rule of thumb is fifteen times the river width or two habitat cycles (Gammon et al. 1981; Karr et al. 1986). Reproduction by fishes occurs within a smaller habitat scale than adult species occurrence. Fishes may rely on a broader area for foraging and etching out an existence, however, only specialized "select" habitats are utilized for reproduction and serve as a nursery habitat. Because of patchy distribution of eggs and larvae a large enough area needs to be investigated to determine local use of a particular stream reach.

Gear Types. The more complex the environment the more numerous and sophisticated are equipment needs. The most typical equipment used for collection of larval fishes include, plankton nets; seines, dip nets, and sweep nets; light traps; and push nets and benthic sleds. Snyder (1983) provides documentation on rationale and use of most of the above equipment. Light traps can be constructed for lentic (Faber 1981, 1982), and lotic waters (Muth and Haynes 1984), and information on the use of the equipment can be determined from references contained therein. Push nets and benthic sleds are described by Tuberville (1979) and Burch (1983).

Geographical Considerations. Landscape differences have long been recognized, and methods to differentiate between various scales have been attempted using zoogeographical realms, biomes, and most recently ecoregions. The ecoregion concept is the most consistent means of evaluating community composition for a water quality based approach. Omernik (1987) defined the conterminous United States into a series of smaller discrete units. Aquatic biological characterization using this approach has been completed for adult fish and macroinvertebrates in several States including Ohio (Larsen et al. 1986; Ohio EPA 1988), Arkansas (Bennett et al. 1987; Geise and Keith 1988), North Carolina (Penrose and Overton 1988), and Vermont (Langdon 1988). These

Table 1. Taxonomic literature useful for identification of larval and early juvenile North American Freshwater fish.

Author (s) and Publ. Date	Region
Fish, 1932	Lake Erie
Mansueti and Hardy, 1967	Chesapeake Bay Region
May and Gasaway, 1967	Oklahoma, Canton Reservoir
Colton and Marak, 1969	Northeast Coast, Black Island to Cape Sable
Taber, 1969	Oklahoma and Texas, Lake Texoma
Scotton et al, 1973	Delaware Bay Region
Lippson and Moran, 1974	Potomac River Estuary
Hoque et. al, 1976	Tennessee River
Hardy et. al, 1978 (six volumes each ind. authored)	Mid-Atlantic Bight, including tidal and freshwater zones
Drewry, 1979	Great Lakes Region
Wang and Kernehan, 1979	Deleware Estuary
Elliott and Jimanez, 1981	Beverly Salem Harbor Area, Massachusetts
Snyder, 1981	Upper Colorado River System, Colorado
Wang, 1981	Sacramento-San Joaquin Estuary and Moss Landing Harbor Elkhorn Slough, CA
Auer, 1982	Great Lakes Basin, emph. Lake Michigan
Holland and Huston, 1983	Upper Mississippi River
McGowan, 1984	South Carolina, Robinson Impoundment
Sturm, 1988	Alaska
Wallus et. al, 1989	Ohio River basin, emphasis on Tennessee and Cumberland Drainages
McGowan, 1989	North Carolina Piedmont Impoundments

approaches are applauded and similar direction is needed for calibrating the I^2.

Spatial Considerations. Riffles or rapid flow areas are not the most likely places to encounter larval or juvenile fishes, rather the head of a pool, side margin of a channel, and backwater areas are preferred. A representative larval sample should be collected from all available habitats within a stream reach. For example, a large river sample should consist of various depth fractions from the main channel, main channel border, side border and backwaters. Low flow areas will reveal higher diversity of taxa while the remaining large river species will be collected while drifting in the main channel (Simon 1986a). These diverse areas should be pooled for an overall evaluation of the site while each component habitats, "relative value", can be quantitatively assessed for its contribution to the whole. Creeks, stream, and small rivers will require fewer areas to comprise a representative sample, however, any reduced flow or eddy area will be in need of sampling within a given location. Ideal habitats include those with submerged and emergent aquatic macrophytes, overhanging bank vegetation and roots.

Temporal Considerations. Numerous reports and journal articles have documented spawning temperature requirements of various faunas. In order to collect a representative sample from a particular location, familiarity with the reproductive literature and selection of appropriate sampling times are necessary. For example, in the midwest the earliest spawning fishes initiate spawning under the ice, with larval emergence and hatching immediately after ice-out during late March and early April. The last species to initiate spawning are usually finished by mid-July with a majority of species spawning during June (Simon 1986a). Ichthyoplankton and early juvenile sampling should be initiated in the midwest, no sooner than mid-June and no later than the end of September to ensure collection of a representative sample.

The use of different gear types will facilitate collection of families which are earlier spawning, e.g. percids, cottids, salmonids, and catostomids. Due to north to south temperature clines, and east to west rainfall differences, species will cue on spawning earlier in the south and west and later in the north and east for the same species. Sampling needs to be adjusted accordingly.

Equally important is diel differences in specimen collection. Numerous studies have documented significant differences between dusk and sunset, daylight, and night sampling. The general pattern is the more turbid the water body the less likely diel affects will be a problem. Whenever one decides to sample is not as important as it is for them to be consistent. Safety considerations and study objectives may not deem night sampling necessary. However, light trap use, set up using an automatic timing device may enable night time sampling without the inconvenience and danger. This method has successfully been used by Alabama Power on the Tallapoosa River.

Ichthyoplankton Index Rationale and Description

Metrics

Since much of the North American fauna is incompletely described (Simon 1986b), use of the index is limited to a family approach until the taxonomic literature facilitates species specific recognition. The eleven I^2 metrics are based on three broad categories. Metrics are organized into taxonomic composition, reproductive guild, and abundance, generation time and deformity categories. No single metric is always a reliable indicator of degradation, however, relative sensitivity is determined by region, scale, and application.

The metrics will react differentially based on the type of perturbation. For example, if contaminated sediments are suspected, the proportion of lithophils and number of sensitive families should decline depending on the magnitude of the impact, while equitability and perhaps deformity should increase.

The remainder of this section provides information, justification, and rationale behind each of the I^2 metrics (Table 2). Additional refinement may be necessary to meet the objectives of the investigators study.

Taxonomic Composition. This category is useful for assessing family diversity and community richness. The current level of taxonomy requires that discussion be limited to a family level but future use of the index may make this a species specific approach. Expectations should be determined for various stream size and calibrated by equipment based on information presented in Fausch et al. (1984). Taxa diversity has been determined to be the best sole indicator of "good" water quality. Sensitive families such as percids, cottids, ictalurids, and others listed in Table 3, are useful for determining the extent of impact to sediments and nursery habitats. Finally, dominance of tolerant species increases proportionally to environmental degradation.

Metric 1. Total Number of Families. The fluctuation in number of families of an ecoregion increases with stream order. If the same order stream, in the same ecoregion, with similar habitat cycles were sampled, then reduction in number of families would correspond to environmental degradation. A number of investigators have determined number of taxa is the single most important metric which highly correlates with more pristine water quality (Ohio EPA 1987; Davis and Lubin 1989: Plafkin et al. 1989).

Metric 2. Number of Sensitive Families. Certain families of freshwater fish are sensitive to degradation, particularly as a result of reproduction requirements and early life ecology (Table 3). Families such as Percidae, Cottidae, and Salmonidae are intolerant to siltation and low dissolved oxygen. Sediment contamination due to toxins and low dissolved oxygen inhibits most benthic families (e.g. Ictaluridae). Reduction in habitat quality (e.g. channelization, thermal inputs, reservoir flooding) reduces Catostomidae, Centrarchidae, Cyprinidae, and Fundulidae. Sensitive families should be restricted to those most sensitive to low dissolved oxygen, toxic chemicals, siltation, and reduced flow. Karr et al. (1986) suggested

Table 2. Metrics used to assess ichthyoplankton communities from freshwaters of North America.

Category	Metric	Scoring Criteria 5	3	1
Taxonomic Composition				
1.	Total Number of Families	Drainage Size and Ecoregion Dependent		
2.	Number of Sensitive Families	Drainage Size and Ecoregion Dependent		
3.	Equitability/Dominance	>0.8-1.0	>0.6-0.8	0-< 0.6
4.	Family Biotic Index	0-4.5	>4.5-7.5	>7.5-10
Reproductive Guild				
5.	% Non-guarding Guild A.1 and A.2	Drainage Size and Ecoregion Dependent		
6.	% Guarding Guild B.1 and B.2	Drainage Size and Ecoregion Dependent		
7.	% Bearers Guild C.1. and C.2	Drainage Size and Ecoregion Dependent		
8.	% Simple Lithophil Mode Reprod.	Drainage Size and Ecoregion Dependent		
Abundance, Generation Time, and Deformity				
9.	Catch per Unit Effort	Drainage Size and Gear Type Dependent		
10.	Mean Generation Time	Drainage Size and Ecoregion Dependent		
11.	% Deformity or Teratogenicity	< 1%	> 2-5%	>5%

Table 3. Sensitivities, Mean Generation Time, and Reproductive Guild characteristics of 34 North American Freshwater Fish Families.

Family	Sensitivity	Generation Time[a]	FBI[b]	Reproductive Guild
Petromyzontidae	Moderate	Short/Moderate	3	A.1
Acipensideridae	Moderate	Long	2	A.1
Polyodontidae	Intolerant	Long	2	A.1
Lepisosteidae	Tolerant	Moderate	4	A.1
Amiidae	Tolerant	Moderate	8	B.2
Anguillidae	–	Moderate	3	A.1
Clupeidae	Moderate	Short	6	A.1
Hiodontidae	Intolerant	Short/Moderate	4	A.1
Salmonidae	Intolerant	Moderate/Long	1	A.1, A.2
Osmeridae	Moderate	Short	5	A.1
Umbridae	Tolerant	Short	9	A.1
Esocidae	Moderate	Moderate	6	A.1
Characidae	Moderate	Short	5	A.1
Cyprinidae	Moderate	Short	6	A.1,A.2,B.1,B.2
Catostomidae	Intolerant	Moderate	4	A.1, A.2
Cobitidae	Intolerant	Short	4	A.1
Ictaluridae	Intolerant	Moderate	3	B.2
Claridae	Tolerant	Moderate	10	A.2
Amblyopsidae	Intolerant	Short	4	C.1
Aphredoderidae	Tolerant	- Short	8	C.1
Percopsidae	Moderate	Short	7	A.1
Gadidae	Moderately	Moderate/Long	5	A.1
Oryzintidae	Tolerant	Short	7	C.2
Cyprinodontidae	Intolerant	Short	2	A.1, A.2
Fundulidae	Intolerant	Short	5	A.1, A.2
Poeciliidae	Tolerant	Short	8	C.2
Atherinidae	Moderate	Short	3	A.1
Gasterosteidae	Tolerant	Short	9	B.2
Moronidae	Intolerant	Moderate	6	A.1
Centrarchidae	Intolerant	Moderate	5	B.1
Elassomatidae	Intolerant	Short	3	B.2
Percidae	Intolerant	Short	0	A.1,A.2,B.1,B.2
Sciaenidae	Moderate	Moderate	4	A.1
Cichlidae	Tolerant	Moderate	7	B.2
Cottidae	Intolerant	Short	0	B.2

(a) Classified as short, moderate, and long appropriately scored 1, 3, 5, respectively. A community mean is calculated by summing scores and dividing by total number of families.

(b) Scored from 0 to 10. The higher the score the greater the tolerance to organic enrichment.

that species sensitive to habitat degradation, especially siltation, are most likely to be identified as intolerant.

Metric 3. Equitability/Dominance. As water quality declines certain taxa tend to become increasingly abundant (Karr et al. 1986). Also, species defined as r-strategists tend to inundate the environment with early life phases (MacArthur and Wilson 1967). The strategy to produce large numbers of young are indicative of "pioneer" species which are attempting to colonize perturbed areas. In habitats with least impacted environments, taxa tend to be equally distributed and more moderately abundant. The Shannon diversity index and the measure of evenness are used to determine quality environments which have balanced communities. These single unit measures are not adequate in themselves to extrapolate excellent quality, but they do determine increasing levels of disturbance. Equitability (Lloyd and Ghelardi 1964) is determined by comparing the number of families in the sample with the expected number of families from a community which conforms to the MacArthur broken stick model. MacArthurs' broken stick model is normally higher than real diversity and is the ecologically maximum diversity attainable (Washington 1984). Equitability is measured by:

$$e = s'/s$$

where:

s = number of taxa in the sample,

s' = the tabulated value based on the Shannon diversity index

The diversity index is the $\bar{d}$ formulation of Lloyd, Zar, and Karr (1968). The diversity index is:

$$\bar{d} = C/N\ (N \log_{10} N - E\ n_i \log_{10} n_i)$$

where:

C = 3.321928,

N = total number of individuals in the ith taxa,

n_i = total number of individuals in the ith taxa.

An example calculation and reproduction of Lloyd and Ghelardi's table (1964) are include in the Appendix and are taken from Weber (1973). As a side note, if solely ichthyoplankton data sets are to used excluding juveniles, the following families need to be omitted: Clupeidae, Sciaenidae, and Osmeridae.

Metric 4. Family Biotic Index. Discussions with other ichthyoplanktologists studying the ecological and taxonomic early life stages of fishes suggest varying degrees of sensitivity exists between organic pollution and perturbations such as sediment degradation, siltation, low dissolved oxygen, toxic chemicals, and flow reduction (Table 3). The calculation of the Family Biotic Index (FBI) is modeled after Hilsenhoff's modified biotic index (1988) which summarizes tolerances to organic pollution. Tolerance values range between 0 to 10 for families and increase as water quality decreases. The formula for calculating the Family Biotic Index is:

$$FBI = E\ x_i t_i / N$$

where:

x_i = total number of individuals within a taxon,

t_i = tolerance value of a taxon,

N = total number of organisms in the sample.

Reproductive Guild. Reproductive requirements of fishes coupled with early life history strategies enable a diversification of the ways habitats are used. Balon (1975, 1981) divided reproductive modes of fishes in order of evolutionary trends. Species are divided into nonguarders (guild A), guarders (guild B), and bearers (guild C). The increase in evolutionary sophistication from guilds A to C, generally conforms to levels of increased diversification and reduction in niche overlap in complex environments (Table 4).

Guild dynamics are determined by three metrics in this category. The destruction of diverse habitats not only reduces utilization of these habitats for reproduction by adults, but also destroys nursery habitats for larval and juvenile phases.

Metric 5. Proportion of Non-guarding Guild A.1 and A.2. The non-guarding guild includes mostly r-stragegists which provide little parental investment into each egg, usually possess early reproduction, small body size, many small offspring, single reproduction, and exhibit a type III mortality (MacArthur and Wilson 1967). Balon (1975) described the non-guarding guild as broadcast spawners, usually without much developmental specialization, and although may construct some nests always abandons them post-reproduction. These species are often "pioneer" species and frequently are dominant only in stressed areas which are periodically disturbed.

Metric 6. Proportion of Guarding Guild B.1 and B.2. The guarding guild typically include k-strategists as defined by MacArthur and Wilson (1967). This strategy favors slower development, greater competitive ability, delayed reproduction, larger body size, repeated reproduction, fewer larger progeny, and exhibits types I and II mortality. The guarding guild (Balon 1975) is a solely ethological aspect of guilds with profound ecomorphological consequences. Better protected from enemies, guarded eggs need not be numerous to assure survival of the species. As a consequence, eggs can be larger and result in more viable offspring with less food specialization. Spawning sites with low oxygen content can be used because the guarding parents clean the eggs and produce a flow of water around them by fin-fanning and oral ventilation. Fishes that do not build complicated structures, nests, but that deposit their eggs on top of a selected object, are also included in this section. The evolutionary progression has been from (i) an exclusively parental male, (ii) shared parental care by the male and female, to (iii) a division of roles with the female as the direct parent and the male as the guardian, to (iv) polygyny (Barlow 1974).

Metric 7. Proportion of Bearers Guild C.1 and C.2. This group is divided into external and internal brooders (Balon 1975). External brooders carry their developing eggs on the surface of their bodies or in externally filled body cavities or special organs. These include transfer, forehead, mouth, gill-chamber, skin and pouch brooders. Internal brooders have eggs fertilized internally before they are expelled from the body cavity. Special organs are developed to facilitate sperm transfer. Mating

Table 4. Classification of reproduction styles in fishes in order of evolutionary trends (after Balon 1981).

Guild	Ethological section	A. Nonguarders
	Ecological group	A.1. Open substratum spawners
Guild		Selected key features of early ontogeny
A.1.1	Pelagic spawners (pelagophils)	Numerous buoyant eggs, none or poorly developed embryonic respiratory organs, little pigment, no photophobia
A.1.2	Rock and gravel spawners with pelagic larvae (lithopelagophils)	Adhesive chorion at first, some eggs soon buoyant, after hatching free embryos pelagic by positive buoyancy or active movement, no photophobia, limited embryonic respiratory structures
A.1.3	Rock and gravel spawners with benthic larvae (lithophils)	Early hatched embryo photophobic, hide under stones, moderately developed embryonic respiratory structures, pigment appears late
A.1.4	Nonobligatory plant spawners (phytolithophils)	Adhesive eggs on submerged items, late hatching, cement glands in free embryos, photophobic, moderately developed respiratory structures
A.1.5	Obligatory plant spawners (phytophils)	Adhesive egg envelope sticks to submerged live or dead plants, late hatching, cement glands, not photophobic, extremely well developed embryonic respiratory structures
A 1.6	Sand spawners (psammophils)	Adhesive eggs in running water on sand or fine roots over sand, free embryos without cement glands, phototropic, feebly developed respiratory structures, large pectorals, large neuromast rods (cupulae)
A.1.7	Terrestrial spawners (aerophils)	Small adhesive eggs scattered out of water in damp sod, not photophobic, moderately developed respiratory structures
	Ecological group	A.2 Brood hiders
A.2.1	Beach spawners (aeropsammophils)	Spawning above the waterline of high tides, zygotes in damp sand hatch upon vibration of waves, pelagic afterwards
A.2.2	Annual fishes (xerophils)	In cleavage phase blastomeres disperse and rest in 1st facultative diapause, two more resting intervals obligate – eggs and embryos capable of survival for many months in dry mud
A.2.3	Rock and gravel spawners (lithophils)	Zygotes buried in gravel depressions called redds or in rock interstices, large and dense yolk, extensive respiratory plexuses for exogenous and carotenoids for endogenous respiration, early hatched free embryos photophobic, large emerging alevins
A.2.4	Cave spawners (speleophils)	A few large adhesive eggs, must hide in crevices, extensive embryonic respiratory structures, large emerging larvae
A.2.5	Spawners in live invertebrates (ostracophils)	Zygotes deposited via female's ovipositor in body cavities of mussels, crabs, ascidians or sponges(?), large dense yolk, lobes or spines and photophobia to prevent expulsion of free embryos, large embryonic respiratory plexuses and carotenoids, probable biochemical mechanism for immunosuppression
	Ethological section	B. Guarders
	Ecological group	B.1 Substrate choosers
B.1.1	Pelagic spawners (pelagophils)	Nonadhesive, positively buoyant eggs, guarded at the surface of hypoxic waters, extensive embryonic respiratory structures
B 1.2	Above water spawners (aerophils)	Adhesive eggs, embryos with cement glands, male in water splashes the clutch periodically
B.1.3	Rock spawners (lithophils)	Strongly adhesive eggs, oval or cylindrical, attached at one pole by fibers in clusters, most have pelagic free embryos and larvae

(continued)

B.1.4	Plant spawners (phytophils)	Adhesive eggs attach to variety of aquatic plants, free embryos without cement glands swim instantly after prolonged embryonic period
	Ecological group	B.2 Nest spawners
B.2.1	Froth nesters (aphrophils)	Eggs deposited in a cluster of mucous bubbles, embryos with cement glands and well developed respiratory structures
B.2.2	Miscellaneous substrate and material nesters (polyphils)	Adhesive eggs attached singly or in clusters on any available substratum, dense yolk with high carotenoid contents, embryonic respiratory structures well developed, feeding of young on parental mucus common
B.2.3	Rock and gravel nesters (lithophils)	Eggs in spherical or elliptical envelopes always adhesive, free embryos photophobic or with cement glands swing tail-up in respiratory motions, moderate to well developed embryonic respiratory structures, many young feed first on the mucus of parents
B.2.4	Gluemaking nesters (ariadnophils)	Male guards intensively eggs deposited in nest bind together by a viscid thread spinned from a kidney secretion, eggs and embryos ventilated by male in spite of well developed respiratory structures
B.2.5	Plant material nesters (phytophils)	Adhesive eggs attached to plants, free embryos hang on plants by cement glands, respiratory structures well developed in embryos assisted by fanning parents
B.2.6	Sand nesters (psammophils)	Thick adhesive chorion with sand grains gradually washed off or bouncing buoyant eggs, free embryo leans on large pectorals, embryonic respiratory structures feebly developed
B 2.7	Hole nesters (speleophils)	At least two modes prevail in this guild: cavity roof top nesters have moderately developed embryonic respiratory structures, while bottom burrow nesters have such structures developed strongly
B 2.8	Anemone nesters (actiniariophils)	Adhesive eggs in cluster guarded at the base of sea anemone, parent coats the eggs with mucus against nematocysts, free embryo phototropic, planktonic, early juveniles select host anemone
	Ethological section	**C. Bearers**
	Ecological group	C.1 External bearers
C.1.1	Transfer brooders	Eggs carried for some time before deposition: in cupped pelvic fins, in a cluster hanging from genital pore, inside the body cavity (earlier ovi-ovoviviparous), after deposition most similar to nonguarding phytophils (A.1.4)
C.1.2	Auxiliary brooders	Adhesive eggs carried in clusters or balls on the spongy skin of ventrum, back, under pectoral fins or on a hook in the supraoccipital region, or encircled within coils of female's body, embryonic respiratory circulation and pigments well developed
C.1.3	Mouth brooders	Eggs incubated in buccal cavity after internal, external synchronous or asynchronous, or buccal fertilization assisted by egg dummies, large spherical or oval eggs with dense yolk are rotated (churning) in the cavity or densely packed when well developed embryonic respiratory structures had to be assisted by endogenous oxydative metabolism of carotenoids, large young released
C.1.4	Gill-chamber brooders	Eggs of North American cavefishes are incubated in gill cavities
C 1.5	Pouch brooders	Eggs incubated in an external marsupium: an enlarged and everted lower lip, fin pouch, or membraneous or bony plate covered ventral pouch, well developed embryonic respiratory structures and pigments, low number of zygotes

(continued)

	Ecological group	C.2 Internal bearers
C.2.1	Facultative internal bearers	Eggs are sometimes fertilized internally by accident via close apposition of gonopores in normally oviparous fishes, and may be retained within the female's reproductive system to complete some of the early stages of embryonic development, rarely beyond the cleavage phase; weight decreases during embryonic development (examples**: *Galeus polli, Rivulus marmoratus, Oryzias latipes*)
C.2.2	Obligate lecithotrophic livebearers	Eggs fertilized internally, incubate in the reproductive system of female until the end of embryonic phase or beyond, no maternal-embryonic nutrient transfer; as in oviparous fishes yolk is the sole source of nourishment and most of the respiratory needs; some specialization for intrauterine respiration, excretion and osmoregulation; decrease in weight during embryonic development (examples: *Torpedo ocellata, Poeciliopsis monacha, Poecilia reticulata, Xenopoecilus poptae, Sebastes marinus*)
C.2.3	Matrotrophous oophages and adelphophages	Of many eggs released from an ovary only one or at most a few embryos develop into alevins and juvelines⁺, feeding on other less developed yolked ova present and/or periodically ovulated (oophagy), and in more specialized forms, preying on less developed sibling embryos (adelphophagy), specialization for intrauterine respiration, secretion and osmoregulation similar to the previous guild, large gain in weight during intrauterine development (examples: *Lamna cornubica, Eugomphodus taurus, Latimeria chalumnae*?)
C.2.4	Viviparous trophoderms	Internally fertilized eggs develop into embryos, alevins or juveniles whose partial or entire nutrition and gaseous exchange is supplied by the mother via secretory histotrophes ingested or absorbed by the fetus via epithelial absorbtive structures (placental analogues) or a yolksac placenta, small to moderate gain in weight during embryonic development (examples: *Galeus canis, Mylobatis bovina, Mustelus canis, Sphyrna tiburo, Zoarces viviparus, Ameca splendens, Poeciliopsis turneri, Heterandria formosa, Anableps dowi, Embiotoca lateralis, Clinus superciliosus*)

* See the final amendment on p. 389.

** Note differences in the earlier paper (Balon 1975a).

⁺ Terminology as in Balon (1981b)

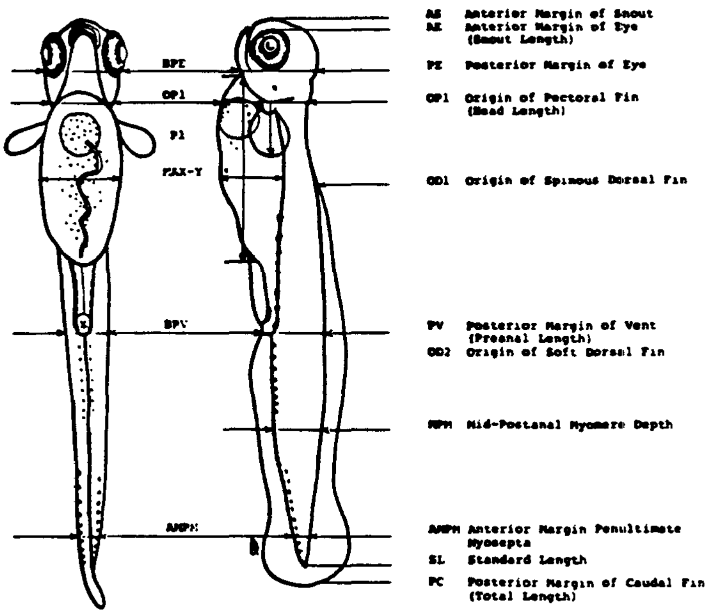

FIGURE 1.—Morphometric characteristics for larval fishes. The yolk sac (Y) is included in width and depth measurements, but fin folds are not. "B" means immediately behind, but not including, the eye or vent. Location of width and depth measures at OD can only be approximated before the dorsal fin begins to form. Fin length is measured along the plane of the fin from the origin to the most distal margin.

does not necessarily coincide with fertilization. After fertilization eggs can be expelled and incubated externally or retained in the body cavity of the female, after which full-grown juveniles are born (Hoar 1969; Balon 1975, 1981).

Metric 8. Proportion of simple Lithophil Mode of Reproduction. This metric is used by Ohio EPA (1987) as a substitute in the adult IBI for hybrids. Simple lithophils spawn where their eggs can develop in the interstices of sand, gravel, and cobble substrates without parental care. Genrally, as the level of environmental degradation increases, the proportion of simple lithophils decreases. This is important in determining impacts from chronic levels of exposure in sediments, and settling out of toxins in pools or backwater habitats.

Abundance, Generation Time, and Deformity. Impacts to individuals often are a compounding problem effecting community analyses. Reduction in numbers of individuals, lowering of community mean generation time, and increases in observed deformity and teratogenicity correspond with environmental degradation. Loss of longer-lived species which require specialized habitats, e.g. Acipenser fulvescens and Atractosteus spatula, during reproduction and nursery are increasing at an alarming rate. Mean generation time is a function of the time to first reproduction. This metric may need further research before it can be utilized since it is proposed as a community metric rather than as a individual metric as it was conceived.

Metric 9. Catch per Unit Effort. Population abundance varies with ecoregion, stream size, and gear type used. It may be expressed as catch per unit effort, either by area, distance, or time sampled. Sites with lower biological integrity will have reduced numbers of individuals, however, rapidly flowing riffles should be excluded from comparison with pools and run habitats (see spatial considerations). Organic enrichment usually increases the number of individuals. Steedman (1988) addressed this situation by scoring catch per minute of sampling. Unusually low numbers generally indicate toxicity which is readily apparent at low levels of biological integrity.

Metric 10. Mean Generation Time. Mean generation time is the average age of parenthood, or the average age at which all offspring are born. A longer-lived k-strategists species often spend several years before reaching reproductive maturity, e.g. Salmonidae, Polyodontidae and Acipenseridae. Vulnerability of these organisms to perturbations may have significant impact to future recruitment during the larval and juvenile stages of development. Mean generation time is an average value for a family based on life strategy of representative taxa. Mean generation time is calculated as:

$$\bar{T} = (a + w)/2$$

where:
a = age at first reproduction,
w = age at last reproduction

The community mean generation time is the sum of all generation times for all families collected, divided by the total number of families.

Metric 11. Proportion of Deformity or Teratogenicity. Toxicological literature suggests that increased exposure to metals and organic chemical compounds increases the proportion of teratogenicity among fathead minnows (Birge et al. 1985; Simon 1988). Additional effects have been documented in a recent literature review by Weis and Weis (1989), as well as, exposure to radiation (B. Lathrop, pers. comm.). Teratogenic effects include edematous yolk sacs, post caudal swellings, clear blood, reduced heart beat, lack of fusiforme shape, enlarged craniums, square eyes, or improper development of the mandible (Simon 1988). An increase in deformities or teratogenicity is a result of increased exposure to toxic chemicals or radiation. In reference and complex effluent testing using the fathead minnow embryo-larval survival and teratogenicity test, I very infrequently observed any teratogenicity in control samples. When deformities were observed they were always less than 1% (Simon, pers. obsv.).

Improperly preserved specimens will exhibit signs of deformity. Birchfield (1987) determined that cranial anomalies were induced in centrarchids and clupeids by fixing them in low concentrations of formalin (<10%), exposing them to high temperatures, or vigorously shaking the fixed specimens. No cranial anomalies were found in larval fish fixed in formalin solutions greater than 10% or in Bouin's fluid.

Taxonomic Considerations

The ability to differentiate families of larval fishes requires a basic understanding of the morphometric and meristic characteristics which are included in most taxonomic studies (Fig. 1). Extensive literature exists on specific families of larval fishes and alternative measurements, but certain standard measurements and counts continue to be the main ones reported in the literature. The following explanation of how to construct the character in question and the appropriate position to measure or count the character is defined by Simon (1987) and Simon et al. (1987).

Characteristics are subdivided into morphometric, measureable structures, and meristic, countable structures. Standard length and total length are measured from the tip of the snout to the posterior portion of the notochord and to the tip of the caudal finfold, respectively. Morphometric measurements include head length- from the snout to pectoral fin origin; snout length- from tip of the snout to anterior margin of eye; eye diameter-anterior to posterior margin; preanal length- snout to posterior margin of anus; body depth- vertical distance at anus; greatest body depth (also referred to as shoulder depth or head depth)- largest vertical distance (usually anterior dorsal finfold) or measured at origin of pectoral fin; mid-postanal depth- vertical distance measured from dorsal to ventral margin of body at anterior apex of the mean of the postanal myomeres; caudal peduncle depth- vertical distance at anterior apex of penultimate myomere; head width- measured dorsally at the posterior margin of eyes; yolk sac length and depth- measured horizontally and vertically, respectively at the greatest distance on the yolk sac.

Meristic measurements include the enumeration of all fin rays following methods in Hubbs and Lagler (1958); head canal pores

(Hubbs and Cannon 1935); preanal myomeres- those anterior to a vertical line drawn from the posterior portion of the anus including those bisected by the line, while postanal myomeres include a urostylar element.

Provisional Key to the Families of North American Freshwater Fishes

(Adequate information is not available for all early life phases. Families ommitted from this key include Amblyopsidae, Cichlidae, Cyprinodontidae, Poeciliidae, Umbridae, Cobitidae, Claridae, Oryziatidae, and Elassomatidae).

1a. Body tubular, elongate, eel-like 2

1b. Body not eel-like; usually with a single gill opening; stomodeum or functional jaws present.... 3

2a. Body tubular, elongate, eel-like; seven gill openings; oral sucking disc without jaws; lacking paired fins and distinct eyes ... Petromyzontidae

2b. Body eel-like; usually with a single gill opening; stomodeum, or functional jaws present; eye large; possessing paired fins ... Anguillidae

3a. Barbels present on chin; mandibular barbels at corners of mouth; usually hatching with some incipient fin rays present; yolk large usually with complex vitelline veins ... Ictaluridae

3b. Chin barbels and mandibular barbels absent; if barbels are present limited to ventral portion of snout or single on chin ... 4

4a. Adhesive disc present on snout; caudal fin heterocercal ... 5

4b. Adhesive disc absent on snout ... 6

5a. Adhesive disc papillose; preanal myomeres number x; snout elongate with remnant of adhesive disc until 20 mm total length (TL); dorsal and anal finfolds originating posteriorly, finfold with dark triangular areas near future dorsal, anal, and caudal fins ... Lepisosteidae

5b. Adhesive disc smooth; preanal myomeres number x; without elongate snout; dorsal finfold originating anterior pectoral fin; gular plate present; body robust ... Amiidae

6a. Larvae 10-11 mm TL at hatching; preanal length 60-65% TL; yolk sac large, oval, vascularized; barbels developing on ventral extension of snout; head small ... 7

6b. Larvae < 10 mm TL at hatching; preanal length greater than or less than 60-65% TL; large, oil globule; without barbels on ventral surface of snout ... 8

7a. Decreasing preanal length at increasing length, 65% TL becomes 60% TL > 11 mm; moderate dorsal finfold originates immediately behind head; dorsal finfold origin length 25% TL; late protolarvae with four barbels; dorsal fin origin posterior to vent; posterior margin of operculum not extending past base of pectoral fin; scutes developing at juvenile stages ... Acipenseridae

7b. Decreasing preanal lengths at increasing length, 60% TL becomes 50% TL at > 11 mm; dorsal finfold originates at mid-preanal; dorsal finfold origin length 35% TL; late protolarvae with two barbels; dorsal fin origin anterior anus; posterior margin of operculum extending past base of pectoral fin; no scutes developing at juvenile stages ... Polyodontidae

8a. Preanal length greater than 65% TL ... 9

8b. Preanal length 60% TL or less ... 19

9a. Preanal length greater than 75% TL ... 10

9b. Preanal length between 65-75% TL ... 13

10a. Preanal length 76-89% TL; total myomeres greater than 45 ... 12

10b. Preanal length usually less than 75-79% TL; total myomeres less than 45 ... 11

11a. Preanal myomeres > 27; mouth subterminal; body elongate, with usually one to several rows of dorsal pigment ... Catostomidae

11b. Preanal myomeres >   ; mouth superior; body elongate usually without pigmentation dorsally ... Clupeidae

12a. Postanal myomeres 13-17; yolk sac small, round and far forward ... Osmeridae

12b. Postanal myomeres < 10; yolk sac larger, elongate or oval, situated posteriorly ... Clupeidae

13a. Preanal myomeres greater than or equal to 40 ... 14

13b. Preanal myomeres less than 40 ... 15

14a. Postanal myomeres 14-15; preanal length 72-75% TL; adipose fin present; swim bladder visibly present ... Osmeridae

14b. Postanal myomeres 15-22; preanal length 67-72% TL; adipose fin absent; swim bladder not visible ... Esocidae

15a. Yolk sac long, bilobed with the anterior portion thick and oval, posterior section thick and tubular; preanal length 58-74% TL ... 16

15b. Yolk sac not bilobed, either elongate or oval; if bilobed usually with both sections of equal portion; preanal length 68-75% TL ... 17

16a. Larvae densely pigmented, evenly over body, with a dark stripe over gut; usually less than 27 preanal myomeres; body robust ... Cyprinidae

16b. Pigmentation limited to dorsum, usually on cranium and sometimes mid-dorsally in two to four distinct rows; body elongate ... Catostomidae

17a. Preanal myomeres < 31, postanal myomeres less than 41 ... Catostomidae

17b. Preanal myomeres ≥ 31 ... 18

18a. Postanal myomeres < 41; larvae large, at 7 mm still possess yolk; preanal length 62-64% TL ... Hiodontidae

18b. Postanal myomeres ≥ 41; preanal length 67-74% TL ... Cyprinidae

19a. Preanal length ≥ 48% TL ... 20

19b. Preanal length < 48% TL ... 27

20a. Preanal length ≥ 56% TL ... 21

20b. Preanal length 48-55% TL ... 23

21a. Preanal myomeres > 26; preanal length 56-58% TL; larvae large, yolk sac present until 7-10 mm TL ... Hiodontidae

21b. Preanal myomeres < 26; preanal length < 56% TL; yolk sac larvae < 7 mm TL ... 22

22a. Preanal myomeres 8-12; postanal myomeres 9-15 ... Moronidae

22b. Preanal myomeres 15-26; postanal myomeres 18-26 ... Percidae

23a. Preanal myomeres ≥ 15 ... Percidae

23b. Preanal myomeres < 15 ... 24

24a. Total myomeres ≤ 26 ... Moronidae

24b. Total myomeres > 26 ... 25

25a. Preanal myomeres 14-16; preanal length > 50% TL ... Gasterosteidae

25b. Preanal myomeres < 14 ... 26

26a. Postanal myomeres < 19; gut massive, uncoiled; pectoral fins proportional ... Centrarchidae

26b. Postanal myomeres $\geq$ 19; large pectoral fins ... 27

27a. Preanal length < 35%; preanal myomeres 6-7; postanal myomeres 28-31 ... Atherinidae

27b. Prenal length > 35% ... 28

28a. Postanal myomeres approx. 40; preanal length 39-44% TL ... Gadidae

28b. Postanal myomeres much less than 40; preanal length 44% TL ... 29

29a. Postanal myomeres $\leq$ 11; posterior oil globule in yolk sac ... Scianidae

29b. Postanal myomeres > 11; oil globule diffuse in yolk sac ... 30

30a. Postanal myomeres > 20; mouth terminal to superior; preanal length > 45% TL ... Fundulidae

30b. Postanal myomeres < 20; mouth subterminal to inferior; preanal length < 45% TL ... Percopsidae

Discussion

The loss of habitat through the accumulation of toxic chemicals in the sediment, reduction of dissolved oxygen, and increase in siltation, is perhaps the greatest obstacle to the protection of environmental quality the environmentalist must face. Degradation by conventional non-point sources of pollution have yet to be addressed, rather efforts have concentrated on point sources. EPA has spent two decades quantifying the effluent quality of point source dischargers. With toxicity endpoints established in industrial and municipal permits, attention must be focused on instream degradation through chronic exposure to ambient residents.

The effort to combine a community approach for addressing these issues has been accomplished in adult fish (Karr 1981; Karr et al. 1986), macroinvertebrates (Plafkin et al. 1989), and now with ichthyoplankton (current study). Karr and colleagues have described in detail the rationale for this overall approach. I refer you to their documentation for further reading rather than repeating their rationale (Karr et al. 1986). I have provided details for the scoring and formation of an ichthyoplankton index using a communtiy based approach.

Table 5. Total Ichthyoplankton Index (I^2) scores, integrity classes and attributes (modified from Karr 1981).

Total I^2 Score (sum of 11 metrics)	Integrity Class	Atttibutes
53-55	Excellent	Comparable to the best situations without human disturbance; all regionally expected taxa for habitat, stream size, and ecoregion, including the most intolerant forms; balanced guild structure and reproduction.
44-48	Good	Species richness somewhat below expectations, especially due to loss of the most intolerant forms; some taxa are present with less than optimal abundances; guild structure indicates signs of some stress.
37-40	Fair	Signs of additional deterioration include loss of intolerant forms, skewed dominance, and guild structure. Reduction in simple lithophils and in mean generation time.
26-31	Poor	Dominated by r-strategists, tolerant forms and pioneer species. Increase in guild A.1, and in deformities or teratogenic fish.
11-20	Very Poor	Few fish present, lack of successful reproduction in any guild, deformed or teratogenicity frequently observed.
	No Fish	Repeated sampling finds no fish.

The need to look at various trophic levels in the analysis of environmental degradation, through biological integrity, is difficult to explore in insects due to taxonomic and limited ecological information. In fishes, ontogenetic shifts during development not only is apparent in morphological changes (Fuiman and Corazza 1979), but also niche shifts (George and Hadley 1979; Brandt 1986). The early life stages of fishes often document the use of habitats by endangered or rare species when the adults can frequently not be found. The protection of these important habitats require further consideration in protection of species diversity.

Although the I^2 is an additional tool which can be concurrently conducted using IBI type techniques, the method may prove useful in both lotic and lenthic habitats. The difficulty in assessing lentic habitats is the inability of species to recolonize closed systems. Field evaluations of both habitat types are necessary prior to further evaluation of the method.

The implications of data quality depends on the calibration of the metrics and collection of a representative sample (Davis and Simon 1988). Every effort should be made to incorporate quality assurance checks into standard operating procedures and data analysis. Further refinement of techniques and interpretation will become apparent with increases in knowledge of a balance aquatic environment especially as recruitment success and early life history stages of fishes are influenced.

Interpretation of the I^2 follows that previously established by the IBI. The use of a three tiered scoring criteria, 5, 3, and 1, are assigned to each metric depending on whether it approximates, deviates somewhat from, or deviates strongly from the value expected at the least impacted ecoregion reference site. The sampling site is then assigned to one of six quality classes based on the sum total of the eleven metric ratings. The highest score, 55, indicates a site without perturbation and deviations decline proportionally. The qualitative ratings and descriptions of Karr (1981) range from excellent to very poor (Table 5). These similar integrity classes and attributes have been appropriately scaled for the I^2 bases on those of Karr et al. (1986).

Finally, although the level of discernment of taxa to a species level would be highly desired, the taxonomic literature is unable to support this level currently. The family level of discernment will reduce confusion among novices using the techniques, provide a high level of reproducability, and subsequently data quality assurance through accuracy. As an increase in the ecological requirements and taxonomic literature become available, a more sensitive analyses will be possible. Stimulation of single species and comparative larval descriptions and species reproductive characterization should receive higher priority among researchers in the field.

Acknowledgements

I extend an enormous amount of gratitude to educators, colleagues and associates who have helped form the ideas and concept foundations. Especially appreciated are R. Wallus, W. Davis, D. Snyder, L. Fuiman, D. Faber, J. Dorr III, D. Jude, T. Poulson, J. Brown, D. Bardack, and L. Holland-Bartels. I appreciate their constructive criticism, free sharing of advise and ideas, and foundation concepts of current ecological thought.

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Appendix A. The diversity of species, $\bar{d}$, characteristic of MacArthur's model for various numbers of hypothetical species, s'*.

s'	$\bar{d}$	s'	$\bar{d}$	s'	$\bar{d}$	s'	$\bar{d}$
1	0.0000	51	5.0941	102	6.0792	205	7.0783
2	0.8113	52	5.1215	104	6.1069	210	7.1128
3	1.2997	53	5.1485	106	6.1341	215	7.1466
4	1.6556	54	5.1749	108	6.1608	220	7.1796
5	1.9374	55	5.2009	110	6.1870	225	7.2118
6	2.1712	56	5.2264	112	6.2128	230	7.2434
7	2.3714	57	5.2515	114	6.2380	235	7.2743
8	2.5465	58	5.2761	116	6.2629	240	7.3045
9	2.7022	59	5.3004	118	6.2873	245	7.3341
10	2.8425	60	5.3242	120	6.3113	250	7.3631
11	2.9701	61	5.3476	122	6.3350	255	7.3915
12	3.0872	62	5.3707	124	6.3582	260	7.4194
13	3.1954	63	5.3934	126	6.3811	265	7.4468
14	3.2960	64	5.4157	128	6.4036	270	7.4736
15	3.3899	65	5.4378	130	6.4258	275	7.5000
16	3.4780	66	5.4594	132	6.4476	280	7.5259
17	3.5611	67	5.4808	134	6.4691	285	7.5513
18	3.6395	68	5.5018	136	6.4903	290	7.5763
19	3.7139	69	5.5226	138	6.5112	295	7.[illegible]08
20	3.7846	70	5.5430	140	6.5318	300	7.6250
21	3.8520	71	5.5632	142	6.5521	310	7.6721
22	3.9163	72	5.5830	144	6.5721	320	7.7177
23	3.9779	73	5.6027	146	6.5919	330	7.7620
24	4.0369	74	5.6220	148	6.6114	340	7.8049
25	4.0937	75	5.6411	150	6.6306	350	7.8465
26	4.1482	76	5.6599	152	6.6495	360	7.8870
27	4.2008	77	5.6785	154	6.6683	370	7.9264
28	4.2515	78	5.6969	156	6.6867	380	7.9648
29	4.3004	79	5.7150	158	6.7050	390	8.0022
30	4.3478	80	5.7329	160	6.7230	400	8.0386
31	4.3936	81	5.7506	162	6.7406	410	8.0741
32	4.4381	82	5.7681	164	6.758-	420	8.1087
33	4.4812	83	5.7853	166	6.7757	430	8.1426
34	4.5230	84	5.8024	168	6.7929	440	8.1757
35	4.5637	85	5.8192	170	6.8099	450	8.2080
36	4.6032	86	5.8359	172	6.8266	460	8.2396
37	4.6417	87	5.8524	174	6.8432	470	8.2706
38	4.6792	88	5.8687	176	6.8596	480	8.3009
39	4.7157	89	5.8848	178	6.8758	490	8.3305
40	4.7513	90	5.9007	180	6.8918	500	8.3596
41	4.7861	91	5.9164	182	6.9076	550	8.4968
42	4.8200	92	5.9320	184	6.9233	600	8.6220
43	4.8532	93	5.9474	186	6.9388	650	8.7373
44	4.8856	94	5.9627	188	6.9541	700	8.8440
45	4.9173	95	5.9778	190	6.9693	750	8.9434
46	4.9483	96	5.9927	192	6.9843	800	9.0363
47	4.9787	97	6.0075	194	6.9992	850	9.1236
48	5.0084	98	6.0221	196	7.0139	900	9.2060
49	5.0375	99	6.0366	198	7.0284	950	9.2839
50	5.0661	100	6.0510	200	7.0429	1000	9.3578

*The data in this table are reproduced, with permission, from Lloyd and Ghelardi, Reference 33.

	Number of individuals in each taxa (n_i's)	$n_i \log_{10} n_i$ (from Table 5)
	41	66.1241
	5	3.4949
	18	22.5949
	3	1.4314
	1	.0000
	22	29.5333
	1	.0000
	2	.6021
	12	12.9502
	4	2.4082
Total	109	139.1391

Total number of taxa, s = 10

Total number of individuals, N = 109

$N \log_{10} N$ = 222.0795 (from Table 5)

$\Sigma\, n_i \log_{10} n_i$ = 139.1391

$= \frac{3.321928}{109}(222.0795 - 139.1391)$

= 0.030476 × 82.9404

= 2 5

Ecological Assessment At The EPA: Superfund Guidance and EPA'S Ecological Risk Assessment Guidelines

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Abstract

A revised National Oil and Hazardous Substances Pollution Contingency Plan (NCP) has been proposed, which governs the implementation of the amended Superfund law. The proposed NCP, states that CERCLA remedies will "be protective of environmental organisms and ecosystems." A revised Hazard Ranking System will allow prioritization of cleanups based on ecological concerns to a greater extent. However, regardless of whether a site is listed for ecological problems, EPA intends that baseline ecological evaluations occur during Remedial Investigations/Feasibility Studies (RI/FS) when appropriate, and that site managers choose environmentally sound remedies. Superfund's new Environmental Evaluation Manual was developed to supplement revised RI/FS guidance, and to clarify the information needs of a baseline ecological assessment. Using the Biological Technical Assistance Group model, the manual provides a science policy framework for the ecological evaluation, which Regions can tailor to their specific operating needs.

EPA is also working towards developing Agency-wide guidelines for ecological risk assessment. The Ecotoxicity Subcommittee of the Risk Assessment Council has developed the scientific rationale for supporting a general ecological assessment guideline.

Keywords: Hazardous Waste, Ecology, Risk Assessment, CERCLA, Guidelines, Superfund.

Superfund's Framework

The Comprehensive Environmental Response Compensation and Liability Act (CERCLA) of 1980, provided a framework for cleaning up uncontrolled hazardous waste sites, and a funding mechanism (Superfund) for ensuring cleanups are performed. It also imposed liabilities on responsible parties and provided for claims for damages to natural resources. The Superfund Amendments and Reauthorization Act (SARA) of 1986 reauthorized CERCLA for five years, greatly increased the funding authority of the program and strengthened EPA's enforcement role. SARA also imposed many ambitious goals for cleanup schedules and standards.

The National Contingency Plan (NCP), the major framework regulation for Superfund, includes procedures and standards for how EPA, other Federal agencies, States, and private parties respond under CERCLA to releases of oil and hazardous substances. Initially issued under the Clean Water Act, it was revised under CERCLA in 1985.

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SARA required EPA to propose additional revisions to the NCP. Under the proposed 1988 revisions, removal program authorities are expanded (more money and greater work efforts can be used to remove immediate hazards). Also proposed are substantial changes in the remedial program, which include adjusting the range of cleanup options to focus more on treatment technologies. Early action and streamlining of remedial activities are also encouraged, and the use of specified criteria for evaluating and selecting remedies is described. While the emphasis will continue to be on protecting public health, Superfund remedies "will also be protective of environmental organisms and ecosystems" (USEPA 1988a).

Hazardous waste sites qualify for remedial actions by inclusion on the National Priorities List (NPL). However, they must first be evaluated by a series of progressively detailed assessments. The hazardous sites are eventually scored by the Hazard Ranking System (HRS), with a score of 28.5 required to be listed on the NPL. The inclusion of ecological factors in the current HRS score is limited to scoring the distance from a site to the nearest "sensitive" environment. This score is but part of the "summary" surface water and air migration score.

The Agency has proposed revisions to the HRS (USEPA 1988b). The new HRS will expand the list of sensitive environments and incorporate scores that reflect contaminant levels in wastes and surface waters relative to Federal Ambient Water Quality Criteria (AWQC) and other toxicity values for aquatic species. The larger summary scores will include an "environmental threat" sub-pathway in the surface water migration pathway, and a new "on-site exposure" pathway that includes the "sensitive environments" component.

In fall of 1988 EPA issued "interim final" guidance for performing a Remedial Investigation/ Feasibility Study (RI/FS) at a CERCLA site (USEPA 1988c). The RI/FS process is an iterative one, and is used to characterize the risks posed by the site, and to investigate alternative remedies and technologies should remedial action be necessary. The RI/FS guidance clarifies the information requirements for a "baseline" ecological assessment at a CERCLA site.

Natural Resource Trustees and Ecological Assessment

It is important to distinguish between "ecological evaluation" (ecological assessment) and "natural resource damage assessment", which is an important activity under the Superfund law. The terms "natural resource damage claim", "natural resource damage assessment", "preliminary natural resource surveys", or other such activities carried on by or for natural resource trustees, are not equivalent to, nor can they substitute for, a baseline ecological evaluation which may be required to be conducted as part of an RI/FS. The former are trustee activities performed outside of EPA's purview, and may relate to claims for monetary compensation due for injury to designated natural resources for which trustees have management responsibility. The latter is an exercise within EPA's authority and is essentially a evaluation of the receptor environmental organisms or populations, and the abiotic components of ecosystems, regardless of their status as "trust resources" (USEPA 1989a). However, data obtained through an environmental evaluation will, in all likelihood, be useful to natural resource trustees seeking to assess potential or actual injury to their trust resources.

Ecological Risk Assessment at CERCLA Sites

The development of ecological assessment guidance in Superfund has benefitted from the availability of testing protocols such as those for short-term bioassessment (Porcella 1983), and from descriptions of the role such data may play at hazardous waste sites (Athey et al. 1987).

Generally, the CERCLA risk assessment process is comprised of four components: contaminant identification; exposure assessment; toxicity assessment; and risk characterization. Acute and chronic toxicity, including mortality and reproductive effects, as well as bioaccumulation, teratogenesis and mutagenesis, are some examples of endpoints used in ecological assessments of Superfund sites.

Until the interim final RI/FS guidance was issued, many ecotoxicological assessments at CERCLA sites were not undertaken until after the contaminant identification/exposure assessment phase of the (RI/FS). Supplemental ecological assessment guidance (USEPA 1989a) was developed to assist remedial project managers (RPMs) to better implement the ecological baseline studies potentially required for an RI/FS. The guidance is also intended to help on-scene-coordinators (OSC) manage ecological concerns arising during a removal action.

The Environmental Evaluation Manual provides a science policy framework for managing the ecological effects portions of the RI/FS. From an ecotoxicological perspective, perhaps its most important mandate is that ecological factors are to be considered "up front" in the assessment process. This means that starting with the project scoping and work plan development phases, RPMs should be aware that specific ecological information may be needed for the baseline risk assessment, and that a tiered approach to determining the appropriate level of effort for a particular site is recommended to avoid unnecessary expenditures of time and money (not all sites will require the same assessment effort).

The information requirements will also help RPMs do a better job of selecting environmentally sound remedies. To this end the guidance recognizes the importance of the advisory role of EPA Regional Biological Technical Assistance Groups (BTAGs) for hazardous waste site assessment. The guidance specifies that decision-making and managerial control of the overall project is retained by the RPM. BTAGs exist in many, if not all EPA Regions. RPMs and OSCs can draw in the ecological expertise of the BTAG, when in need of technical advice on work plan development, data quality objectives, or project status review.

Some BTAGs include members from other government agencies with environmental assessment interests at Superfund sites, e.g., the U.S. Fish and Wildlife Service, the National Oceanic and Atmospheric Administration (NOAA) and state natural resource agencies. BTAGs, however, are directed by EPA Regional personnel, who determine the rules for membership, organization and operation of their groups. Moreover, neither the EPA site managers nor the Natural Resource Trustees should rely on participation in a BTAG to create any immunity or fulfill any legal obligation on the part of the trustee agency or the EPA. Applicable legal and procedural responsibilities for natural resource matters remain in force and are probably not fulfilled by virtue of participation of a trustee on a BTAG. The sole purpose of a BTAG, according to EPA guidance, is to provide technical advice to the RPM and OSC, if they choose to seek such advice.

Test methods and protocol references can be found in a new compendium of ecotoxicological methods published by EPA's Office of Research and Development (USEPA 1989b). It is intended as a companion volume to the Superfund ecological assessment guidance, and it outlines specific laboratory and field tests which can be used during ecological investigations of CERCLA and RCRA sites.

EPA Agency-wide Ecological Assessment Guidelines

In the fall of 1987, in response to the EPA's increased efforts to control the ecological effects of certain pesticides and other toxic hazards, EPA's management charged a group of senior level ecologists from EPA headquarters, laboratories, and Regional offices with developing guidelines for selecting ecological endpoints, and methods to assess ecological risk.

This group, known as the "Ecotoxicity Subcommittee" of the Risk Assessment Council, prepared fifteen case studies, including two CERCLA cases, that demonstrated the diversity of EPA's ecological assessment activities, showing they often entailed retrospective assessment of impacts, rather than predictions of risks.

The subcommittee then developed a risk assessment framework, which is a modification of that proposed by the National Academy of Sciences (NAS 1983) and adopted by EPA for its human health risk assessments. The ecological framework is based on levels of organization from an individual organism to an entire ecosystem. The framework can be used both for "top-down" assessments based on field studies and "bottom-up" assessments based on laboratory bioassays (Bascietto et al. 1989).

The components of ecological risk assessment are very similar to those for human health: hazard identification,exposure assessment, and characterization of risk. However, unlike human assessment, many different organisms may be at risk. Therefore, the receptors must be identified and their response to the hazard or stress determined. Delineating the individual organism's response, however, will not be sufficient in this new framework. There are questions of population effects as well as effects on communities, and entire ecosystems to be answered. This adds greatly to the complexity and difficulty of performing ecological assessments, but is also its challenge.

By 1990, the Ecotoxicity Subcommittee plans to have drafted guidelines for ecological assessments in aquatic populations and communities, and for terrestrial populations.

Acknowledgments

I am indebted to Dr. A. Dexter Hinckley, who contributed substantially to this report. Dr. Dave Charters, Dr. Michael Dover, Pat Mundy, and H. Ron Preston deserve no small measure of appreciation for their work in developing the Environmental Evaluation Manual. The BTAG model exists because of the efforts of Dr. Alyce Fritz, NOAA's Coastal Resource Coordinator in EPA's Philadelphia, PA regional office.

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Discrimination of Sediment Toxicity in Freshwater Harbors Using a Multitrophic Level Test Battery

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Abstract

Sediments were collected from Waukegan and Indiana Harbours in Lake Michigan as part of a multi-laboratory study of sediment toxicity. These sites were known to be contaminated with elevated levels of synthetic organics and metals. Sediments were tested in solid phase and/or elutriate phase with 48 h exposures using the following organisms: Daphnia magna, Ceriodaphnia dubia, Hyalella azteca, and Selenastrum capricornutum. In addition, microbial dehydrogenase, alkaline phosphatase, ■-galactosidase, and ■-glucosidase activities were determined on both phases. Waukegan sediments showed toxicity increased in sediments nearer to an industrial source of PCB contamination. Macrofaunal species sensitivity was as follows: cladocerans > algae > amphipod. Solid phase and elutriate exposure toxicity were not significantly different, generally, for the cladocerans but were with H. azteca. Microbial activity results did not reveal any clear trends; however, the three Waukegan sediments exhibited contamination response relationships. This approach proved beneficial in detecting areas where bioavailable toxicants are located at acute levels, thereby aiding chemical data interpretation and remediation studies.

Introduction

Toxicant impact assessments of ecosystems must address multiple levels of ecosystems to ensure detection of the toxicant(s) target site(s). Possible sites where toxicant concentration or impacts may occur include water, soil, sediment, pore water, or plant and animal tissue, thereby affecting key metabolic processes and/or biogeochemical cycles. It is apparent that no one single species toxicant assay can be used to detect ecosystem impacts due to the varying target sites and factors which influence sensitivity. Thus, the dilemma exists as to which and how many assays should be used to evaluate impacts.

Several approaches have been recommended for evaluating sediment quality (USEPA 1987). Recommended approaches have included Equilibrium Partitioning (USEPA 1987), Apparent Effects Threshold (USEPA 1987), the Sediment Quality triad (Chapman 1986), Screening Level Concentration (Neff et al. 1987), and laboratory sediment toxicity tests (USEPA and US Army Corps of Engineers 1977). In some cases these latter approaches (all of which include a biological component) may yield similar sediment quality assessments (Chapman 1986) and are superior to previous chemically-oriented approaches.

Most sediment toxicity testing has consisted primarily of single species testing using Chironomus sp. (Nebeker et al. 1984; Giesy et al. 1988; Williams et al. 1986), *Hexagenia* sp. (Nebeker et al. 1984; Malueg et al. 1984), *Hyalella azteca* (Nebeker et al. 1984; Nebeker and Miller 1988), *Gammarus pulex* (Nebeker et al. 1984; Cairns et al. 1984), *Daphnia magna* (Nebeker et al. 1984; Giesy et al. 1988; Cairns et al. 1984), or Microtox (Giesy et al. 1988). Indigenous community assays have been used in a limited number of sediment toxicity effect studies and included phytoplankton (Munawar and Munawar 1987) and microbial assemblages (Burton 1988).

The present study (Burton et al. 1989) investigated the ability of several different toxicity tests, comprising multiple trophic levels, to detect sediment contamination at 2 sites where historical data existed, documenting high levels of sediment concentrations of PAH's, metals, and/or polychlorinated biphenyls (PCB's). This study was part of a larger, interlaboratory, collaborative study, coordinated by the Illinois Natural History Survey (INHS).

Methods

One of the two test sites was Waukegan Harbor, located on the western shore of Lake Michigan approximately 30 miles north of Chicago. The harbor is 0.9 miles long and the shores are lined with commercial and industrial facilities, discharging approximately $0.25 \times 10^3 m^3$ effluent per day, including runoff. The harbor sediments are heavily contaminated with PCB's and PAH's. Samples were collected from Stations A, B, and C. Station A is located nearest to the historical PCB discharge and C is the furthest away, but within the harbor.

The second test site was the Indiana Harbor Canal in Gary, Indiana. Sediments were contaminated primarily with PAH's and metals (USEPA 1985a). The Indiana Harbor Canal is located south of Chicago, Illinois and northwest of Gary, Indiana on the shore of Lake Michigan. The waterway serves as a shipping canal for industries located in the area. In past years, the harbor canal functioned as a sediment trap for suspended particles carried in from the Lake George and Grand Calumet River branches toward Lake Michigan. Currently, the Indiana Harbor Canal and Grand Calumet River drain a highly industrialized watershed basin into Lake Michigan when water levels are normal. Thirty-nine permitted outfalls drain into the waterway, adding treated municipal and industrial wastewater, industrial cooling water, sewage, and run-off to the canal. Due to the lack of project maintenance by periodic dredging, particulate transport from these sources of contamination has significantly decreased the depth of the channel (1.8-2.4 m). The reference sediment was collected from Homer Lake, a small recreational lake in the agricultural region of central Illinois.

Sediment samples were collected by Ponar dredge on November 16, 1987. Sediments were placed in acid-washed, methanol-rinsed, polyethylene containers and returned to the INHS on ice. Sediments were thoroughly mixed in the laboratory, subsamples withdrawn and placed on ice for transport to Wright State University. Toxicity testing was begun within 48 h of initial collection, and completed within 96 h.

Sediments were placed in test chambers from a container of source material that was being continuously stirred. Elutriate samples were prepared by shaking a 1:4 mixture of sediment and reconstituted hardwater (USEPA 1985b) for 30 minutes on a shaker, followed by centrifugation for 15 min (16,319 x g). The supernatant was then distributed to the test beakers. Elutriates used for the algal assay were filtered, after centrifugation, through a 0.45 Millipore filter.

Treatments were conducted in triplicate and consisted of: reconstituted water control; Homer Lake reference (whole sediment and elutriate); Waukegan Harbor stations A, B, and C (whole sediment and elutriate); and Indiana Harbor stations D and E (whole sediment and elutriate). A 30 ml sample was placed in each test beaker (250 ml) and 120 ml of reconstituted water added carefully so as not to resuspend sediments. Test systems were maintained at 25°C ± 1°.

Water quality measurements of dissolved oxygen, temperature, pH, alkalinity, and hardness (American Public Health Association et al. 1985) were monitored during the assays. No aeration was required during the 48 h test period. Sediment dry weight was determined in quadruplicate, after drying at 105°C for 24 hs and particle size was measured using the hydrometer method (Day 1956). Metal and organic toxicant analyses methods (USEPA 1979) and were conducted by INHS, Wright State University (WSU) and the U.S. Fish and Wildlife Service (USFWS) at Columbia, MO (USEPA 1979). Organic analyses consisted of GC-MS scans for polynuclear aromatic hydrocarbons (PAH) and polychlorinated biphenyls (PCB) (USEPA 1979; Tiernan 1985).

Daphnia magna and Ceriodaphnia dubia neonates (less than 24 h old) were used for toxicity testing. Ten C. dubia and 10 D. magna neonates were randomly distributed to 250 ml test beakers (20 neonates per beaker, 3 beakers per test sediment).

Hyalella azteca juveniles were provided by the USFWS (Columbia, MO). H. azteca were randomly distributed to triplicate 250 ml test beakers (10 juveniles per beaker).

S. capricornutum cultures were maintained following standard methods (USEPA 1985c). Tests were not conducted on whole sediments. Elutriates were tested (100 ml) in triplicate 250 ml Erlenmeyer flasks by adding 1.0×10^6 algal cells and 0.1 ml of each standard nutrient solution (except EDTA) per 100 ml of elutriate. Algal cells were enumerated at 48 h using a particle size counter (Coulter Model ZF).

Enzymatic activity was determined using previously described methods (Burton and Lanza 1985). Assays consisted of: 1) electron transport system activity (ETS) (or dehydrogenase activity) using the tetrazolium salt substrate, 2-iodophenyl-3-phenyl-5-nitrophenyl tetrazolium chloride (INT) and basic method of Jones and Simon (1979); 2) alkaline phosphatase activity (APA) using the substrate p-nitrophenyl phosphate (Sigma Chemical Co.) and method of Sayler et al. (1979); 3) ■-galactosidase activity (GAL) using the substrate p-nitrophenyl-■-D-galactoside (24); 4) ■-glucosidase activity (GLU) using the substrate p-nitrophenyl-■-D-glucoside. Samples were homogenized and subsampled in triplicate. Briefly, enzyme activity was measured as follows. Approximately 1 to 2 ml of test water or cold homogenized sediment was placed in triplicate test tubes containing buffer. Enzyme substrate, for example, p-nitrophenyl-■-D-glucoside, was added to the tubes, vortexed, and incubated in the dark at 25°C for 30 min to 2 h. Activity was terminated by placing the tubes on ice and adding 1 to 2 ml acetone, vortexing, and centrifuging (4424 X g) for 10 min. The colored reaction product in the supernatant is then measured spectrophoto-metrically. Substrate was added after activity termination for control tests. Controls consisted of test mixtures without the enzyme substrate and also with substrate acetone, and test mixtures. Absorbance was converted to g of product formed using a standard curve and activity defined as product formed per milliliter of water (or gram dry weight of sediment) per incubation time.

Percent survival, growth or activity and standard deviations were calculated on each treatment as compared to controls and the Homer Lake reference sample. Response differences between stations were calculated using Dunnett's procedure (Zar 1974), with an EPA DUNNETT program, written in IBM-PC FORTRAN. Statistically significant differences were determined with a Bonferroni adjustment which was incorporated into the program. Station profile toxicity response patterns were compared by Pearson correlation analyses for significant relationships using the Statistical Analysis System (SAS) version 5.18 (PROC CORR).

Results

Chemical analyses confirmed extensive contamination existed at the Waukegan and Indiana Harbor sites with extremely elevated PCB sediment concentrations (85 to 150 mg/kg dry wt) at Waukegan Station A and a decreasing concentration gradient towards Station C. The same pattern was seen with PAH scans. Indiana Harbor Site D had greater levels of metals (Cd, Cr, Zn) than did Site E, however, Site E had substantially more PAH contamination than Site D.

Results of macrofaunal 48 h exposure to whole sediments and elutriates are presented in Tables 1 and 2, respectively. Control survival was good in all test treatments. H. azteca was the least sensitive organism with no response to elutriates and marginal toxicity (70-93.3% survival) observed at four of five test sites. Indiana Site D was the most toxic sediment to H. azteca, however, differences between sites were not significant.

Waukegan Site A was acutely toxic to D. magna in whole sediment and elutriate phase exposures, with 0 to 3.3% survival, respectively. Site B was also toxic (43.3% survival), but only in whole sediment systems. Indiana E produced slight effects in elutriate tests.

C. dubia also was acutely affected at Waukegan A with no survival at 48 h, however, no significant effect was observed at Site B. In contrast to D. magna, C. dubia showed high toxicity to Indiana Harbor sediments (0-1% survival), and to a greater extent in whole sediment exposures than the elutriate phase (53.3 and 76.7% survival). D. magna and C. dubia responses were similar when comparing all test data in whole sediment ($r=0.93$, $p<0.006$) and elutriate phase exposures ($r=0.95$, $p<0.004$).

S. capricornutum exhibited both inhibitory and stimulatory growth responses when exposed to test elutriates. The most inhibitory (61.2% growth as compared to control growth of 100%) sediment was Waukegan A, as noted with the cladoceran responses. Sediment elutriates from Indiana E were also inhibitory (69.1% growth) when compared to the control treatment cell numbers. Indiana D and Waukegan C, however, increased growth rates of S. capricornutum (145.8 and 122.9%, respectively).

Table 1. Survival of macrofaunal surrogates exposed to whole sediments for 48 h.[a]

Sample	*H. azteca*	*D. magna*	*C. dubia*
Control	100.0 (0)[b]	96.7 (5.8)	90 (10)
Homer	100.0 (0)	96.7 (5.8)	100 (0)
Waukegan A	93.3 (11.5)	0 (0)	0 (0)
Waukegan B	100.0 (0)	43.3 (15.3)	90 (10)
Waukegan C	73.3 (23.1)	90.0 (17.3)	100 (0)
Indiana D	70.0 (26.5)	96.7 (20.0)	0 (0)
Indiana E	80.0 (17.3)	96.7 (5.8)	1 (1)

a Percent survival compared to control.
b Standard deviation. N = 3.

Table 2. Survival or growth of macrofaunal surrogates exposed to elutriates for 48 h.

Sample	*H. azteca*[a]	*D. magna*[a]	*C. dubia*[a]	*S. capricornutum*[b]
Control	100 (0)[c]	100.0 (0)	100.0 (0)	100.0 (6.7)
Homer	100 (0)	93.3 (5.8)	100.0 (0)	80.2 (7.6)
Waukegan A	100 (0)	3.3 (2.9)	0.0 (0)	61.2 (4.5)
Waukegan B	100 (0)	100.0 (0)	86.7 (23.1)	93.9 (20.1)
Waukegan C	100 (0)	100.0 (0)	96.7 (5.8)	122.9 (24.4)
Indiana D	100 (0)	93.3 (5.8)	76.7 (5.8)	145.8 (4.1)
Indiana E	100 (0)	80.0 (10)	53.3 (28.9)	69.1 (13.3)

a Percent survival compared to control sample
b Percent growth compared to control sample
c Standard deviation. N = 3.

Microbial activities in whole sediment and elutriate phase exposures are presented in Tables 3 and 4, respectively. As with the algal test, both stimulatory and inhibitory responses were observed. Since these assays were of indigenous activity, effects were compared to Homer Lake activities. The ETS assay revealed slight stimulatory effects in whole sediments when comparing responses to the Homer Lake reference. Greatest activity occurred in Waukegan A, followed by Waukegan B sediments, with a graded decrease through Site E. APA also showed highest activity rates in Waukegan A tests, with significant inhibition in the Indiana D and E whole sediment assays (15 and 9% of Homer, respectively). This pattern was not seen in elutriate responses, however, inhibition did occur at all test sites. The GAL whole sediment assay revealed greatest extra-cellular activity levels from Waukegan A and lowest activities in Indiana D and E (26% of Homer). Depressed activity was reversed to

Table 3. Indigenous microbial activity in whole sediments.[a]

Sample	ETS	APA	GAL	GLU
Recon[b]	2.5 (1.0)[c]	46.9 (8.2)	6.0 (0.6)	5.8 (0.8)
Homer[b]	3.3 (0.3)	143.5 (36.8)	13.1 (0.2)	22.2 (2.7)
Waukegan A	4.2 (0.1)	337.1 (42.5)	45.7 (1.2)	168.0 (18.2)
Waukegan B	3.8 (0.2)	105.5 (9.9)	10.5 (1.6)	12.7 (1.3)
Waukegan C	3.4 (0.1)	141.5 (19.2)	24.8 (9.4)	42.1 (5.5)
Indiana D	3.3 (0.1)	21.8 (0.9)	3.4 (0.7)	5.3 (0.6)
Indiana E	2.9 (0.1)	12.5 (2.9)	3.4 (0.5)	6.4 (2.0)

[a] ETS, electron transport system; APA, alkaline phosphatase; GAL, ■-galactosidase; GLU, ■-glucosidase activities. Activity as g product/g dry wt sediment/unit time.
[b] Recon = reconstituted hard water; Homer = Homer Lake sediment
[c] Standard deviation. N = 3.

Table 4. Indigenous microbial activity in elutriates.[a]

Sample	ETS	APA	GAL	GLU
Recon[b]	2.40 (.44)[c]	0.83 (.03)	2.50 (0)	0.42 (.12)
Homer[b]	2.72 (.48)	2.62 (.03)	1.08 (.20)	0.60 (.05)
Waukegan A	2.73 (.24)	1.53 (.08)	3.93 (.88)	0.98 (.10)
Waukegan B	2.87 (.36)	0.95 (.13)	1.48 (.66)	0.43 (.10)
Waukegan C	2.95 (.36)	9.28 (.94)	2.25 (.30)	3.00 (.85)
Indiana D	2.68 (.13)	1.22 (.04)	4.43 (1.12)	2.63 (.94)
Indiana E	2.82 (.49)	1.38 (.32)	2.53 (.12)	2.55 (.74)

[a] ETS, electron transport system; APA, alkaline phosphatase; GAL, ■-galactosidase; GLU, ■-glucosidase activities. Activity as g product/ml elutriate/unit time.
[b] Recon = reconstituted hard water; Homer = Homer Lake sediment
[c] Standard deviation. N = 3.

elevated activity in Indiana elutriate exposures; a response also observed with the GLU assays. As in the other enzymatic assays, whole sediments from Waukegan A had the greatest activity levels and Indiana sediments the lowest (24 and 29% of Homer).

Significance of the toxic response of the 5 test sediments, compared with Home Lake reference and reconstituted hard water controls, were determined using Dunnetts Procedure (Tables 5-7). In macrofaunal tests, there were no differences in response patterns in whole sediments when using reconstituted hard water or Homer Lake as the statistical control; however, some pattern differences between station responses were noted in elutriate controls (Table 5).

D. magna toxicity at Waukegan A and B was statistically significant, while *C. dubia* showed sediments at Waukegan A, Indiana D and E to be toxic when compared to control and reference tests. This latter pattern

Table 5. Significant macrofaunal responses from sediment exposures.

Assay	Reference	Phase[a]	Station Differences[b]
H. azteca	Recon[c]	S,E	none
	Homer[c]	S,E	none
D. magna	Recon	S	A,B
	Homer	S	A,B
		E	A
C. dubia	Recon	S	A,D,E
	Homer	S	A,D,E
S. capricornutum	Recon	E	A,D+[d],E
	Homer	E	C,D

[a] S, whole sediment phase; E, elutriate phase
[b] Statistically significant difference between reference and test sediment, with Bonferroni adjustment.
A,B,C = Waukegan stations; D,E = Indiana Harbor stations
[c] Recon = reconstituted hard water; Homer = Homer Lake sediment
[d] + = elevated response

Table 6. Significant microbial responses from sediment exposures

Assay[a]	Reference	Phase[b]	Station Differences[c]
APA	Abiotic	S	A+,B+,C+, Homer+[d]
		E	C+, Homer+
	Homer	S	A+
		E	A,B,C+,D,E
ETS	Abiotic	S	A+,B+,C+
	Homer	S	A+,B+
GAL	Abiotic	S	A+,C+
	Homer	S	A+
GLU	Abiotic	S	A+,B+,Homer+
		E	C+,D+,E+
	Homer	S	A+,B,C+,D,E
		E	A+,B,C+,D+,E+

[a] APA, alkaline phosphatase; ETS, electron transport system;
GAL, ■-galactosidase; GLU, ■-glucosidase activities
[b] S, whole sediment phase; E, elutriate phase
[c] Statistically significant difference between reference and test sediment, with Bonferroni adjustment.
A,B,C = Waukegan stations; D,E = Indiana Harbor stations
[d] + = elevated response

Table 7. Number of significant test responses for sediments tested with 8 assays

Station	Solid	Elutriate	Solid	Elutriate	Solid	Elutriate
Waukegan A	3	3	4	3	7	6
Waukegan B	1	0	4	2	5	2
Waukegan C	0	1	3	2	3	3
Indiana D	1	1	1	3	2	4
Indiana E	1	1	1	3	2	4
TOTAL	6	6	13	13	19	19

[a] Total of 8 assay types. Differences are statistically significant with Bonferroni adjustment.

was also seen with *S. capricornutum* when using a control comparison.

The microbial APA, ETS, and GAL whole sediment responses were similar to macrofaunal assay responses, in that they showed Waukegan A, or A and B were significantly different from the Homer Lake reference (Table 6). The APA and GLU responses, however, detected differences between all test sites (A-E) when compared to Homer Lake elutriates.

Both similarities and differences in sediment toxicity responses were observed with the test battery. Waukegan Harbor Site A was toxic to 7 of 8 assay systems (Table 7). A greater number of station differences were detected using the indigenous microbial assays than the macrofaunal assays. Differences between Waukegan A, B and C were observed with microbial and *D. magna* responses; however, their pattern differed. Indiana D and E whole sediment toxicities were not significantly different in most cases.

Discussion

Numerous investigators have emphasized the importance of using multiple toxicity tests in evaluations of pollutants in aquatic ecosystems (Birge et al. 1986; Burton and Stemmer 1988; Cairns 1980; LeBlanc 1984). A battery of tests is preferred because species sensitivity to toxicants varies due to differing modes of action and metabolic processes. In addition, ecosystem sensitivity is influenced by a myriad of factors, such as indigenous species sensitivity, physicochemical alteration of toxicity (due to natural or anthropogenic factors), seasonal effects, and food web interactions. There has also been concern over the validity and effectiveness of using single species surrogates, e.g., *Daphnia magna*, *Pimephales promelas*, rather than resident species or multispecies tests in evaluations of aquatic ecosystem impacts (Cairns 1985). Both approaches have been effectively used to document the presence or absence of toxicity, however, the complex nature of ecosystem structure and function relationships has impeded thorough validation of these and other assessment methodologies.

Species sensitivity varies with test sites and contaminant type. Algae and daphnids were the most sensitive test species at hazardous waste sites contaminated with metals and insecticides, followed by Microtox■, oxygen depletion rate, seed germination, and earthworm toxicity assay responses (Miller et al. 1985). In other studies, indigenous microbial activities proved to be more sensitive indicators of stream degradation due to metals or polynuclear aromatic hydrocarbons than was D. magna, C. dubia, P. promelas and/or S. capricornutum (Burton and Stemmer 1988;Burton 1989). In calcareous sediments, cadmium levels of 400 mg/l were unavailable and not toxic to D. magna but were toxic (LOEL 6.2-12.5 mg/l) to indigenous microbial activity (Stemmer 1988). Effluent toxicity evaluations showed C. dubia to be the most sensitive test species, in most cases, when compared to D. magna, H. azteca, or S. capricornutum in 48 h exposures. In some studies, however, no cladoceran toxicity was observed while algal growth was significantly inhibited (Stemmer 1988). Other investigations revealed Microtox as the most sensitive indicator of sediment toxicity (Giesy et al. 1988). It is appropriate, therefore, that a test battery be used which is comprised of multiple assays, representing different trophic levels and levels of organization, i.e., single species and multispecies. In the future it may be possible to form some generalities and select a reduced number of test assays for evaluations of particular types of toxic contaminants in particular types of ecosystems.

Our results confirmed the premise that multiple test assays are necessary to both detect sediment toxicity and differentiate degrees of toxicity. Bulk sediment chemical analyses revealed extreme contamination in Waukegan and Indiana Harbors, consisting of a complex mixture of PCB's, PAH's and/or metals. Waukegan A was contaminated to the greatest degree and produced the greatest response in 7 of 8 assays (lethality or stimulated activity). A similarity in the response patterns would be expected at such a highly contaminated site. When using macrofaunal surrogates, Waukegan B toxicity was only detected by D. magna (whole sediment) and Waukegan C elutriates only produced effects with S. capricornutum. Indiana Harbor sediment toxicity to macrofaunal surrogates existed in C. dubia whole sediment assays and with S. capricornutum, but not D. magna or H. azteca. The H. azteca 48 h exposure period appears to be inadequate to detect toxicity. Another portion of this interlaboratory study measured H. azteca lethality and growth effects at 10, 20, and 30 day periods, and recorded acute and chronic toxicity in the test sediments (Ingersoll et al. 1988), while we observed no lethality at 48 h.

Microbial activity tests responses were similar to some of the macrofaunal responses, in that Waukegan A and B were significantly different from the Homer Lake reference. Indiana Harbor sediment effects were observed with APA and GLU. The measurement of these two hydrolases showed that all 5 test sites were significantly different from the reference sediment elutriate.

Stimulatory and inhibitory effects were observed in S. capricornutum and indigenous microbial activity responses. Stimulatory effects can be attributed to nutrients, adapted microbial communities, the Arndt-Schultz phenomenon, and/or feedback mechanism disruption (Lamanna and

Mallette 1953; Pratt et al. 1988) whereby low levels of toxicants increase metabolic processes (Savoure 1984). This latter possibility has been reported elsewhere in aquatic impact evaluations (Burton et al. 1987; Baker and Griffiths 1984). Pratt et al. (1988) suggested that elevated structure and function responses were initial stress indicators which probably reflected a disruption of normal feedback mechanisms controlling nutrient dynamics and species interactions. Monitoring microbial responses has been recommended as an early warning indicator of ecosystem stress (Baker and Griffiths 1984; Odum 1985) and as a means of establishing toxicant criteria for terrestrial and aquatic ecosystems (Babich and Stotzky 1983). Resulting changes at the species level should be accompanied by changes in respiration and/or decomposition rates (Odum 1985). The usefulness of monitoring the microbial community is due, in part, to its ability to respond so quickly to environmental conditions, e.g., toxicant exposure, and the major role they play in ecosystem biogeochemical cycling processes and the food web (Griffiths 1983; Griffiths et al. 1982; Porter et al. 1987). Stimulation or inhibition of activity may also result when carbon or nutrient substrates are altered (Griffiths et al. 1982; Porter et al. 1987), so that one enzyme system e.g., APA, is stimulated while another, e.g., GAL, is inhibited. When macro- and meiobenthic invertebrate and protozoan cropping of bacteria is removed, such as may occur in contaminated sediments, the sediments serve as a carbon sink (Porter et al. 1987). Therefore, organic carbon and nutrients necessary for secondary productivity will be unavailable and impacts to the remainder of the food chain are likely (Porter et al. 1987). When comparing test samples with reference samples, inhibitory <u>and</u> stimulatory effects should be regarded as a perturbation.

In the current study responses varied between solid and elutriate phases. The cladocerans were more sensitive to whole sediment exposures. This may be due to their trait of being epibenthic-feeding plankton. They spend a significant amount of time during test exposure, filter feeding on the sediment surface, thereby increasing the potential for toxicant uptake. The microbial responses were mixed, with APA and GLU showing greater responses from elutriate exposure, while ETS and GAL only responded in Waukegan whole sediments. Determinations of assay sensitivity based on comparisons between the elutriate phase of one toxicity assay and the solid phase of another toxicity assay, therefore, should not be made. Test sensitivity is related to exposure method. In addition, the solid phase exposure method is more indicative of normal <u>in situ</u> exposure conditions, than is the elutriate exposure.

The multitrophic level test battery indicated that substantial chemical contamination existed, to varying degrees, at the test sites. Since test response patterns varied between whole sediment and elutriate phase exposures, trophic levels tested, and test sediments; it is recommended that assessments of sediment quality include multiple test exposure systems comprised of sensitive species, from multiple trophic levels to ensure detection of contaminant problems.

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Hazardous Waste Site Characterization Utilizing *In Situ* and Laboratory Bioassessment Methods

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Abstract

Determination of adverse ecological effects at a hazardous waste site [HWS] requires definition of the questions to be assessed plus selection of appropriate measurement tools. Field observations conducted during the initial scoping activities play an important role in defining the ecological concerns to be addressed; the measurement tool box ideally consists of an array of direct field measurements [biological, chemical and physical], *in situ* bioassays, laboratory bioassays, additional analytical measures of site samples as well as statistical and risk assessment modeling. This paper discusses the assembly of the tool box and the selection of tools.

Introduction

Ecology is an integrative discipline which draws upon diverse sources of information [e.g. chemical, physical, geological, biological, etc.] to describe the interactions of organisms, populations, communities and ecosystems with each other and their surroundings. The completed ecological assessment of a HWS should determine if an adverse ecological effect has occurred as a consequence of the materials present at the site (Norton et al. 1988). HWS assessments have historically evaluated human health effects [realized or potential]; chemical analysis of the site samples [soil, water, air]; and toxicity of site materials to selected bioassay organisms. Evaluations of toxicity and exposure have driven regulatory actions at HWS.

Hazard can be considered a function of exposure and toxicity; both toxicity and exposure may in effect be complex functions and be highly variable within problem-specific contexts. **Exposure assessment** may be regarded as a field activity, or an integrated lab/field chore concerned with ecologically significant endpoints. For example, measurement endpoints may consider biological monitors [biochemical, physiological, or histological markers] or residue analyses of biological matrices and other environmental samples. **Toxicity assessment** is routinely regarded as being laboratory-derived; less commonly, toxicity assessment results from *in situ* methods that are completed within a field setting.

Relatively little effort has been directed toward ecological assessments. Whereas ecological assessments may draw upon chemical and toxicological data, neither chemistry nor toxicology should be construed as constituting an ecological assessment. Rather, it is necessary to define an ecological assessment endpoint in terms of a population inhabiting the site, a suite of populations, or an ecosystem process.

Approach to Ecological Assessment

Given budgetary restraints and time limitations, a great deal of care must be given to defining relevant assessment endpoints and selecting the appropriate measurements for a given site. From the outset, a considerable amount of information is available from which the options can be constructed; the geographical [ecoregional] location and the probable chemicals can be defined and identified; and, case histories of similar hazardous wastes can be consulted. Recommended initial steps of the ecological assessment process are: assemble existing data sets including site maps, aerial photos, soils maps, geology and hydrology maps, and ecoregion maps; evaluate the appropriateness of ecological assessment; and define the target zones to be examined.

The strategy for ecological evaluation incorporates varying levels of field sampling. The preliminary evaluation defines the ecological context of the site [ie., landscape features such as geomorphic, hydrologic, climatic, and biologic that potentially influence the site or define off-site transfer of toxicants and biota]; identifies the spatial extent of impact [current and potential] of the site and ecological features that warrant more detailed analysis for current assessment and/or future remediation monitoring.

During the past year, major accomplishments toward instituting ecological assessment into the Remedial Investigation/Feasibility Studies [RI/FS] activities were achieved. The Office of Waste Programs Enforcement and Office of Emergency and Remedial Response prepared a guidance document (US EPA 1989) to assist RPMs in instituting ecological assessments, and the Environmental Research Laboratory [ERL-C], Corvallis, Oregon published the first guidance document on ecological site assessments methodologies (Warren-Hicks, et al 1989). Much remains to be accomplished.

One major point of concern arises from the fundamental misunderstanding of what constitutes an ecological assessment. The key word is <u>integration</u>. A significant obstacle in conducting ecological assessments is the poor delineation of utility and limitations of various tools available to assess site condition (Figure 1). Here we outline the capabilities and limitations of three components for evaluating measurement endpoints. These components of an ecological assessment are: 1) field surveys which focus on distribution and abundance of organisms [usually distinguished by taxonomic groups]; 2) bioassays designed to measure toxicity directly in the field or in the laboratory; and 3) biomarkers selected to report exposure to a specific chemical or class of chemicals.

<u>1. Field Surveys</u>. Assessment of ecological effects requires some measurement of structure and functional relationships of biota. The field component of an ecological assessment may be constructed to incorporate a variety of methodologies. Classical sampling designs and protocols for determination of populations of plants, animals, and microbes have

SITE ASSESSMENT

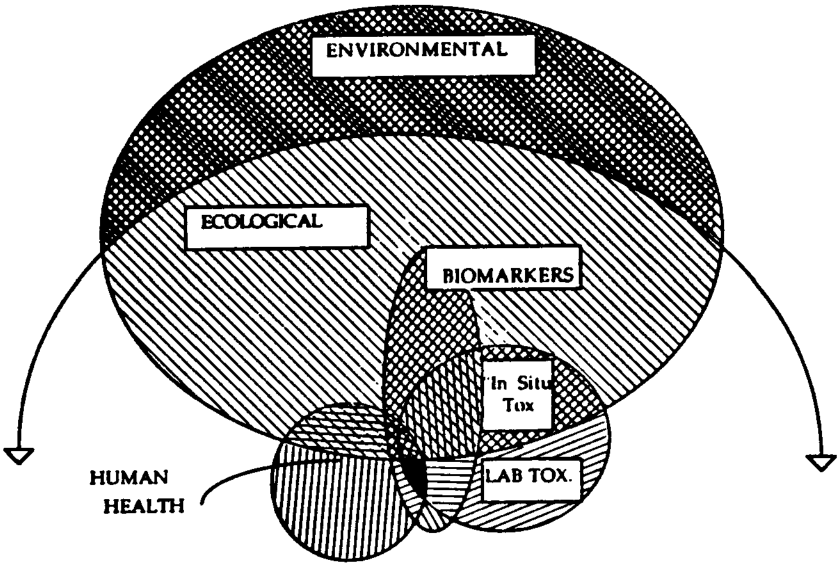

Figure 1. Relationship Among Component Features of Site Assessments. The "Site" is illustrated conceptually as the ellipse labelled ENVIRONMENTAL. The unique portion of the ellipse [the upper zone] portrays non-biological, non-ecological measurement and assessment endpoints performed outside the context of ecological purview. The ECOLOGICAL sphere overlaps and integrates portions of ENVIRONMENTAL assessments, extends beyond the "Site" and can encompass toxicological, human health, and biomarker endpoints.

been the subject of ecology from the inception of the discipline. Although no rigid guidelines for sampling are accepted universally, the concepts of adequacy of sample, objectivity, and precision are well entrenched in all field oriented studies. Researchers are given considerable flexibility in modifying protocols to match the peculiarities of the site and the objectives of the sampling effort. Ecological sampling techniques, like all measurement activities, vary in rigor [ie., detail and/or accuracy] and in the effort [time and cost] required. Often, techniques that can be performed rapidly have inherent limitations of subsequent data manipulation and interpretation. However, rapid and low-cost procedures may provide the information needed. Guidance to plan ecological sampling should be derived from two leading questions "What do I need to know about the site?" [The Data Quality Objectives (DQO)] and "What do I plan to do with the information?" [Quality Assurance Work Plan (QAWP)]. Efficiency comes from integrating the DQOs and QAWP.

Hazardous waste sites present unique restrictions of access and risk to workers. Because of extremely limited size and/or the nature of disturbance, some sites do not pose substantive ecological concerns. Proposed remediation actions may also minimize the level of effort that should go toward ecological evaluation. However, in a large number of sites, ecological assessment can play a major role in defining the nature of the problems associated with the site. Furthermore, ecological assessment should be considered a benchmark for evaluating the success of remedial actions in those situations where the nature of the site warrants action based upon a finding of adverse ecological impact.

Given the temporal limitations on data collection which often pertain to hazardous waste sites, it is crucial to recognize the rather large error margins accompanying most of the resulting data. One-time sampling efforts almost always underestimate species richness. Ephemeral populations are easily missed. Quantitative estimates from one-time sampling efforts are static and thus miss the dynamics of the site. Nevertheless, indispensable information can be acquired from field sampling, in some cases through rather cursory reconnaissance [See Table 1].

Vegetation structure and to some extent composition can be determined remotely utilizing conventional aerial photography, infrared photography, or more sophisticated radiometric signal such as the Thematic Mapper [TM] sensors available in satellites or fixed-wing aircraft [and the new ABRIS sensors under development]. To some extent, [especially with conventional aerial photography], archived data can be used to generate a history of land use. Such gross analyses permit generalized glimpses of spatial and temporal changes at and surrounding an HWS which can be informative not only of the vegetational responses but also suggestive of habitat conditions important for animal populations. More importantly, the infrared photography and radiometric sensors, show great promise for use in defining the spatial boundaries of impact at an HWS. Because the plant leaves are sophisticated light harvesting assemblages, toxicants like those at many HWS can alter the spectral reflectance patterns. If this property proves reliable, it will become a major tool to help delineate the spatial distribution of phytotoxic substances.

Conventional ecological surveys of vegetation and animal populations can be utilized to generate patterns of distribution and abundance of the respective taxonomic groups. In most cases, acquiring accurate measurements of population sizes is costly and involves excessive on-site time which might pose unacceptable risk to the persons gathering the data. HWS conditions impose rigid demands that the DQOs be specified precisely and that the QAWP be equally targeted. Furthermore, as discussed earlier, we seldom have the basis to evaluate the long-term consequence of a given change in population numbers, particularly in light of the differential susceptibility of genotypic variants to a specified toxicant. This is a limitation of the science; it should not be construed as a fatal limitation of field surveys.

<u>2. Bioassays to Determine Toxicity</u>. Bioassays are instruments which yield some defined measurement [Figure 2]. The "sensor" and in most cases the "meter" in the bioassay instrument package is an organism. In theory the organism detects a multitude of signals, processes those signals in some fashion which may or may not be understood, and reports a quantifiable unit of measure [eg. death, growth rate, or

Table 1. Summary of capabilities and limitations of field surveys at HWSs (adapted from Murphy and Kapustka 1989).

Capabilities
+ Surveys can be used to define endpoints of relevance.
+ A large selection of sampling techniques is available to permit desired measurement to a specified accuracy.
+ They are the most direct way to demonstrate adverse change.
+ Field surveys reflects the biological integration of all stresses.
+ Major vegetation components are amenable to sophisticated remote sensing technology.

Limitations
- Legal and safety concerns restrict access.
- Large natural variability may mask subtle but significant effects.
- Detailed sampling can be expensive.
- Survey data are restricted to correlative analysis.
- Their "snapshot" view misses the dynamics [past and future].

Table 2. Summary of capabilities and limitations of toxicity tests for assessment of HWSs (adapted from Murphy and Kapustka 1989).

Capabilities
+ Tests can be used to establish causality.
+ They provide an extensive laboratory data base [especially from single chemical toxicity tests].
+ Multiple, simultaneous chemical stresses are integrated into a defined biological response.
+ The response "interprets" bioavailability.
+ Test conditions can be manipulated or adapted to meet different specification [including adaptation to *in situ* conditions].
+ There are many assays to choose.

Limitations
- Assay conditions [especially in the laboratory] are artificial.
- Tests are restricted to culturable organisms.
- Test organisms selected to exhibit narrow statistical variance [ie., genetically diversity minimized].
- The artificial test conditions [especially in the laboratory] may not reflect proper exposure conditions.
- Extrapolation is restricted to individuals.

other specified biological metric]. In this regard, a bioassay should be considered as any other instrument; an analytical tool equivalent to a gas chromatograph, a spectrophotometer, etc. As spectrophotometers may be modified or adapted to permit different types of analyses, so can bioassays. Each instrument operates with some level of precision and accuracy. Each has boundaries defining legitimate uses.

In a regulatory sense bioassays have been indispensable in determining the permissible levels of chemical release into the environment [See Table 2]. Just as the medical profession has used the white rat or the rhesus monkey as surrogates of humans, environmental biologists have utilized the fathead minnow as a surrogate for fresh water fishes, daphnids as surrogates of aquatic invertebrates, radish or

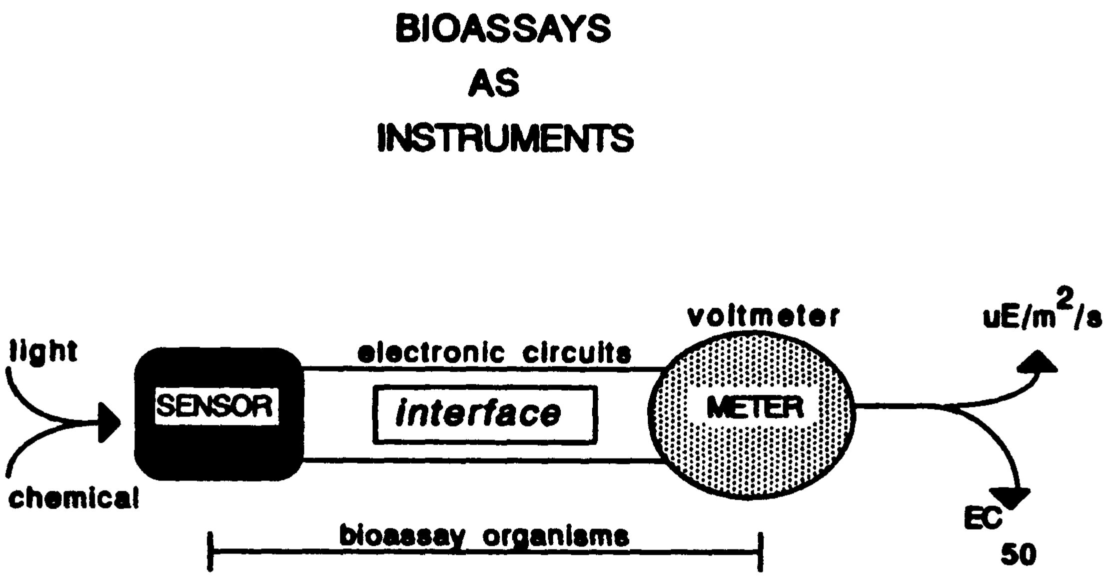

Figure 2. Conceptual model portraying common features of bioassays and a representative analytical instrument.

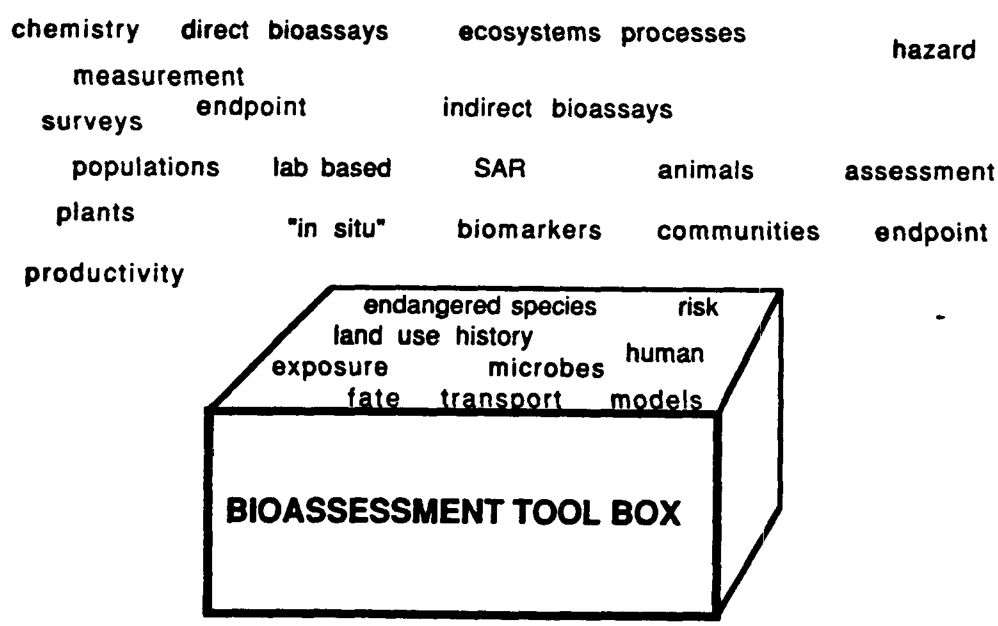

Figure 3. Bioassessment tool box for site assessments.

lettuce as surrogates for terrestrial vascular plants, and some would hold that a single "most sensitive" test organism could serve as a surrogate for the ecosystem as a whole. In the absence of better information, surrogates provide exceedingly valuable "range finding" information. From human health experiences we know that white rat studies can lead to false negative as well as false positive findings. We should not be surprised to encounter similar "mistakes" in performance of bioassays.

The greatest use of bioassays has been to determine the toxicity of single chemicals in simplified medium under controlled environmental conditions. A prime consideration of the bioassay organism is the ease of culturing in the laboratory. Another critical attribute is uniformity or in a statistical sense, narrow variance. Together these three features [controlled environment, "domestication," and homogeneity] run counter to environmental conditions. More recently, bioassays have been employed to evaluate toxicity of complex mixtures such as effluent from waste water discharge or soil elution. Here these instruments perform an analytical function not achievable by other means; namely the integration of organism response from simultaneous exposure to multiple differentially toxic agents.

Toxicity testing typically incorporates an array of bioassay organisms representative of different trophic levels and varied life forms within trophic levels. Additionally, tests have been developed to discriminate among short exposures [acute], long exposures [chronic], maximum effect [lethal], and sub-lethal effects [eg. reduced growth, reduced reproductive rate]. Although these options permit selection of an "instrument" which better approximates the organisms of interest [eg. one species of fish being the surrogate of another species of fish; a worm for a worm; etc.], the laboratory versions of bioassays seldom can be made representative of the exposure conditions and the myriad of environmental factors that come to bear on organisms in the field.

Cognizant of such serious limitations, we are continuing efforts toward developing a broader array of bioassay organisms and toward adapting existing bioassay procedures so that the tests may be performed _in situ_. Successful examples of _in situ_ terrestrial bioassays to date include detecting and monitoring environmental contamination utilizing honey bees and earthworm bioassays. In the near term, it will be necessary to utilize a combination of laboratory and _in situ_ assays. This duplicity is needed in order to provide appropriate calibration of laboratory and _in situ_ measurements.

3. Biomarkers to Determine Exposure. Biomarkers are measures of molecular and/or physiological features of organisms which reveal a sublethal [often subtle] response to some stressor. A given biomarker response may be ephemeral or sustained; it may be specifically linked to a chemical or it may be associated with a general class of stressors. The biomarker response in most cases is measured in an individual and provides evidence that the individual in question has experienced exposure to the stress. Although this discipline of environmental biology is in its infancy, excellent tools exist; some with clearly defined relationships between the measurement endpoint and the assessment endpoint [See Table 3].

Table 3. Summary of capabilities and limitations of biomarkers for assessment of HWSs (adapted from Murphy and Kapustka).

Capabilities
+ Biomarkers provide evidence of exposure to sublethal concentrations of stressors.
+ They may be diagnostic.
+ They are amenable to both laboratory and field conditions.
+ This is a very active area of research showing great promise.

Limitations
- Linkage to ecological effects not inherently clear.
- Only a few established biomarker systems available.
- Use may be operationally complex.

Several key virtues of biomarkers are flexibility for use in the lab or in the field as well as on cultured ["domesticated"] or wild organisms. Biomarkers can be used wisely to aid in defining relationships between laboratory and *in situ* bioassays as well as relationships between bioassay organisms and the larger array of wild organisms.

Although several limitations to the generalized use of biomarkers for HWS assessment exist [eg. technical uncertainties regarding the sensitivity, interference, general applicability across taxonomic lines], some have been used very effectively to demonstrate adverse effects on organisms due to contaminants. Selected examples to illustrate use of the biomarker tool kit include cholinesterase, mutation frequency in plants, karyotype analysis, flow cytometry to measure cellular DNA content, DNA unwinding, and analysis of genetic diversity of populations via measurement of allelic distributions of metabolic enzymes. In all likelihood as more studies are completed, and as new biomarkers are perfected for field measurements, the theoretical framework to linking biomarker measurements to ecological endpoints will come into sharper focus.

Summary

Each approach [ie., field surveys, toxicity tests, and biomarkers] contains numerous methods to acquire data for site assessments. Given the restrictions imposed by time, access, and resources, the selection of methods must be compatible with the specific site DQOs. The collection of methods may be envisioned as a tool box from which one may "extract" the correct tool for the specified task (Figure 3). At ERL-C we are striving to define the specifications of the tools appropriate to perform ecological assessments of HWS.

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Overview of Citizen-Based Surface Water Monitoring

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Abstract

Citizen involvement is a critical component of State and Federal water pollution control efforts. As water pollution protection efforts become increasingly more complex. resource limitations lead State and Federal program managers to consider alternative ways to collect much needed monitoring information. Citizen groups have successfully made significant contributions to other programs. These existing citizen-based monitoring efforts fulfill a broad range of monitoring objectives including assessment of long term water quality trends, evaluation of specific water quality problems and identification and solution of acute water quality problems. Emerging monitoring areas such as toxicants and nonpoint source pollution assessment and control are identified as areas where citizens could become more involved in the future. Monitoring efforts directed at citizens pose unique challenges to data quality assurance and utilization within the regulatory agency. It is recommended that the government should encourage better coordination of citizen data collection efforts.

Key words: Monitoring, surface water, volunteer, citizen monitoring

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Introduction

The field of water pollution control is becoming increasingly complex. While the regulatory focus of the 1970s was on controlling conventional pollutants from point sources, most current controls address both conventional and toxic pollutants from point sources as well as the less defined nonpoint sources (NPS). These NPS water quality problems are harder to identify and controls are more difficult to design and implement. Environmental managers are faced with increasing needs for monitoring information and decreasing resources to spend on data collection and analysis. In many areas of the country, citizen volunteers have been mobilized to collect some of this much needed environmental data.

This paper discusses the scope of these existing citizen-based monitoring efforts, identifies areas where citizens could become more involved in the future, addresses the ongoing challenges of monitoring efforts directed at citizens, and discusses a future role that government could play to encourage better coordination of citizen data collection efforts.

Ongoing Efforts in Citizen Monitoring

Citizen involvement in environmental monitoring is not a new concept. The National Weather Service pioneered citizen monitoring efforts, and has continuously maintained a nationwide citizen-based weather monitoring network since 1890. The program now involves 11,500 volunteers who record daily rainfall, snowfall and maximum and minimum temperatures at over 500 stations nationwide. The collected data are stored in the National Weather Service database and are

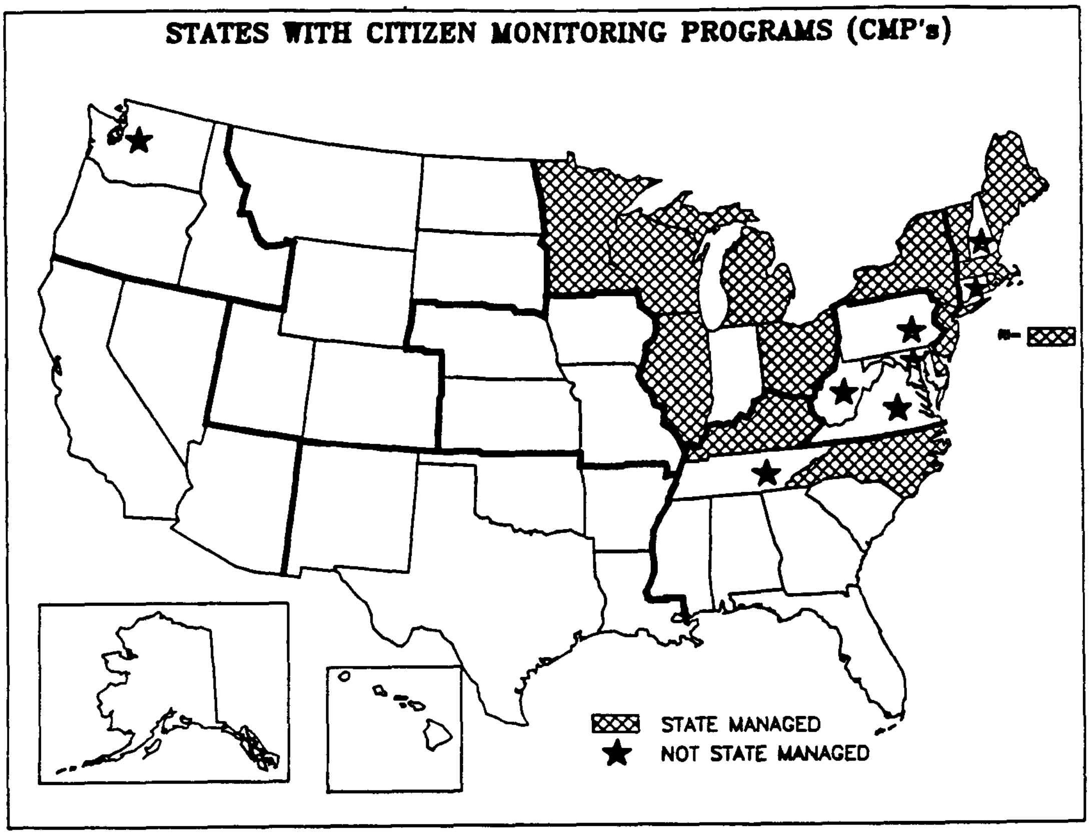

Figure 1. States with citizen monitoring programs.

used to verify damage caused by adverse weather, and to justify Congressional funding for flood and weather observation networks.

In many areas of the country, citizens are also being used to collect surface water quality data. In May 1988, EPA and Rhode Island Sea Grant sponsored a workshop on the Role of Citizen Volunteers in Environmental Monitoring. The participants in this workshop identified approximately 37 active citizen monitoring programs that collect environmental data. Of these, 22 are designed to collect surface water data. The geographical distribution of these programs is shown in Figure 1.

The existing programs cover a broad spectrum of waterbody types and use volunteers to collect data on a wide variety of water quality parameters. The programs fulfill three overall monitoring objectives: identification of long term water quality trends; studies of specific WQ problems; and identification and resolution of acute water quality impairments.

Several programs will be discussed as illustrations of these three general categories of existing citizen monitoring programs.

<u>Monitoring to Identify Long Term Water Quality Trends</u>

These programs use volunteers to collect water quality data at fixed stations on regular basis over an extended time. Volunteer lake monitoring programs which exist in a number of States provide a good example of this overall type. The

Chesapeake Bay Citizens monitoring Program also illustrate this monitoring category.

Most volunteer lake monitoring programs were established in response to deficiencies in a State's ambient lake monitoring program. States hoped to use volunteer collected data to extend their monitoring coverage of lakes, establish baseline lake trophic conditions and identify lakes experiencing acute water quality problems.

In a typical volunteer lake monitoring program, secchi disk depth data is collected at 1 or 2 lake stations, and 2-4 times a month during the spring and summer. Volunteers often record observations on weather conditions, recreational activities on the lake and the anesthetic condition of the lake. Water samples are occasionally collected for chemical and bacteriological analyses.

The Chesapeake Bay Citizen Monitoring program was designed to collect long term chemical monitoring data. The program currently used forty volunteers to sample 36 stations on the James, Pautuxent and Conestoga Rivers which drain into the Chesapeake Bay. The stations are located upstream of the State's regular monitoring sites and provide additional information on pollutant inputs to the Bay.

The Ohio Scenic River Stream Quality Monitoring Program uses volunteers to collect qualitative information on benthic macroinvertebrate communities on Ohio's 10 scenic rivers. The data are interpreted with a simplified water quality index and are used to assess long term trends and identify acute water quality problems.

Monitoring to Study Specific Water Quality Problems

The programs use volunteers to collect water quality data at selected sites over a short time period. The data are used to answer a specific water quality question. Two programs provide good illustrations of this category: the Massachusetts Audubons' Acid Rain Monitoring Program and the Tennessee Valley Authority's teacher/student surface water quality monitoring network.

Massachusetts Audubon's acid rain monitoring program uses volunteers to collect water samples throughout the State for pH, alkalinity, metals and major cation and anion analyses. Samples are collected twice a year to coincide with the summer high pH/alkalinity period and the spring low pH/alkalinity period. Samples are analyzed by volunteer local laboratories and all analyses are subjected to an expensive quality assurance program. Massachusetts's program has been ongoing for six years and has used over 1000 volunteers to sample approximately 3500 sites around the State. The data have been used to influence the State's emission reduction policy.

The Tennessee Valley Authority teacher/student surface water quality monitoring network began in 1986 as part of a science education program. Selected design experiments focused on surface water monitoring and receive training in environmental science. To date, approximately 20 streams have been assessed.

Monitoring to Identify and Resolve Acute Water Quality Impairments

These programs use citizen volunteers to evaluate water quality conditions in their local area and report on acute problems and violations of water pollution control laws and regulations.

The Maryland Save-Our-Stream program is a good example of this type of program. Volunteers receive training on local sediment control regulations and learn about the proper design and installation of sediment control devices. They are then encouraged to inspect construction sites in their local area and report problems to the city, State and/or county authorities.

Nonpoint Source Pollution Assessment: An Emerging Area for Citizen Involvement

Nonpoint sources are reported by States as the leading cause of failure to support designated used in the nation's lakes, steams and estuaries (USEPA 1987a). Agricultural runoff is by far the most commonly reported nonpoint source, followed by runoff from urban areas, construction sites and surface mines. Sediment and nutrients are the most prevalent pollutants linked to nonpoint sources.

The Water Quality Act of 1987 strengthened EPA's mandate to assess and control nonpoint source pollution. The Act gives States and local governments primary responsibility for nonpoint source solutions. The national program is designed to support and reinforce local efforts. EPA's Office of Water recently developed a 5 year plan for federal nonpoint source control (USEPA 1989). This Agenda for the Future identified five objectives for federal nonpoint source activities, one of which was public awareness. Nonpoint source pollution is primarily caused by land use and misuse and is generally controlled at the local level. Public awareness of NPS problems and their solution is central to their control. Government sponsored citizen monitoring and involvement programs will greatly assist in this endeavor.

Citizens can contribute to the nonpoint source assessment effort in four general categories (Hansen, et al, 1988).

1. Identification of waters: Citizens have a local knowledge of water resources and are often familiar with stream conditions before, during and after storm events. They can help States and local governments identify waters impacted by nonpoint source pollution.

2. Identification of sources: Local residents are familiar with land use in their area and can help identify potential sources of nonpoint source pollution.

3. Review controls: Citizens should actively review and evaluate selected best management practices. They can develop an appreciation for which controls are most effective for the types of pollution affecting their local waters.

4. Oversee implementation: Local residents can monitor the progress of control implementation and evaluate the effectiveness of the controls.

Obstacles to Citizen Monitoring Efforts

Citizen monitoring programs have been successful in many areas of the country. However, a number of problem areas still remain. Four of these ongoing obstacles are discussed briefly below:

1. Professional distrust of data collected by volunteers. Although several citizen monitoring programs have demonstrated that volunteers can collect credible data, many water quality professionals remain skeptical about using

this information in their assessments.

2. Matching data needs with capabilities of volunteers. Volunteer monitoring program managers must carefully assess the information needs of the agencies and individuals who will be using the collected data. Volunteers should be selected who are capable of providing the types of information likely to be accepted and used.

3. Funding. Volunteer monitoring programs produce cost effective environmental data. However, the programs are not free and will not succeed without adequate funding and management support.

4. Coordination. For volunteers monitoring efforts to prosper, new and existing programs must share data and information on effective sampling methods and analyses. Program managers should concentrate on ways to coordinate efforts rather than simply promote their own approach.

Ways EPA can Promote Citizen Monitoring

Participants in the 1988 workshop on Citizens Volunteers in Environmental Monitoring suggested several actions that EPA could take to foster citizen monitoring activities and overcome the obstacles to program success. These recommendations were:

1. EPA should publicly endorse citizen monitoring programs.
   A. Highlight successful citizen monitoring programs through nation promotions.
   B. Issue letters of commendation recognizing current citizen monitoring programs.
   C. Sponsor annual conferences for information exchange among citizen monitoring program.
   D. Sponsor a national newsletter.

2. EPA should develop policies that support citizen monitoring programs.
   A. Authorize States to use Federal funds to develop and implement citizen monitoring programs.
   B. Request each State to designate a citizen monitoring program coordinator.
   C. Develop guidance document for State managers on starting/ managing citizen monitoring program.

3. EPA should provide technical support for citizen monitoring efforts.
   A. Research monitoring procedures appropriate for volunteers.
   B. Develop training manuals and seminars on monitoring methods, data interpretation and analysis.
   C. Develop standard methods manual for citizen monitoring.

4. EPA should appoint a National Coordinator who will:
   A. Promote citizen monitoring activities within EPA.
   B. Foster communication between citizen monitoring groups.
   C. Factor citizen monitoring into new EPA initiatives.
   D. Provide technical assistance to States and EPA.

At the present time, EPA is actively researching existing citizen monitoring programs. A guidance document directed at State managers is being developed to provide information on how to start and manage a citizen monitoring program. EPA will also be writing a methods manual for citizen-based lake monitoring. Citizen monitoring is a central component of the EPA Office of Marine and Estuarine Protection's national estuary program and is being incorporated into the nonpoint source program.

EPA has recognized the utility of citizen monitoring programs and will be working to further integrate these programs into the water program. As citizen monitoring activities grow in popularity throughout the U.S., EPA can help encourage and coordinate these programs to maximize the benefits for State monitoring efforts.

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Volunteer Monitoring Data Applications to Illinois Lake Management

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Abstract

The Illinois Environmental Protection Agency (IEPA) initiated the Volunteer Lake Monitoring Program (VLMP) in 1981 to supplement Agency lake data collection efforts and provide public education in lake/watershed management. The VLMP is implemented in cooperation with Areawide Planning Commissions using Clean Water Act (CWA-Sections 106 and 205j) and state funding. Program administration includes volunteer training, specialized data management and QA/QC procedures, technical assistance, and report preparation. Approximately 160 public and private lakes are monitored twice per month from May - October for Secchi disk depth and field observations at three sites/lake. Volunteers for 30-50 lakes also collect water samples for analysis of suspend ed solids and nutrients. The VLMP data is used to diagnose lake problems; guide implementation of watershed management and lake restoration projects; evaluate effectiveness of projects; and meet Federal reporting requirements (for CWA Sections 305(b), 314, and 319). The VLMP plays an important role in facilitating local lake and watershed management activities in Illinois.

Key words: Illinois, volunteer monitoring, Secchi disk, lake management

Program Objectives

In 1981, the Illinois Environmental Protection Agency (IEPA) initiated one of the first comprehensive citizen monitoring programs in the nation. The Volunteer Lake Monitoring Program (VLMP) was designed to educate the public about lake quality and management options, while supplementing IEPA data collection on Illinois' lakes. The major objectives of the VLMP are to encourage development and implementation of sound lake protection and management plans, provide technical assistance, collect baseline data, and establish long term water quality trends.

Approximately 225 volunteers participated in monitoring 160 lakes in 1988. Public water supply operators, Soil and Water Conservation District personnel, and state park site personnel were well represented among the volunteers, as were lake association members, lake residents, sportspersons, and interested citizens.

Since 1981, the VLMP has been a tremendous success. Lake assessment information, Secchi disk data, and field observations have been collected for over 400 Illinois lakes. Citizens have contributed

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over 24,000 hours of volunteer service to the program. The number of volunteers has increased 45 percent and the number of lakes with 100 percent data return (sampled during all 12 monitoring periods) has increased by 173 percent since 1981. Furthermore, three or more years of consistent data have been provided for over 140 lakes.

The VLMP has also been successful in helping citizens more effectively protect and manage their lakes. The VLMP has served as a catalyst for local lake protection and restoration efforts. Virtually all VLMP lakes have had lake protection and management measures implemented following participation in the program.

Sampling Protocol

Three monitoring stations are usually established by IEPA on each lake: one over the deepest portion of the lake near the dam (most Illinois lakes are impoundments), one at mid-lake (medium depth), and one in the lake headwaters (shallow depth). The number of sampling sites will vary depending upon lake size and configuration. VLMP participants measure total depth and Secchi disk depth and record field observations at each sampling site twice per month (at approximately two week intervals) between May and October, for a total of 12 sampling periods. More frequent sampling is suggested for those wishing to define watershed/lake quality relationships or assess the effectiveness of lake and watershed management practices.

In addition to the depth data, the participants also record weather conditions, previous week's precipitation, as well as qualitative assessments of water color and amounts of suspended sediment, suspended algae, and aquatic plants (see Table 1). Volunteers return the forms to IEPA in addressed, postage-paid envelopes immediately after sampling.

For 30 - 50 selected lakes, volunteers also collect water samples once per month from May to October. The criteria for selecting these lakes include: public ownership or access; proven volunteer reliability at the lake; lake size; amount of lake use; and level of public concern. Sampling consists of immersing a one-quart bottle at a depth of one foot, transferring the contents to a 4 oz. bottle with preservative for nutrient analysis, then filling the large bottle again to provide a suspended solids sample. The bottles are immediately packed in a cooler with a 48-hour ice pack and mailed to the IEPA laboratory. At the laboratory, samples are analyzed for the parameters listed in Table 1.

Volunteer Training

Citizens select the lake they wish to monitor from among Illinois' 2,900 public/private lakes that are six acres or more in surface area. The volunteers' commitment includes attending a mandatory training session, providing their own boating equipment, and collecting Secchi disk and field observations data consistently throughout the monitoring season at designated sites in their lake.

Volunteers also complete a three-page lake assessment survey which provides information on lake morphology, uses, water quality conditions, shoreline and watershed conditions, potential pollution sources, and current lake protection/management practices. This information proves valuable in assessing waterbodies to meet Federal reporting requirements (discussed later) as well as in interpreting the Secchi data.

Table 1. Summary of Illinois' Volunteer Lake Monitoring Program

Volunteer Secchi Monitoring

Participants: 160 lakes, 225 volunteers
Sites: three or more per lake, 480 total
Frequency: twice per month, May - October
Monitoring Parameters: Secchi disk, Total depth, transparency
Field Observations:

Water color	Suspended sediment	Suspended algae
Aquatic weeds	Other substances	Odor
Previous weather	Current weather	Water level
Recreational use	Management practices	Comments

Volunteer Water Quality Monitoring
Participants: 30 - 50 lakes, 100 sites
Sites: one to three per lake
Frequency: once per month, May - October
Monitoring Parameters:

Total suspended solids	Nitrate+nitrite-nitrogen
Volatile suspended solids	Total ammonia-nitrogen
Total phosphorus	

During the training session, the coordinator and volunteer use the volunteer's boat to visit each designated site on the lake, whereupon the volunteer in instructed in the proper procedures for using the Secchi disk, recording field observations, and completing the required data forms for each site.

Volunteer Recognition
To recognize volunteer commitment, citizen monitors receive awards based upon the number of completed sampling periods and seasons. The awards include a thank you letter and a certificate of appreciation signed by the IEPA Director, cloth emblems, engraved wooden plaques, and lapel pins. The awards are presented during the VLMP session of the Illinois Lake Management Association Conference held annually in the spring.

The purpose of the VLMP session is to retrain returning volunteers and recognize outstanding volunteers. Participants exchange information, attend retraining sessions, and meet with VLMP staff to discuss concerns. Volunteers may participate in a panel discussion describing how VLMP data has been used to promote local lake protection and management. Holding the VLMP session at the ILMA conference allows the volunteers to discuss their concerns with lake management professionals and increases their exposure to broader lake management issues.

Four newsletters are mailed to volunteers during the monitoring season. The newsletters feature important points regarding monitoring techniques and educational information on lake conditions and management.

As a result of the program's emphasis on personal contact with volunteers, most participants reapply to the VLMP annually, thereby reducing the need to recruit new volunteers. Currently, the program operates at maximum capacity and recruitment is targeted for special lake studies identified by the IEPA. Returning volunteers receive detailed monitoring instructions and data forms in the spring.

Data Management

Information from the data forms submitted by volunteers is entered into a PC data management system as soon as possible following arrival at the IEPA. This procedure serves four major purposes: 1) check-in of forms and tracking of volunteer participation; 2) review of data for errors or omissions; 3) entry of Secchi disk data and qualitative information into a data base with graphical and tabular outputs; and 4) entry of Secchi and total depth data into STORET. Coding is not necessary because the data entry screen mimics the data sheet submitted by the volunteers.

Verification consists of two phases. First, the data are printed in tabular form and checked against the original data sheets as well as for reasonableness. Second, the data are plotted and examined for outliers so that simple recording mistakes, such as assigning data to the incorrect sampling site or reporting Secchi depth in feet instead of inches, can be identified. Questionable data are discussed with the volunteers who keep a separate log sheet at home to further document procedures.

Following verification, the data are uploaded to STORET. VLMP data is stored in a unique file to distinguish it from IEPA-collected data. Statistical analyses performed using STORET and SAS include calculations of the minimum, maximum, and mean Secchi disk depth; calculation of a Carlson Trophic State Index; and analysis of Tukey's Multiple Range Test to compare year-to- year changes in mean Secchi disk depth. The IEPA staff also examine within-lake variation in clarity by comparing Secchi depth data from the three sites on each lake. Observational data are used to interpret clarity data.

Quality Assurance Plan

The IEPA Quality Assurance Plan consists of several components:

- All new volunteers are trained on site at their lake. Since the VLMP Coordinator visits the lake and takes part in collecting data on it, the reasonableness of subsequent data from the lake can be assessed.

- Volunteers obtain detailed written monitoring instructions to supplement the oral instructions at the training session.

- Volunteers keep a personal record of observations.

- Forms are reviewed as received and volunteers called regarding questionable data.

- Specialized data verification procedures are employed as previously discussed.

- A retraining session is held in the spring at the Illinois Lake Management Association conference.

- Pointers regarding monitoring techniques are provided in newsletters throughout the monitoring season.

- Ideally, a quality control visit is scheduled annually. (In practice, this has only been possible in areas administered by

Areawide Planning Commissions).

- IEPA periodically samples VLMP lakes; IEPA-collected data is compared with the VLMP data.

These QA/QC procedures have enhanced confidence in the accuracy of the Secchi readings themselves. Although field observations are more subjective and less confidence can be placed in their accuracy, they are still very useful in interpret-ing the Secchi data and assessing a lake when no other data exists.

Use of Data

Emphasis is placed on using the information generated, and thus reports are prepared which present the VLMP data in a professional format. A statewide summary report and six companion regional volumes containing individual lake data analyses and suggestions for lake protection and management are published annually. The volumes are distributed to Federal, State and local agencies, libraries, and lake owners/managers, as well as to individual volunteers. This data provides the framework for technical assistance and educational activities, which are an integral and important part of the VLMP.

The VLMP data is used in conjunction with other available data to encourage planning and implementation of lake and watershed management projects. The data is also used to determine water quality trends and effectiveness of lake or watershed management projects. The number and completeness of waterbody assessments reported in the Water Quality, Nonpoint Source Assessment, and Lake Water Quality Assessment Reports required by Sections 305(b), 314, and 319 of the Clean Water Act is enhanced by VLMP data. For the IEPA's 1988 305(b) report, VLMP data was the only information available for over half of the lake water-bodies assessed.

Federal, State, and local agencies use the data to select priority lakes for Clean Lakes funding under Section 314(a) of the Clean Water Act and priority watersheds for non-point pollution control funding from the U.S. and Illinois Departments of Agriculture.

Data obtained from the VLMP are also used to:

- Identify prevailing conditions in different parts of the lake so as to pinpoint in-lake problems and possible solutions;

- Document the impacts of point and nonpoint pollution on water quality;

- Establish a historical data base for the lake, which includes morphological data; information on water quality conditions and problems; lake, watershed, and shoreline uses; potential pollution sources; and lake management undertaken - in addition to transparency, field observations, and total depth data.

- Guide decision-making by determining appropriate in-lake/watershed protection/ management techniques to implement.

Program Administration

The VLMP is a cooperative effort involving two divisions within IEPA and three Areawide Planning Commissions. The Lakes Program subunit of IEPA's Planning Section in the Division of Water Pollution Control has lead responsibility for the program. A 3/4 time Statewide

VLMP Coordinator administers all aspects of the VLMP, including guiding the activities of the Areawide Planning and Community Relations Coordinators; acquisition and distribution of monitoring materials and equipment; coordination of recruitment, training, follow-up, data management, and laboratory analysis; preparation of the annual summary reports, newsletters and educational materials; presentations; and technical assistance regarding lake monitoring and management. Other Lakes Program personnel also assist with various aspects of the pro grams such as supervision, training, data management, and computer programming.

The IEPA contracts with designated Areawide Planning Commissions located in the Chicago, St. Louis, and southern Illinois areas to administer the VLMP in their regions. The Areawide VLMP Coordinators are responsible for volunteer training and follow- up, data management, preparation of a regional report and a newsletter, and technical assistance regarding lake monitoring and management in their region of the state. For the remainder of the state, these duties are performed by the Statewide VLMP Coordinator, with the assistance of IEPA Community Relations Coordinators (Office of Community Relations) for volunteer training, follow-up visits, and report writing.

Program Expenses and Funding

The success of a citizen monitoring program in protecting and improving lake resources statewide is directly related to the time and effort devoted to it. The State and Federal Environmental Protection Agencies in Illinois have made this commitment, which has resulted in substantial progress in lake protection and management statewide.

The Illinois VLMP (which includes the state's technical assistance and information/education program for lake monitoring and management) is funded through Clean Water Act Section 106 and 205(j) grants and State matching funds. Approximately 2 full-time equivalent employees (FTE's) in IEPA staff plus $75,000 in contracts to Areawide Planning Commisions are devoted to VLMP and IEPA educational/technical assistance programs. Laboratory analysis totals $20,000 and Secchi disks with attached calibrated nylon ropes cost $20 each.

Conclusions

A Volunteer Lake Monitoring Program:

- Develops local "grass roots" support for environmental programs and fosters cooperation among citizens, agencies, and various units of government.

- Increases citizens' knowledge of the factors that affect lake quality and promotes ecologically sound lake protection/management.

- Promotes local self reliance and implementation through local resources.

- Targets public and private resources for lake protection and improvement.

- Documents water quality impacts of point and nonpoint source pollution.

- Provides a historic data baseline for documenting future changes and evaluating pollution control/management programs.

- Provides data to complete assessments required by the Clean Water Act.

- Supports lake management decision-making.

- Furnishes the framework for an educational and technical assistance program.

- Requires Agency support and resource commitment.

Acknowledgements

This paper was adapted from a draft description of Illinois' Volunteer Lake Monitoring Program (VLMP) for a Citizen Monitoring Guidance Document being prepared by Julie Duffin of Research Triangle Institute for the U.S. Environmental Protection Agency and a presentation by Janet Hawes at the workshop on "Role of Citizen Volunteers in Environmental Monitoring" held May, 1988 at the University of Rhode Island. Robert Kirschner of the Northeastern Illinois Planning Commission and Janet Hawes, Amy Burns, Jeff Mitzelfelt, and J. William Hammel of the Illinois Environ mental Protection Agency and have contributed greatly to the operation and success of Illinois' VLMP.

A Naturalist's Key to Stream Macroinvertebrates for Citizen Monitoring Programs in the Midwest

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Abstract

The purpose of this taxonomic key is to assist naturalists, citizen monitoring coordinators, and other professionals not trained in the identification of stream macroinvertebrates, to identify the major taxa groups of benthic macroinvertebrates (benthos) found in Midwestern streams. The proliferation of citizen monitoring and rapid bioassessment programs created a need for an easily used taxonomic key to the benthos. This key focuses on the inhabitants of riffles and wadable reaches of the stream which are most amenable to sampling by citizen monitors and for rapid assessments. Information on what kinds of organisms are living in a stream reach, when coupled with a knowledge of their environmental requirements and their "pollution tolerances", can yield valuable information about the "health" of that part of the stream. This key is not meant as a substitute for the established taxonomic keys, but it is useful as an "intermediate" key containing descriptive terms that are more familiar to naturalists and the public.

Key words: Benthos, identification, taxonomy, key, naturalist, citizen monitoring, rapid bioassessment.

Introduction

The purpose of this taxonomic key is to assist naturalists, citizen monitoring coordinators, and other professionals not trained in taxonomy, with the identification of stream benthic macroinvertebrates (benthos) found in the Midwest, as well as other areas of the United States. This key focuses on the benthos of riffles and wadable reaches of the stream which are utilized for rapid bioassessments (Plafkin et al. 1989) and citizen monitoring programs (Kopec and Lewis 1988; North Carolina DNRCD undated; Kentucky NREPC 1986). Information regarding the types of organisms found in the riffles (rapids), coupled with a knowledge of their environmental requirements and "pollution tolerances" can yield valuable information about the "health" of the stream reach.

A brief explanation of some terms used in stream monitoring may avoid later confusion. Riffles are those areas of a stream where the water is relatively shallow and at least some of the larger rocks (larger cobble or boulders) break the surface of the water at some time of the year, usually during "base" flow. Runs are slightly deeper areas very similar to riffles except that no rocks break the surface of the water. Pools are areas of the stream where the water is much deeper and the current is slower. Generally, riffles and shallow runs are the wadable areas for sampling the benthos. Benthos are those bottom-dwelling aquatic animals without a backbone which can be seen with the naked eye. A hand lens, however, is often necessary to see characteristics used to identify different organisms. A group of benthos, such as mayflies or riffle beetles, is referred to as a taxon.

Pollution Tolerances

Pollution tolerance information and ecological requirements for the benthic macroinvertebrates can be found in the references listed at the end of the key. The pollution tolerances of many taxa have been numerically presented in the form of biotic indices. The most common biotic indices used in the midwest were developed by Hilsenhoff (1977, 1982, 1987) for use in Wisconsin and by Illinois EPA (1987).

More recently, Hilsenhoff (1988) developed the Family-level biotic index specifically for use in rapid bioassessments which also has great potential for use in citizen monitoring programs. These biotic indices are based upon a taxon's tolerance to organic pollution (nutrient enrichment) which usually manifests itself by lowering the dissolved oxygen level in the water. Other pollutants, such as heavy metals, toxic organics, thermal pollution, and siltation may yield different results. Davis and Lathrop (1989) provide more discussion on the use of assessment indices.

Taxonomic Key

This key was developed after working with citizen monitoring groups for several years. There are many outstanding taxonomic keys available for use for a variety of experience levels (Hafele and Roederer 1987; Lehmkuhl 1978; Merritt and Cummins 1984; Needham and Needham 1962; Pennack 1978). However, a simplified field key with easily understood terms was felt to be the best tool for aspiring biologists to identify commonly found benthos.

The organism groups (taxa) identified in this key are listed in Table 1. The taxa are presented by their scientific nomenclature beginning with the largest classification within the animal kingdom, the Phylum, and proceeding to the smaller classifications as follows: Phylum, Class, Order, Family, Genus, Species.

Depending upon the skill and time available to the taxonomist, the level of identifications desired will vary. Water quality assessments have successfully been conducted at a variety of taxonomic levels. Plafkin et al. (1989) present assessment schemes for three levels of identification: Order, Family, and Genus/Species. Hilsenhoff developed his biotic index for both genus and family levels (Hilsenhoff 1987, 1988).

In using this key, please note that each couplet offers two options (in some cases there are three). Each couplet is numbered and the numbers in parenthesis refer to the previous couplet from which the present couplet came (e.g. couplet #1 came from couplet #2). In some instances, taxa may key to more than one couplet based on their different characteristics. Lines below the taxa indicate size ranges for organisms within that group. Some organisms, such as the aquatic moths (Lepidoptera), have been omitted because they are rarely found in riffles. This keys focuses on the commonly found benthos in the wadable parts of streams. The taxonomic level of this key is directed for use by naturalists and citizen monitoring coordinators. As a last note, please be aware that some individual organisms collected may have missing body parts so it is best to look at several specimens.

Table 1. Classification of important benthic macroinvertebrates described in this key.

Phylum	Class	Order	Family	Common Name
PLATYHELMINTHES	Turbellaria			Planaria
ANNELIDA	Oligochaete			Worm
	Hirudinea			Leech
MOLLUSCA	Gastropoda	Pulmonata	Planorbidae	Planorbid Snail
			Ancyclidae	Limpet
			Physidae	Pouch Snail
			Lymnaeidae	River/Pond Snail
		Mesogastropoda		Operculate Snail
	Bivalvia		Unionidae	Clams/Mussels
			Sphaeridae[1]	Fingernail Clam
			Corbiculidae[1]	Asiatic Clam
ARTHROPODA	Crustacea	Decapoda		Crayfish
		Isopoda		Sowbug
		Amphipoda		Scud
	Insecta	Plecoptera		Stonefly
		Ephemeroptera	Oligoneuridae	Torpedo Mayfly
			Heptageniidae	Clinging Mayfly
			Ephemeridae[1]	Burrowing Mayfly
			Potomanthidae[1]	Burrowing Mayfly
		Megaloptera	Corydalidae	Dobsonfly
			Sialidae	Alderfly
		Coleoptera	Elmidae	Riffle Beetle
			Gyrinidae	Whirligig Beetle
			Psephenidae	Water Penny
		Odonata	Zygoptera[2]	Damselfly
			Anisoptera[2]	Dragonfly
		Trichoptera	Helicopsychidae	Snailcase Caddisfly
			Hydropsychidae	Net-spinning Caddisfly
			Rhyacophilidae	Free-living Caddisfly
			Brachycentridae	Caddisfly
			Glossosomatidae	Saddlecase Caddisfly
			Hydroptilidae	Pursecase/Micro Caddisfly
		Hemiptera	Gerridae[3]	Water Strider
		Diptera	Athericidae	Snipe Fly
			Ceratopogonidae	Biting Midge Fly
			Chironomidae	Midge Fly
			Simuliidae	Black Fly
			Tipulidae	Crane Fly

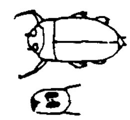
Notes:
[1]These families are not distiguished among themselves in the key.
[2]These classifications are sub-orders.
[3]Other families in this group include Veliidae and Mesoveliidae.

1\. A. Organisms found on top of the water -- **SURFACE ORGANISMS**................2
These organisms are more common on the quieter waters of pools and runs, although occassionally found on riffles. Because they are out of the water and do not rely it on as their oxygen source, they are relatively unaffected by water quality, although they may be affected by surface pollutants such as oil films.

B. Organisms found on the bottom substrate, clinging to rocks or vegetation, or burrowing in softer sediments -- **BENTHIC ORGANISMS** (Benthos).........3

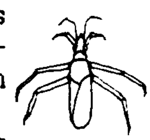
NOTE: Macroinvertebrates that spend most of their lives swimming (nekton) or floating (plankton) in the water column are uncommon in riffle areas although they ay be present in nearby pools. Consult another source for identification of these organisms.

2.(1) A. Body ovoid, front (top) wings hard; two pairs of eyes; mouthparts designed for chewing; often swim on water in a swirling motion;..**WHIRLIGIG BEETLES**
Coleoptera: Gyrinidae. Larvae are fully aquatic and benthic.



side view

B. Body relatively thin, legs long; back half of top wings membranous, not hard or beetle-like; one pair of eyes; mouthparts tubular, designed for sucking; size variable; skate on water...**WATER STRIDERS**
Hemiptera: Gerridae, Veliidae, Mesoveliidae. Spend their lives on top of the water.



3.(1) A. With a hard calcareous shell of one or two valves -- **MOLLUSKS**..........4
Mollusca: Bivalvia (Clams and Mussels), Gastropoda (Snails and Limpets). In general, mollusks are found in hard (much carbonate) waters with a pH near or above neutral (pH 7)

B. With a spiral (snail-shaped) case of sand; animal hidden within case; with 6 jointed legs; small and inconspicuous, often overlooked..............................**SNAIL-CASE CADDISFLIES**
Trichoptera: Helicopsychidae (<u>Helicopsyche</u>). Fairly intolerant.

C. Without a hard, calcareous shell or spiral-shaped sand case (may have a non-spiral case of sand, pebbles or plant material)..................8

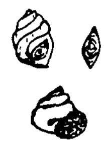
4.(3) A. Shell of one valve -- **SNAILS**....................................5

B. Shell of two valves held together by a non-calcareous ligament -- **CLAMS and MUSSELS**..6

A

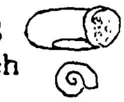
B

5.(4) A. Snails with an operculum (a hard covering used to close the apperature or opening)........................**OPERCULATE SNAILS**
Gastropoda: Prosobranchia: Several families. These snails are usually found in the much slower waters of pools and are generally more tolerant of low oxygen levels.



B. Snails without an operculum..8

6.(5) A. Shell discoidal (coiled in one plane)..........**PLANORBID SNAILS**
Gastropoda: Planorbidae. Generally found in slower waters such as runs. Fairly tolerant.



B. Shell patelliform (cup-shaped), limpet-like..**FRESHWATER LIMPETS**
Gastropoda: Most belong to the family Ancyclidae although two other families have limpet-like members. Found in riffles. Somewhat tolerant to pollution.

C. Shell with a distinct spiral..7

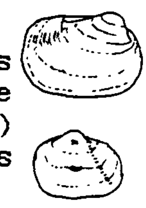
7.(6) A. Shell sinistral ("left-handed")....................**POUCH SNAILS**
Gastropoda: Physidae (<u>Physella</u>). Often found in slower waters. Generally tolerant.

B. Shell dextral ("right-handed")............**RIVER and POND SNAILS**
Gastropoda: Several families. Most are somewhat intolerant, although seldom found in the fastest currents of riffles.

NOTE: "Handedness" is determined by holding the shell spire up with the apperature facing you. If the apperature is on the right, the snail is "right handed" or dextral, if the apperature is on the left, the snail is "left handed" or sinistral.

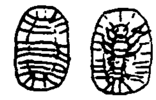
8.(4) A. Small bivalves, < 2 cm long........**FINGERNAIL and ASIATIC CLAMS**
Bivalvia: Sphaeriidae and Corbiculidae. Fingernail clams are very small, Most are somewhat tolerant to pollution.

B. Large bivalves (mostly > 2 cm long)...........**CLAMS and MUSSELS**
Bivalvia: Several families, the most common of which is Unionidae. Tolerance varies and is somewhat dependent on the tolerance of the host species of the early stages (glochidia) of the mollusk; most somewhat tolerant. Very young individuals may be less than 2 cm long.

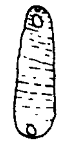


NOTE: Characteristics used to distinguish different bivalves are internal but most have distinct shells and can be roughly picture keyed.

9.(3) A. Entire body distinctly segmented, flattened and oval in shape; head, 6 pairs of jointed legs and gills present but hidden ventrally; copper or brown in color; cling tightly to rocks... ....WATER PENNIES
Coleoptera: Psephenidae. Fairly intolerant.



B. Body oval or elongate, soft and indistinctly segmented; head, legs and gills lacking; with anterior and posterior ventral suckers..LEECHES
Annelida: Hirudinea. Somewhat tolerant.

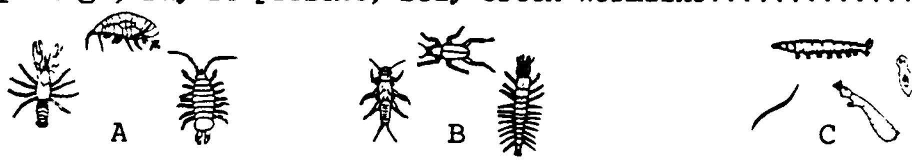


C. Body not a distinctly flattened oval in shape with or without legs; without suckers..10

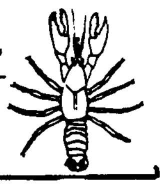
10.(9) A. With more than 6 true, jointed legs -- **CRAYFISH, SCUDS, SOWBUGS**......11

B. With six true, jointed legs -- **INSECTS (Insecta; except Diptera)**.....13

C. With less than six true, jointed legs, although non-jointed legs (prolegs) may be present; body often wormlike........................31



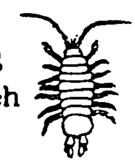
11.(10) A. Generally large organisms with two large claws (chelipeds), one or both of which may be missing. Small (young) individuals are common in some areas in spring..............CRAYFISH
Crustacea: Decapoda (Astacidae). Somewhat tolerant.



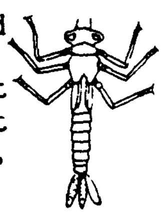
B. Smaller, lacking large claws..12

12.(11) A. Flattened laterally (from side to side), tan, white or gray in color..SCUDS
Amphipoda. Three common genera, two of which are fairly tolerant and one which is fairly intolerant.

B. Flattened dorsoventrally (top to bottom); gray ....SOWBUGS
Isopoda. Sowbugs resemble the terrestrial "pill bugs" which belong to the same order. Tolerant.



13.(10) A. With three broad, oarlike "tails" (gills); body long and thin; wing pads present..........................DAMSELFLIES
Odonata: Coenagrionidae, Lestidae, Calopterygidae. The first two families are uncommon in streams and are somewhat tolerant to pollution. The third, the Stream Damselflies, are fairly intolerant.



B. With, one two, or three thin caudal filaments ("tails")............14

C. With no thin caudal filaments, although prolegs or other appendages, such as spines or hooks, may be present..........................18

14.(13) A. With one caudal filament; body brown or copper in color, head and "tail" lighter in color........................**ALDERFLIES**
Megaloptera: Sialidae (<u>Sialis</u>). Fairly intolerant.

B. With two caudal filaments -- **STONEFLIES or MAYFLIES**................15

C. With three caudal filaments -- **MAYFLIES**............................16

B

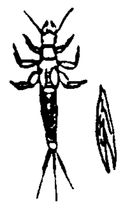
C

NOTE: The caudal filaments of mayflies often break off easily; look for "tail" stubs. You will need a hand lens to see the tarsal claws.

15.(14) A. One tarsal claw; gills present on abdominal segments; individuals are generally more flimsy................**MAYFLIES**
Ephemeroptera: Some members of the families Heptageniidae and Baetidae. Somewhat intolerant.

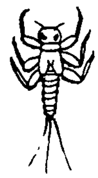
B. Two tarsal claws; gills, if visible, not located on abdomen; body tan, brown or yellow, sometimes patterned; size varies but most are robust..............................**STONEFLIES**
Plecoptera: Several families all of which are intolerant.

16.(14) A. Mandibles modified into tusks (elongated past head); body creamy white, tan or with brown and white pattern; gills forked...................................**BURROWING MAYFLIES**
Ephemeroptera: Three families. Found in soft substrates burrowing in sand, muck, silt, etc. Most are intolerant although the species <u>Hexagenia</u> is fairly tolerant.



B. Without tusks...17

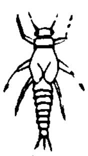
17.(16) A. Body flattened dorsoventrally (top to bottom); eyes large and located on top of head.....................**CLINGING MAYFLIES**
Ephemeroptera: Heptageniidae. Tolerance ranges from intolerant to somewhat tolerant; two common genera (<u>Stenonema</u> and <u>Heptagenia</u>) are somewhat tolerant.



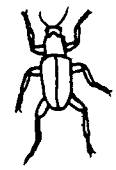
B. Body not flattened dorsoventrally....................................18

18.(17) A. Body slightly compressed from side to side; thorax slightly humped; torpedo-shaped; front legs with a dense row of hairs ....**TORPEDO MAYFLIES**
Ephemeroptera: Oligoneuridae. One of the swimming mayfly groups. Intolerant.

B. Body not compressed from side to side; front legs without a dense row of hairs...........................**OTHER MAYFLIES**
Ephemeroptera: Swimming Mayflies (Baetidae, Siphlonuridae) and Crawling Mayflies (Caenidae and Tricorythidae). Most are somewhat tolerant.

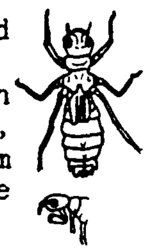


19.(13) A. Entire body including front wings hard; small, dark beetles either long and thin or ovoid in shape..........**ADULT BEETLES**
Coleoptera: Several families including Elmidae and Dryopidae (Riffle Beetles), Haliplidae (Crawling Water Beetles), Dytiscidae (Predaceous Diving Beetles), the most common of which is Elmidae. Tolerances have been determined only for larvae since adults can leave the area by air.



B. Entire body not hard..20

20.(19) A. With external wing pads; lower jaw (labium) large, hinged and folded up on itself concealing other mouthparts...**DRAGONFLIES**
Odonata: Several families. Dragonflies are seldom found in riffles but may be found burried in soft sediments (i.e sand, silt or mud) or in vegetation and detritis along the stream edge or in slightly slower waters. Stream dwellers are fairly intolerant to pollution.



B. Without external wing pads; labium not hinged......................21

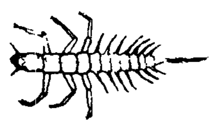
21.(20) A. Abdomen with lateral appendages....................................22

B. Abdomen without lateral appendages (ventral gills my be present)....24

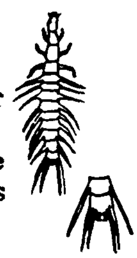
A

B

22.(21) A. Lateral appendages long and thick; abdomen with a pair of hooked terminal appendages or a single caudal filament; body dark (brown to black); most are large, some to 10 cm (4") long -- **"HELLGRAMMITES"**..23



B. Lateral appendages long and thin, or if short, then thick; terminal hooks on abdomen, if present, not on appendages; body lighter in color, tan, whitish or yellow; mostly smaller (< 2 cm long)..................................**BEETLE LARVAE**
Coleoptera: A few families key out here including the Gyrinidae (Whirligig Beetles), some Dytiscidae (Predaceous Diving Beetles), some Haliplidae (Crawling Water Beetles). Most somewhat tolerant

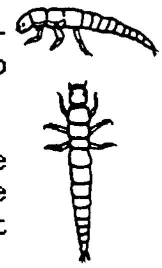


23.(22) A. Abdomen with a single filament................**ALDERFLY LARVAE**
Megaloptera: Sialidae (<u>Sialis</u>). Fairly intolerant.

B. Abdomen with hooks on short appendages.......**DOBSONFLY LARVAE**
Megaloptera: Corydalidae. One genus (<u>Corydalus</u>) has abdominal gill tufts under the lateral appendages. Fairly intolerant.

24.(21) A. With hooks at end of abdomen; individuals often curl into a "C" shape when held or preserved; body color variable, but head usually brown or yellow, abdomen whitish, tan or green; pronotum (first dorsal thoracic segment) with a distinctly scleriterized plate; abdomen membranous and of a different color from thoracic plates; many build some sort of portable or stationary case of plant material, sand or pebbles -- **CADDISFLIES**..25

B. Without hooks at the end of the abdomen; body brown, copper-colored or tan and somewhat "leathery"; thorax similar to abdomen, without distinctly scleraterized plates; no cases... ....**RIFFLE BEETLE LARVAE**
Coleoptera: Elmidae. Riffle beetle larve resemble midge larve and are about the same size but riffle beetle larvae are leathery rather than membranous and have true legs. Somewhat tolerant.



25.(24) A. Without portable case (some build retreats of small stone or sand)..26

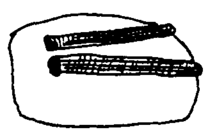
B. With a portable case..28

26.(25) A. Head as wide as thorax; build retreats of stone and sand on rocks --.. **NET-SPINNING CADDISFLIES**..27

B. Head narrower than thorax; dorsal plate on last abdominal segment; free-living..................**FREE-LIVING CADDISFLIES**
Trichoptera: Rhyacophilidae. Intolerant.

27.(26) A. Each thoracic segment with a single dorsal plate; abdomen with gills ventrally; > 5 mm in length.........**HYDROPSYCHIDAE**
Trichoptera: Hydropsychidae. Somewhat tolerant
Microcaddisflies, which also have 3 dorsal plates on the thorax, resemble Hydropsychids when the former are out of their cases. Microcaddisflies are very small (mostly < 5 mm), lack abdominal gills, and their abdomens are swollen (larger than thorax). They build cases of silk which some cover with sand or other substrates.

B. Prothorax with dorsal plate, metathorax (third thoracic segment) partly or entirely membranous.....**OTHER NET SPINNERS**
Trichoptera: Three families, Psychomyiidae, Philopotamidae and Polycentropodidae, ranging from fairly intolerant (first) to somewhat tolerant (last).


28.(25) A. Case of organic detritis (eg. small sticks, leaves)................29

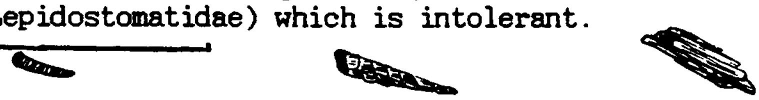
B. Case of sand or small stones......................................30

NOTE: There are two groups of Tube-case Caddisflies, one builds organic tubes and the other mineral tubes

C. Case of silk, may be covered with sand or organic material; animal very small (2-5 mm); each thoracic segment with a single dorsal plate; no ventral abdominal gills..PURSE-CASE OR MICROCADDISFLIES
Trichoptera: Hydroptilidae. Resemble the Hydropsychidae but much smaller and without ventral abdominal gills. Somewhat tolerant.

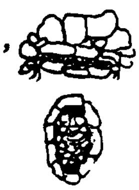
29.(28) A. Case square in cross-section........BRACHYCENTRID CADDISFLIES
Trichoptera: Brachycentridae. Intolerant.

B. Case cylindrical.......................TUBE-CASE CADDISFLIES
Trichoptera: Four families, three of which (Leptoceridae, Phryganiidae and Limnephilidae), are somewhat tolerant and one (Lepidostomatidae) which is intolerant.



30.(28) A. Case of sand, snail-shaped.............SNAIL-CASE CADDISFLIES
Trichoptera: Helicopsychidae. Fairly intolerant.

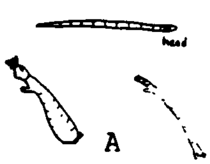
B. Case of small stones and sand, turtle-shaped (top-domed, underside flat)......................SADDLE-CASE CADDISFLIES
Trichoptera: Glossosomatidae. Intolerant.

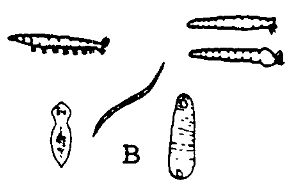


C. Sand or stone case tube shaped..........TUBE-CASE CADDISFLIES
Trichoptera: Three families, two of which (Molanidae and Limnephilidae) are somewhat tolerant and one (Odontoceridae) which is intolerant.

31.(10) A. Body with a distinct, visible head capsule.........................32

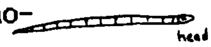
B. Body without a distinct head capsule or head capsule retracted......34


A

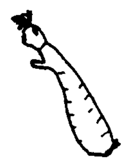

B

32.(31) A. Body with one or two pairs of prolegs either of which may appear as a single leg..33

B. Body straight; without prolegs................BITING MIDGES
Diptera: Ceratopogonidae. Also known as "punkies" or "no-see-ums". Fairly tolerant.

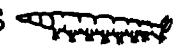


33.(32) A. With one pair of anterior prolegs; abdomen with a distinct bulge posteriorly; usually gray or mottled brown in color.... ....BLACK FLIES
Diptera: Simuliidae. Usually found in very fast moving water. Most are intolerant. A few species are fairly tolerant.



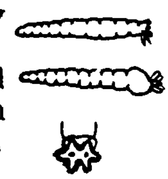
B. With one pair anterior and one pair posterior prolegs; body tubular, width about equal throughout (no posterior bulge); color variable but usually white, green or red....TRUE MIDGES
Diptera: Chironomidae. A highly diverse group although they all look about the same without a microscope. Identification beyond the family level requires a compound microscope. Most are somewhat tolerant with one tribe (Tanytarsini) intolerant and one genus, called Blood worms, very tolerant.

34.(31)A. With 8 abdominal prolegs and a pair of long terminal appendages; head region distinctly prolonged......SNIPE FLIES
Diptera: Athericidae (Atherix). Fairly intolerant.



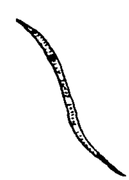
B. With other characteristics; if prolegs present, then without a pair of long terminal appendages and head not distinctly prolonged; prolegs may be lacking altogether...35

35.(34) A. With 4 to 8 short tubes at one end (posterior); body usually soft and membranous...............................CRANEFLIES
Diptera: Tipulidae. Some Tipula are large and membranous and most are fairly intolerant to pollution. Hexatoma are swollen near the short tubes and are somewhat tolerant. Others vary, but the family is generally considered somewhat intolerant.



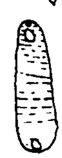
B. Without short tubes at either end.................................36

36.(35) A. Body, segmented, thin and hairlike, not flattened; resemble earthworms..................................."AQUATIC WORMS"
Annelida: Oligochaeta. Better known as aquatic oligochaetes, they are related to the terrestrial earthworms. Members of the family Tubificididae are highly tolerant.



B. Body wide, flattened, and not segmented, often gray; with visible eye spots...................................PLANARIA
Platyhelminthes: Tricladida. Tolerance uncertain, although most are probably somewhat tolerant.

C. Body flattened and indistinctly segmented; long or oval in shape; with anterior and posterior ventral suckers....LEECHES
Annelida: Hirudinea. Somewhat tolerant.



Acknowledgements

I am very grateful for the technical/taxonomic reviews of this key that were performed by the following professionals: Larry Abele, N. Wilson Britt, Robert Bode, Kenneth Cummins, Wayne Davis, Jeff DeShon, Leonard Ferrington, and Rick Hafele. Your comments and contributions were most helpful.

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The "Why" of Minnesota's Citizen Lake-Monitoring Program

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Abstract

Dr. Joe Shapiro of the University of Minnesota's Limnological Research Center initiated the Secchi Disk Program in 1973. This program was started in an effort to collect additional data on some of Minnesota's 11,842 lakes. It was designed as a volunteer program because no one agency or organization would have the resources to monitor even a fraction of the lakes. The Secchi disk was chosen because it is easy to use, inexpensive, and it yields valuable information about a lake's health. The water transparency or clarity measured by the Secchi disk relates to the algae levels, amounts of suspended sediments, and/or dissolved organics in Minnesota's lakes. The program was transferred to the Minnesota Pollution Control Agency in 1978 and was renamed the Citizen Lake-Monitoring Program. Loon counts and the citizen's assessments of the amount of algae and it's effect on the lake's use were added to the program in 1987. The loon counts will be entered into USEPA's STORET BIOS data management programs and will be used to track the loon population and it's reproductive success. The algal assessments are being studied for their correlations to the ecoregions in Minnesota. Therefore, the "why" of Minnesota's Citizen Lake-Monitoring Program is that it provides valuable data that is being used for several different programs.

Key Words: Lake monitoring, citizen involvement, Secchi Data, water quality, Minnesota,volunteer.

Introduction

We are not proud of the fact that Minnesota does have some algae-covered lakes. But they do exist, along with the crystal clear (or as the old Hamm's beer commercial went, 'Land of Sky Blue Waters') lakes. Being concerned about all of our water resources, Minnesota residents want more information about what is going on in "their" lakes and what is being done to protect them.

History

The Citizen Lake-Monitoring Program (CLMP) was started in 1973 by Dr. Joe Shapiro at the University of Minnesota's Limnological Research Center and was originally called the Secchi Disk Program. He began this program in an effort to address the lack of information for Minnesota's 11,842 lakes - one lake for every 288 residents. He decided to utilize citizen volunteers, in recognition of the fact that by itself, the Center wouldn't be able to gather all of the chemical, physical, and biological data necessary to detect and evaluate changes on even a fraction of those lakes.

The Secchi disk was chosen as the instrument for measuring a lake's water quality because it is easy to use (no extensive instruction is needed and anyone can do it), it is inexpensive, and, most importantly, it yields valuable information. In Minnesota, the transparency of a water body is generally affected by three factors: microscopic algae, suspended sediment, and/or dissolved organic material, in roughly that order. The water's clarity is something that the public can relate to as an indication of water quality.

In 1978 the program was transferred to the Minnesota Pollution Control Agency (MPCA), which had provided part of the initial funding, and officially renamed the CLMP. An Advanced Program was also added at this time and involved the collection of water samples four times during the summer. These samples were preserved by freezing and then sent to the Minnesota Department of Health for nitrogen and phosphorus analyses. This sampling was done in an effort to detect any changes that might occur following the statewide ban on phosphorus in detergents in 1978. The Advanced Program was discontinued following the 1981 sampling season due to continuing resource problems. The current source of funding for the program is the Clean Water Act's Section 106 funds, which are channeled through the state.

In 1981, all of the data that had been collected to that point was entered into the USEPA's STORET data management system under agency code 21MINNL and identified as to its set of data collectors by utilizing parameter 29 (site ID#). This identification system allows anyone looking at the data to eliminate any set by restricting the site location and selected parameters.

The most recent additions to the program are requests for recording the amount of algae that a participant sees on their lake and how this affects lake activities and/or enjoyment. This information is collected along with the number of adult and/or juvenile loons that are seen when the volunteer is taking a Secchi reading. The physical condition (amount of algae) and recreational suitability (activity/enjoyment) columns were added to the Secchi data sheet in 1987 and each have a range from 1 to 5 to use to denote the lake's condition at the time of the Secchi transparency measurement. For the physical condition, 1 represents NO algae visible up to 5 representing floating scum with the possibility of odor present or fish kills also occurring. In the recreational suitability column, which is more subjective in nature, 1 is a lake condition of beautiful (could NOT be better) and continuing on up the scale to 5, which reflects a situation of not even boating on the lake being possible because of the high levels of algae.

Also added in 1987 were the two columns for recording the number of adult and/or juvenile loons seen on the lake. This information will be entered into STORET's BIOS (biological data management system). The loon columns were added at the request of another MPCA staff person who is involved with mercury studies, and as a result of a massive die-off of loons wintering in the Gulf of Mexico. Many of the dead loons that were analyzed were found to have higher levels of mercury than those that died of other causes elsewhere.

Discussion

But what do we do with all of this information that is collected? First, the data is entered into EPA's STORET system (with the exception of the loon data, which will be entered in the near future). Once the data is entered, it is available to any agency or organization with access to STORET.

The very first people to use the

data are the participants themselves. In most cases they keep a personal record of their transparency readings and compare the individual readings to one another, one month to the next, and each year to the previous year's readings. The participants are the first to see if a trend appears. With the recent availability of several years of data, trend analyses can now done for a number of lakes.

The program's participants are the first group to make an effort to protect "their" lake. Some groups/lake associations have done this by education of their own members and ensuring that zoning regulations are enforced. Twin and Sylvia Lakes in Wright County, which are joined by a short, narrow channel, have experienced a doubling of their transparency readings over the last 10 years just through the actions of the lake association alone. Other associations have used the CLMP data to block irresponsible behavior by outside organizations. One developer left a project on a lake in Carlton County due to pressure by the lake association and is reportedly more careful in its approach to another project on a different lake in the area. And in St. Louis County a developer has been blocked from putting up multiple housing units on a lake in the Superior National Forest that also borders the Boundary Waters Canoe Area Wilderness.

The next group to scrutinize the data is the staff of the Minnesota Pollution Control Agency. Of that group, I am the first to see the data sheets - I am the person responsible for making sure that "clean" data is entered into the computer (i.e., clarifying time discrepancies, illegible times, readings, loon counts, verifying the sampling location, etc.). The data sheets then go to our data entry person, who also checks for discrepancies in date, time, and location.

Once the data have been entered into STORET and proofread, it is available for anyone to use. Other members of the MPCA staff that have used this data have done so for a variety of projects. One of the limited uses of this data was in combination with chemistry data gathered during an intensive survey on the Sauk River Chain of Lakes. Legal action was being taken against a discharger to the Sauk River and this combination of chemistry data and background transparency data was strong enough evidence to require the discharger to add tertiary treatment of its effluent.

One of the continuing uses is the inclusion in the Clean Water Act's Section 305(b) Report to Congress of the United States: Minnesota Water Quality. Without the CLMP data, many of the lakes in the state would not be assessed for their designated use. The CLMP transparency data is also used by the MPCA staff to calculate the trophic status of each lake by ecoregions. This information is printed in a report assessing the lakes' water quality by ecoregion. Standards for lake water quality are being developed using this information as guidelines.

The same group of MPCA staff that is working with the transparency data for trophic status assessment is also utilizing the physical condition and recreational suitability data to denote if any difference in perceptions exists for different parts of the state. The data from those columns on the Secchi data sheet has shown that there is a difference among the various ecoregions of the state as to the perception of the lake's water quality. The participants in the Northern Lakes and Forests ecoregion tend to be harsher in their judgment of the lakes than the participants in the Western Corn Belt Plains. The MPCA staff is quantifying these perceptions, mapping them, and as more years of data come in, noting any trends in these perceptions.

After the loon data is entered into BIOS, it will be studied by MPCA and Minnesota Department of Natural Resources personnel to note what the population is, where it is, what its reproductive success appears to be, and to link these with any mercury data. The last condition is to see if a correlation exists between findings of mercury in the lake water with the reproduction, increased incidence of disease, and weakened defenses of loons (the latter of which can lead to higher death rates (from injury due to decreased ability to escape intruders).

CLMP participants and MPCA staff are only two of the groups that look at and use the data. As stated before, the 305(b) report goes to Congress. The annual report for the program itself (The Report on the Transparency of Minnesota Lakes-a.k.a., the CLMP report) is sent to the legislative library at the Minnesota State Legislature. Copies of the latter report are also sent to USEPA's clearinghouse for publications, other volunteer programs, Minnesota's 87 county zoning administrators, and the numerous soil and water conservation districts in the state.

Conclusions

The "why" of Minnesota's Citizen Lake-Monitoring Program is that many people are concerned about the state's water quality and that several different groups are using the data in many different ways.

The Ohio Scenic Rivers Stream Quality Monitoring Program: Citizens in Action

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Abstract

The Ohio Scenic Rivers Stream Quality Monitoring Program was initiated in 1983 to provide an easy means for the general public to be involved in stream resource protection. The procedure involves the collection and identification of riffle-dwelling macroinvertebrates using simple and inexpensive equipment. The program was revised in 1985 to eliminate the need for quantitative analysis as this proved to be the most difficult aspect of the procedure for volunteers. The rating of stream quality is based on assigning point values to 20 taxa of macroinvertebrates depending on their tolerance to levels of pollution. The program has proved to be one of the Department's most popular and successful environmental education efforts, to date. In 1988 alone, nearly 4,000 people monitored 150 stations on ten designated State Wild, Scenic, and Recreational Rivers. Participants included all levels of educational institutions, conservation clubs, as well as 4-H groups, senior citizen centers, individual families, and many others. Improvements to the Ohio Stream Quality Monitoring Program for 1989 will include revision of identification sheets and preparation of preserved specimens to assist participants in identifying the macroinvertebrates upon which the program is based. Plans are also underway to assist Ohio Soil and Water Conservation Districts in a trial program of administering stream quality monitoring at the local level thereby expanding this program to other streams in the state.

Key words: Ohio DNR, scenic rivers, stream quality, citizen monitoring

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Introduction

Recognizing a sincere need to directly involve citizen groups in preserving Wild, Scenic, and Recreational Rivers, Ohio developed the Ohio Scenic Rivers Stream Quality Monitoring Program in 1983. The techniques used were adapted from a component of the National Izaak Walton League's Save Our Streams Program which employs aquatic macroinvertebrate collection and analysis to determine stream water quality. Working with the Ohio Environmental Protection Agency, the Ohio Department of Natural Resources' Division of Natural Areas and Preserves refined and simplified the specific procedures involved to permit a wide range of individuals from young to old the opportunity to quickly become stream quality monitors.

The technique of using riffle-dwelling macroinvertebrates as indicators of water quality is hardly a new phenomenon. There are a number of approaches available using sophisticated equipment and complicated indices that yield highly reliable information. The drawback with these methods is the expense of the equipment and the high level of taxonomic skills and time required by the investigators. Since the analysis often requires precise counts of organisms that are collected, a considerable amount of off-location work is usually necessary. Citizen volunteers are generally not trained aquatic ecologists, nor do they want to invest an exorbitant amount of time on a given project. On the other hand, a de-sophistication of the biological approach to water quality determination can reduce the reliability of the information that is derived. The challenge of arriving at a compromise between ease and simplicity of approach and accuracy of information was met; however, not without some trial, error, and adjustment in the early years.

Ohio Stream Monitoring Procedure

The initial analysis procedure that the Ohio Stream Quality Monitoring Program employed was based not only on qualitative data, but quantitative as well. A problem soon became apparent as participants began to question the validity of the results because of vast differences in individuals' estimates. Some observers would estimate from 75 to 100 mayfly nymphs, while others would often expand their "guesstimate" to as many as 800 to 900. More often than not, this would result in significantly altering the stream quality rating based on nothing more than difference of opinion. Very small organisms, such as young mayfly nymphs, midge larvae, riffle beetles, and others often in very great numbers seemed virtually impossible to accurately quantify without an actual count.

The problem was solved in 1985 when the procedure was modified to an easier means of analyzing the collection by switching to an index system that required only qualitative analysis. The new system also established a cumulative index value of stream quality that is derived from the summation of individual values assigned to each taxa depending upon whether the organism is tolerant to pollution, intolerant, or somewhere in between. The new method caught on very quickly with all participants, and dramatically increased the popularity of the program.

The primary goal of the Ohio Stream Quality Monitoring Program is to educate Ohio citizens, young and old, as to the importance of stream systems as complex biological components of the environment, and the value of protecting these natural resource treasures. Although the data received is extremely valuable for monitoring stream health, seldom do we encounter any surprising or revealing situations depicting stream degradation. This is largely because, to date, all monitoring activity has been confined to streams that are components of the Ohio Scenic Rivers System, and these aquatic resources are usually prime examples of streams with high water quality and aquatic diversity. However, by extensively publicizing the efforts of the hundreds upon hundreds of people involved in the program, community awareness of the rivers' importance increases. This, in turn, builds an impressive constituency for any river preservation effort, and dictates to the industrial and commercial entities, as well as public agencies, a strong community attitude and concern for stream protection.

Station Selection

The Ohio Stream Quality Monitoring Program currently operates on 150 stations on the ten designated state scenic rivers. The criteria by which stations are chosen include suitability of habitat or bottom substrate composition, the location of the area as to potential impacts for developments, industrial or municipal discharges, tributary stream entry points, as well as accessibility and accommodations. In Ohio, trespassing considerations must be addressed as most streams are bordered by private property. It is generally unwise to assume that a participant's perception of the value of stream quality monitoring will necessarily be shared by a streamside property owner. Nothing can destroy the enthusiasm and enjoyment of citizen volunteers more quickly than a confrontation with an angry landowner.

Sample Collection

The actual collection procedure is quite simple, consisting of the placement of a fine mesh seine in a stream riffle area, then thoroughly disturbing roughly a 3 by 3 foot area to dislodge the organisms residing in the area. Since the nine square-foot sample serves to represent the community structure of that entire section of stream, additional samples in other areas of the riffle increase the reliability of the data. Furthermore, the casual observation of those organisms dwelling in shallow water along the stream's edge, or in bordering vegetation, further augment the data, giving a truer picture of the overall macroinvertebrate community. Although the presence of taxa observed is recorded on the station data form by placing an estimated count letter code in the corresponding block, this quantitative estimate is not used in determining the stream quality rating. The purpose of the estimated count is to provide the administer-ing agency with a long-range perspective of the relative abundance and population changes of the macroinvertebrate community.

The 20 taxa of aquatic organisms that are collected are identified only by type, such as mayfly nymphs, stonefly nymphs, caddisfly larvae, or in some instances by the more frequently observed representatives of a certain family or order, such as crane fly larvae and black fly larvae. Even so, the most difficult and intimidating aspect of the entire program troubling virtually all participants is the discomfort of not being sure of identifying all of the organisms. With several training sessions and reassurance from program personnel, however, most participants begin to quickly build their confidence level. Even should some groups never develop a high proficiency in the identification procedure, extreme variance in the reported index values for a given station along with periodic station checks by program personnel, quickly reveal where errors are being made and further training is necessary. There are currently plans to improve the visual aids used in the program for macroinvertebrate recognition.

Base reference collections of organisms preserved in alcohol are being prepared for use at workshops and training sessions. An improved version of the identification sheet depicting different forms of organisms as well as relative sizes is being prepared. A more ambitious undertaking will be the preparation of a durable and easy to use plastic block containing embedded and labeled specimens.

Equipment and Funding

Equipment costs for the Ohio Stream Quality Monitoring Program have been kept at a minimum. Custom designed, one sixteenth inch nylon mesh seines are sewn locally at a cost of around $15.00. Poles for the nets (hoe and shovel handle discards) are donated by Union Fork and Hoe Company in Delaware, Ohio. A Rubbermaid Serve and Store container with a thermometer, plastic specimen cubes, and a magnifying glass purchased from an educational supply company round out the major equipment for an additional $10.00.

Funding for the program has generally come from a combination of general revenue funds (upper and middle level administrative staff time) and monies allocated from a state income tax refund checkoff program. Annual equipment and administrative costs for four seasonal part-time stream monitoring coordinators have averaged $25,000. Additional equipment and promotional support was made available from the National Izaak Walton League through a grant from the Virginia Environmental Endowment.

Data Use

All participants of the Ohio Stream Quality Monitoring Program complete a stream quality assessment form representing one or more sampling per station per day. Additional information such as water temperature, stream conditions, substrate composition, and chemical data if obtained (not required) is provided. These assessment forms are periodically forwarded to the Ohio Division of Natural Areas and Preserves Central Office headquarters where they are carefully checked and entered on computer. At the end of the monitoring season, which generally extends from April to November, all data is printed out chronologically by station which is included in a statewide report to all monitoring groups and other interested agencies and individuals.

When the program was initiated, it was not at all surprising to find that the majority of participants were schools and conservation groups. Indeed, today they still comprise roughly 50% or more of the total stream monitoring force. What was surprising and encouraging, however, was to see the popularity of the program spread to groups and individuals one would not normally associate with environmental monitoring, such as League of Women Voters, Big Brothers/Big Sisters, Inc., 4-H Clubs, YMCA, Senior Citizen Centers, as well as individual families. During 1988, nearly 4,000 men, women, and children participated in the stream quality monitoring effort. Plans are currently underway to expand the program to other streams in the state because of the rapidly growing popularity of stream quality monitoring. As budget restraints and program restrictions cannot permit the Ohio Scenic Rivers Program to service requests outside the system of designated streams, other agencies and organizations have been sought to provide the outside administration needed. Under a cooperative agreement, the Ohio Department of Natural Resources will continue to work with several of Ohio's Soil and Water Conservation Districts during 1989, as was done in 1988, to determine the feasibility of locally administering this program.

The Soil and Water Conservation Society has an obvious interest in water quality and has traditionally been involved with environmental education, is a likely candidate to assist in the extension of the Ohio Stream Quality Monitoring Program. Other possible avenues of local and regional administration might be through the environmental education outreach programs of colleges and universities, as well as through community environmental and conservation organizations willing to provide the necessary coordination and training of participants.

Wisconsin's Self-Help Lake Monitoring Program: An Assessment from 1986 to 1988

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Abstract

Over 200 lakes are monitored in Wisconsin by citizen volunteers as part of the "Self-Help Lake Monitoring Program." Now in its fourth year, volunteers are trained by DNR staff to collect Secchi disc data every two weeks between May and October. Other observations recorded include water color, lake level, public perceptions of water quality, and weather. Data are sent to the DNR; individual lake reports and a statewide summary report are published each year. The data are used by DNR biologists in conjunction with other lake monitoring efforts, in preparation of water quality basin plans, in updating water quality data bases, and in developing water quality standards for lakes. Data are also used by the U.S. Geological Survey, County Land Conservation Districts, and County Extension Agents.

Keywords: Wisconsin, citizen monitoring, water quality, volunteers, lakes

Introduction

Wisconsin's Self-Help Lake Monitoring Program is one of many programs around the country utilizing citizen volunteers to monitor lake quality. This program is one part of the state's Lake Management Program, administered by the Department of Natural Resources (DNR) (Rumery and Vennie 1988). The Self-Help Monitoring Program has grown steadily since its inception in 1986, and at the end of 1988, about 210 lakes were being actively monitored (Figure 1).

The DNR has formally recognized that protecting and managing the State's natural resources is far too great a job for it to do alone. It is essential to share this responsibility with citizens, private enterprise and public officials alike (Besadny 1988). The DNR also recognizes the need to focus some of its attention on information and education to achieve that goal. The Self-Help Monitoring Program is an example of how these goals are being implemented. With 15,000 lakes in Wisconsin, it is not possible for the DNR to monitor, much less manage, each and everyone. Yet, the use of volunteers in a formal and systematic way has enabled the DNR to not only add to its lakes data base, but also to educate its citizens about lakes, monitoring, management, and decision-making.

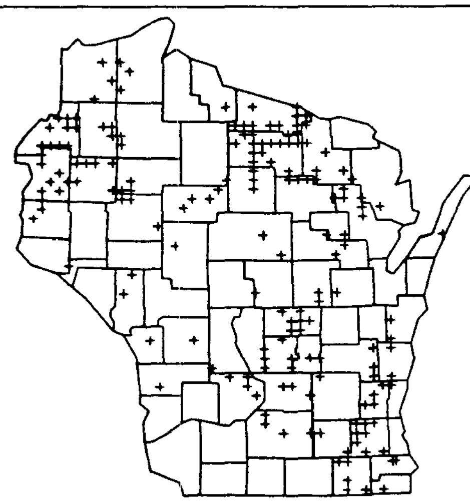


Fig. 1. Wisconsin's Self-Help Monitoring Lakes in 1988

The Self-Help Monitoring Program

The Self-Help Monitoring Program was initiated to give citizens an active role in lake management activities and to assist the DNR with basic data collection on at least some of Wisconsin's 15,000 lakes. In 1988, 210 lakes were monitored, an increase from 175 lakes in 1987 and 129 lakes in 1986. The goals of the program are:

1. To teach citizen volunteers some basic concepts of limnology, and to increase their understanding of local lake water quality.

2. To teach citizens about basic lake sampling techniques, specifically how to use a Secchi disc according to set procedures.

3. To document changes in water clarity over time by recording the data on a centralized computing system and preparing individual lake reports and an annual statewide report.

4. To differentiate between normal seasonal variations in water clarity and long-term trends to determine whether water clarity, and presumably water quality, is getting better, getting worse, or staying about the same.

5. To compare the water clarity data for all the lakes in the program on both a regional and statewide basis.

6. To collect data accurately over time to make sound lake management decisions.

Getting Started

Volunteers learn about the Self-Help Monitoring program through district personnel, a brochure about the program, general interest articles in the popular media, as well as through word of mouth. After initially contacting the DNR, the volunteer will receive a letter in the mail confirming their commitment to monitor their lake. They are contacted again early in the spring of the sampling season and a training session is arranged at the volunteer's house, a local park or other mutually convenient location.

At the training session, volunteers are given a training manual which is updated each year, a Secchi disc, data post cards which are pre-printed and postage paid, and data sheets for the volunteer to keep for his or her own records. The training manual contains a fully illustrated set of step-by-step instructions on how to take the Secchi disc readings, how to read the staff gauge, and how to fill out the data post cards. It also contains a map of their lake showing where they should take the Secchi disc reading. Also included is a 40-page booklet entitled The Lake in Your Community (Klessig et. al. 1986) providing a background on basic limnology. The training sessions provide all volunteers with a consistent methodology for collecting the data, allows them to practice using the Secchi disc with a WDNR staff person watching, and provides a future contact person for the volunteer.

Group training sessions are also scheduled at various locations around the state, particularly in the north central and southeast parts of the state to expedite the training process. In the group sessions, between 3-10 volunteers get together at one location to see slides describing the program and to go out in a boat (usually in groups of 2) with the DNR staff person to take some practice Secchi disc readings. In this way, a large number of volunteers may be trained over one weekend in an efficient and economical way. It also allows volunteers to meet each other and exchange experiences. As a last resort, some volunteers may receive their Secchi discs and related training materials in the mail due to unsolvable schedule conflicts.

Volunteers also receive bimonthly newsletters in the mail between May and November, written in layperson's language covering topics related to the Self-Help Monitoring Program only. A separate newsletter ("Lake Tides"), devoted to more generalized lake topics, is distributed by the University of Wisconsin-Extension to this group and others (UWEX no date). The Self-Help newsletter provides a forum for information exchange, a chance for the volunteers to get to know some of their fellow volunteers through short "personal profiles," and the opportunity to see graphs representing data trends on selected lakes statewide.

Data Collection

All volunteers are asked to measure the water clarity of their lake at least once every two weeks between Memorial Day and Labor Day each year using a Secchi disc. Other data collected include water color and weather observations. Lakes equipped with staff gauges, which are installed by the U.S. Geological Survey in a cooperative program are read by the volunteers on a daily basis. In 1988, a new parameter was added to the data base, asking the volunteers to record their perceptions of the water quality that day using a scale of 1 (best) to 5 (worst) (Table 1).

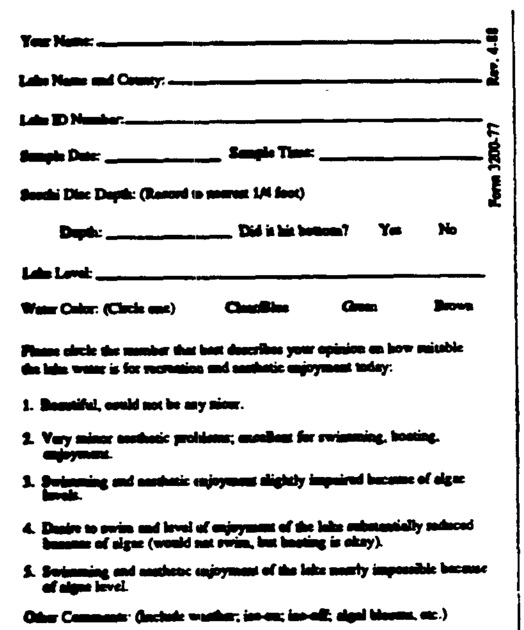
Data Cards

The data reporting cards (Figure 2) provide an easy way for the

Table 1 - Water quality perceptions.

Please circle the number that best describes your opinion on how suitable the lake water is for recreation and aesthetic enjoyment today: (Heiskary and Walker 1988)

1. Beautiful, could not be any nicer.
2. Very minor aesthetic problems; excellent for swimming, boating, enjoyment.
3. Swimming and aesthetic enjoyment slightly impaired because of algae levels.
4. Desire to swim and level of enjoyment of the lake substantially reduced because of algae (would not swim, but boating is okay).
5. Swimming and aesthetic enjoyment of the lake nearly impossible because of algae level.



Your Name:

Lake Name and County:

Lake ID Number:

Sample Date: Sample Time:

Secchi Disc Depth: (Record to nearest 1/4 foot)

Depth: Did it hit bottom? Yes No

Lake Level:

Water Color: (Circle one) Clear/Blue Green Brown

Please circle the number that best describes your opinion on how suitable the lake water is for recreation and aesthetic enjoyment today:

1. Beautiful, could not be any nicer.
2. Very minor aesthetic problems; excellent for swimming, boating, enjoyment.
3. Swimming and aesthetic enjoyment slightly impaired because of algae levels.
4. Desire to swim and level of enjoyment of the lake substantially reduced because of algae (would not swim, but boating is okay).
5. Swimming and aesthetic enjoyment of the lake nearly impossible because of algae level.

Other Comments: (Include weather; ice-on; ice-off; algal blooms, etc.)

Form 3200-77 Rev. 4-88

Fig. 2 Data summary post card.

volunteers to report the data back to the DNR because they are self-addressed and postage-paid. In addition to recording the basic data (date, time, Secchi depth, and lake level), the reporting format allows space for the volunteer to write special comments (usually weather observations) or to ask questions of the DNR. Typical questions are "Why does the Secchi depth increase after a rainstorm?" or "Is my lake sensitive to acid rain?" These questions are answered individually and are sometimes shared in the newsletter.

The most frequent request was "Send more cards"; although each volunteer is equipped with 15 data cards, some volunteers sample as many as 26 times in one season. In 1986, a total of 1580 Secchi disc observations were reported by the volunteers back to the DNR. In 1987, that number had increased to 2500, and in 1988, about 3500. While some volunteers will sample their lake from ice out to freeze up, the most critical observations are those taken in July and August—the prime recreational months and peak times for algal blooms. In early July of each sampling season, volunteers who have not sent in their data cards on a regular basis are sent a letter reminding them that the most important time to collect data is in July and August. The response rate to this reminder letter has been impressive.

Data Management

All of the data recorded on the post cards are stored on an IBM TM personal computer using the LOTUS 1-2-3 TM software program. The data entry process is simplified and sped-up through a special program or macro we designed. Since the data are entered as the cards are received, the data entry process is completed when each volunteer sends in their last card. When all the data are entered, other specially written programs are used to analyze and summarize the data for a statewide report, and for those volunteers in the program for the first year, an individual report.

A second data source used for report preparation are responses to a questionnaire sent out to each volunteer at the end of the sampling season. The questions are broken up into three categories: 1) their overall opinion about the volunteer monitoring program and their participation in it; 2) the problems they perceived on their lake during the past sampling season; and 3) the overall uses of the lake and surrounding land. The response rate to the questionnaire has also been very strong (86% in 1987). These responses are also entered into the computer using the LOTUS 1-2-3 program.

The third data source used to prepare each individual lake report is historical surface water resources inventory data collected by the DNR and published in a set of reports (WDNR 1961-1985). These data are downloaded onto the personal computer from the mainframe. These data describe basic characteristics of each lake such as size, depth, length, width, volume, watershed size, and fisheries.

More current pH and alkalinity data collected by the U.S. Environmental Protection Agency (Kanciruk et al. 1986) replace the older data.

Report to First Year Volunteers

In February or March following the sampling season, each person who has collected data on their lake for the first time, and who has collected data at least four times, will receive an eight-page report specific to their lake written in layperson's language. This report is prepared using the LOTUS Symphony TM software program because of its flexibility and ability to generate form-type reports quickly. The data the volunteer collected during the sampling season are integrated with the Surface Water Inventory data and responses to the questionnaire the volunteer sent in. Carefully written explanations that the lake's water clarity is only one indication of water quality are included in the report, as well as explaining that it is difficult to draw conclusions about the trends of the lake's water clarity, much less overall water quality, with only one year of data. At least five years of data will allow us to begin to differentiate between long-term trends and seasonal or cyclic variations.

Several steps are taken to ensure the comprehensibility of the report to the volunteer. First, each report is written as a letter to the volunteer to make the format friendly and personal. Second, the graphical presentation of the Secchi disc data depicts a Secchi disc being lowered into the water column (Figure 3). This visual representation allows each volunteer to see how the Secchi depth changed over the sampling season. Third, the data the volunteer collected are summarized and tabulated in a format based on several reports in the literature (USEPA 1980; Lillie and Mason 1983). That is, water clarity categories were developed using the words excellent, very good, good, fair, poor, and very poor. The volunteer is told what percentage of the time the data he or she collected fell into each category. This information is presented in a table format and summarized in a sentence such as, "In other words, 80% of the time you collected data, the water clarity of your lake was very good, 14% of the time, it was good, and 6% of the time, it was fair." Thus, for those who may have trouble interpreting the table, a written explanation is provided.

Table 2. Water clarity ranking.

Description	Secchi Depth
Excellent	>20 ft.
Very Good	10-20 ft.
Good	6.5-10 ft.
Fair	5-6.5 ft.
Poor	3.25-5 ft.
Very Poor	<3.25ft.

Press Release

An individual press release is also sent to each volunteer along with the report. The volunteer is asked to send the press release to their local newspaper order to see their names in print as a reward for all of the hard work they did during the sampling season. In turn, we receive copies of the newspaper articles printed using the standard press release. Through these articles, area residents are made aware that a neighbor or local resident is taking the time to monitor their lake and that there is a report available to help them learn more about their lake. These people in turn write to the DNR to request copies of the individual report about their lake. In 1987, we received over 100 requests for reprints.

Statewide Report

A statewide summary of all the 1986 data collected was published in a one volume report (Rumery 1987). A second data report for all 1987 and 1988 data was also published (Rumery 1989). This report includes 1986, 1987, and 1988 data for those lakes where data have been collected for all three years; otherwise it includes data for only those years available. One page is devoted to each lake and includes: the number of Secchi disc observations taken each summer; the minimum and maximum Secchi depths for each season; the dates on which those extremes were observed; and the average summer Secchi depth per sampling season. The summer average is calculated using data from the months of June, July and August.

A table using the water clarity descriptors shown in Table 1 are presented so that each of the three years of data can be compared. This table only uses the June, July and August data since those are the months when algal blooms are most prevalent, they are the busiest recreational months, and they are also the months when most data are available.

Finally, a graph showing three years of data (where available) is presented on each page (Figure 3). Even when only one or two years of data are available, the same scale is used such that a quick flip through the book allows one to make assessments about the variation in water clarity on a large number of lakes in the state.

At this point, it is still difficult to make any hard and fast conclusions about the data that are being reported since at most, there are only three years of data. In addition, since 1988 was a drought year, little runoff to the lakes occurred resulting in particularly high water clarity. Despite that phenomenon, it is apparent that in general, the water clarity on most of the lakes is similar from one year to the next. The regular Secchi disc readings show similarities in minimum and maximum values reflecting algal blooms typical to that lake.

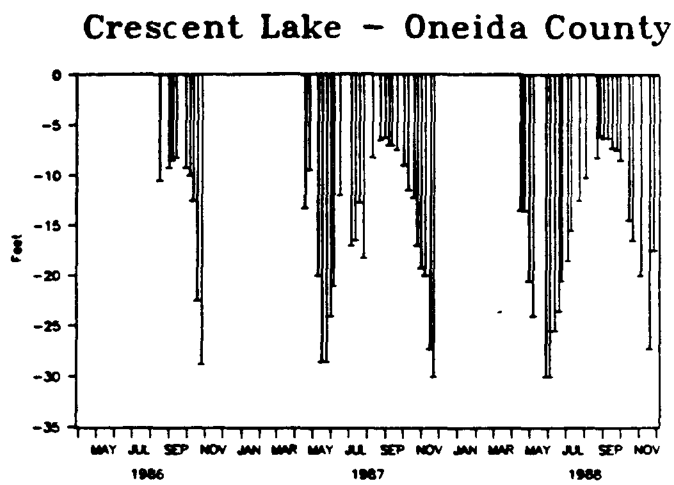


Fig. 3. A 3-Year Data Summary Plot

Data Users

Along with the volunteers, it is apparent that there are other data users interested in the Wisconsin Self-Help Lake Monitoring Program. First, the data are used in conjunction with the DNR's Long-Term Lake Monitoring Program where 50 lakes are being monitored for a period of ten years. DNR biologists monitor these lakes five times a year, testing for biological and chemical parameters. The data the volunteers collect assist in monitoring algal blooms or storm events that our own biologist may miss. The volunteer's data are used in the reporting process for that program.

Second, the data are being used by DNR district personnel in updating existing data bases, or in some cases, in establishing a data base for the first time. This information may prove to be indispensable in future management decisions, and is already proving useful to gain an overall picture of the health of a lake. It is currently used in answering questions the public has on the overall water quality of a lake, with the intention of buying property near the lake.

Third, DNR personnel are also using the data in the preparation of water quality basin plans. The summer water clarity averages (June, July and August data) are being used to define the trophic status of all lakes identified in the state's many basin plans. Phosphorus and chlorophyll data are taken from other sources. This information will be used to identify those water bodies which should receive management attention in the future. In some cases, these data may be the only information available to DNR biologists, or may update a data base that is twenty or more years old.

The U.S. Geological Survey is a fourth user of the data. The USGS has installed staff gauges on about 25 lakes throughout the State where they are most interested in tracking lake level information. These data are collected by the volunteers, sent to and tabulated by the DNR, and forwarded to the USGS where a correction factor is applied. The data are published on an occasional basis (House 1985).

Other users include each of the 72 counties via their Land Conservation Districts. In the southwestern portions of the State where soil erosion has proved to be of particular concern, volunteers have been helpful in documenting the effects of storm events on water clarity.

The data involving the volunteer's perceptions of water quality were solicited with future uses in mind. In particular, this information could be used in developing water quality standards for lakes. A similar approach was used in 1986 when residents around Delavan Lake in southeastern Wisconsin were asked their opinions of acceptable water clarity (IES 1986). This information was used in developing management goals for that lake. The approach used to monitor people's perceptions of water quality was intentionally the same methodology as those used by Vermont and Minnesota. Hopefully the perception of what people find acceptable and unacceptable will be applied on a geographical basis extending beyond the borders of Wisconsin.

Conclusion

Based on three complete sampling seasons, we consider the Wisconsin Self-Help Lake Monitoring Program a success attributed to many factors: agency commitment to the program, direct personal contact between agency staff and the volunteers, frequent communication between the DNR and the volunteers, the sense of ownership the volunteers feel toward the program, and the utilization of the volunteer's data by others besides the volunteers themselves.

The continuing success of the Self-Help Lake Monitoring Program, as well as other volunteer monitoring programs will largely depend the commitment of the sponsoring agency. The volunteers rely on one or more DNR employees to provide them with proper training and guidance. They look for correspondence throughout the sampling season and into the winter, and look forward to receiving reports summarizing the data. This requires that the DNR not just provide the volunteer the necessary equipment, but that we follow up on our end of the agreement. Evidence of this includes the overwhelming receipt of data following a reminder letter sent out in mid-July. Of course the volunteers must keep up their end of the agreement, too!

The future of the Self-Help Lake Monitoring Program is bright. Although the number of parameters the volunteers now collect is quite limited, the program may be expanded in the future. The program is supported by DNR administrators, and by the Governor as reflected in his most recent budget recommendations to the Wisconsin legislature. If the budget is increased, the program could expand by either increasing the number of volunteers who collect Secchi disc data, or by increasing the number of parameters that are being monitored.

The results of the end of the season questionnaire indicate that over 80% of the volunteers are more than willing to collect more than the Secchi disc data. Volunteers are constantly asking for information on where they may purchase kits to collect dissolved oxygen data, pH data and other data. The program could be expanded to a two-tiered approach in that some volunteers could be involved in a more intensive monitoring effort than those taking just the basic Secchi disc readings. However, again, this involves the commitment of the sponsoring agency to administer the program, provide the proper training to use the new equipment, and most importantly, in the data management and reporting processes.

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A Summary of the First Midwest Pollution Control Biologists Meeting

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Abstract

The first Midwest Pollution Control Biologists Meeting was held at the Congress Hotel, downtown Chicago, during February 14-17, 1989. The purpose of this meeting was to gather regional environmental biologists at various government agencies to provide a forum for discussion and technical paper presentations. Approximately 100 biologists attended the 38 presentations and five discussion groups. The presentations and discussion groups addressed the following five topics: citizen monitoring, inland lakes and wetlands, Great Lakes and harbors, biocriteria, and hazardous waste sites.

Keywords: MPCB, USEPA Region V, Meeting, Pollution Control Biologists

Introduction

After the successful national workshop on instream biological monitoring and criteria that Region V's Instream Biocriteria and Ecological Assessment Committee co-hosted and coordinated in December 1987, it was apparent that the content and enthusiasm of that meeting should be focused for midwestern regional environmental biologists. Actually, USEPA Region's I and II, III, and IV have been holding regional pollution control biologist meetings for many years, and those meetings have improved the communication and relationship among the government agencies and private interests. This meeting was organized to provide an overview of the State regulatory biology programs within Region V, case studies of successful applications of regulatory biology, technical papers on selected topics, and follow-up discussions of issues relating to the technical paper topics.

We were fortunate to have Dr. James Karr, from Virginia Polytechnic Institute, present a very critical keynote address regarding the application and implementation of instream biological monitoring and criteria data in USEPA programs. The State program overviews highlighted the successful use of existing programs and the development of newer programs. The technical presentations and subsequent discussion groups addressed the following five topics: citizen monitoring, inland lakes and wetlands, Great Lakes and harbors, biocriteria, and hazardous waste sites.

Discussion Groups

Each discussion group met for a minimum of two hours following the close of the technical sessions, and most groups met for a portion of the following morning. Each discussion group leader was asked to prepare a list of issues for which recommendations would be made by consensus. The recommendations for each group are presented below.

Citizen Monitoring Discussion Group Recommendations

Meg Kerr (USEPA Office of Water) and John Kopec (Ohio DNR) led this discussion group. The group acknowledges that three key problems existed for implementing citizen monitoring programs: (1) limited resources (equipment and staff), (2) lack of recognition with the State regulatory agency, and (3) lack of coordination between State agencies involved with natural resource protection. To reduce these concerns, the group recommended that:

1. The recommendations made to USEPA by the May 1988 Workshop on Citizen Monitoring (held in Rhode Island) be implemented.

2. USEPA should include citizen monitoring in the 305(b) process and (1) encourage the use of citizen monitoring data through the 305(b) guidance documents, and (2) encourage the States to solicit comments on 305(b) assessments via public hearings and distribution of draft 305(b) reports.

3. USEPA should designate national and regional citizen monitoring coordinators. Regional coordinators would:

   - help States promote citizen monitoring in national and local media
   - coordinate citizen monitoring activities with non-EPA State and Federal agencies
   - provide technical assistance to citizen monitoring groups
   - serve as an information clearinghouse
   - coordinate equipment purchases to increase cost effectiveness of large purchases
   - provide information on funding sources and opportunities

4. Regional environmental education coordinators are encouraged to promote citizen monitoring activities through the EPA Environmental Youth Award Program.

5. USEPA is encouraged to investigate and promote the use of graduate students, EPA interns, and retirees for assistance to State citizen monitoring programs. These people could assist with:

   - in-depth analysis and validation of volunteers data. Many States don't have the time to perform rigorous analysis of their data. Results should be published in peer-reviewed journals to enhance professional acceptance of citizen monitoring programs.
   - development of training materials.
   - development and refinement of monitoring methods.

6. USEPA should write an article(s) in the EPA journal about citizen monitoring.

7. Citizen monitoring should be incorporated into future EPA Monitoring Symposia.

<u>Biocriteria Discussion Group Recommendations</u>
Larry Shepard (EPA-Region V, IBEAC) and Linda Holst (EPA-Region V, IBEAC) were the discussion group leaders. Recent developments on biocriteria issues brought to our attention at the National Workshop on Biological Monitoring and Criteria (December 1987) and as a result of recent efforts to develop a national biocriteria policy. The discussion covered five topics: (1) the "weight-of-evidence" approach

versus the "triple-jeopardy" approach, (2) numerical versus narrative biocriteria, (3) non-point sources, (4) application of biocriteria to lakes, wetlands, large rivers, and estuaries, and (5) quality assurance and quality control concerns. A consensus was reached that the formation of a Region V technical workgroup for biosurveys (similar to the Regional Biomonitoring Task Force) would help to standardize methods and promote the usefulness of biosurveys with the Region.

The following are specific recommendations from the discussion group:

1. An integrated approach (i.e. weight-of-evidence) should be used to develop NPDES permit limitations. This approach fully utilizes toxicity test, biosurveys, and chemical-specific information and bases the regulatory decisions on the quality and quantity of the data. This approach is recommended instead of the "triple jeopardy" approach which uses any single piece of information as evidence of use impairment. The weight-of-evidence approach has successfully been applied in the State of Ohio and is relatively conservative since anti-degradation is strictly enforced and the decisions require a demonstration of use attainment by more than one biological measure. We should continue to encourage the inclusion of biosurvey information in the wasteload allocation process.

2. The incorporation of biological surveys into State programs should be encouraged but not required. Whether to use narrative or numerical biocriteria in State water quality standards should be decided by the individual States that will have to implement and enforce the program.

3. The importance of biocriteria in identifying problem areas (i.e. non-attainment) due to either point or non-point sources should continue to be stressed. Biocriteria can be used both to show the level of impairment in a waterbody and to identify goals for attainment.

4. The use of biosurvey techniques and biocriteria should not be limited to small rivers, but should be expanded to lakes, wetlands, large rivers, and estuaries. The current techniques for evaluating small, lotic systems can be modified to be applicable to other systems once the mechanics of the appropriate metrics are formulated.

5. Concern over QA/QC procedures for biosurveys will be greatly reduced if States develop and document standard field and data evaluation methods. If these methods are in place, there is no reason why the quality control for biosurveys should be any more problematic than for chemical monitoring and toxicity testing.

Great Lakes and Harbors Discussion Group Recommendations

The discussion group leader was Glenn Warren (USEPA, GLNPO). Several aspects of Great Lakes biomonitoring and bioassessment were discussed in this session. The Great Lakes represent a range of habitats and sampling difficulties for biological assessment and monitoring. Currently, very little development work has been done on biosurvey methods addressing the specific problems in the Great Lakes. Our recommendations are:

1. Develop benthic macroinvertebrate and fish community-based indices for the nearshore and harbor areas. Ideally, these indices could be used in any of the Great Lakes, taking into account inter-lake differences, and provide an economical tool.

2. Utilize the sediment quality triad approach to provide accurate assessments of sediment contaminant problems. Although the expense of this approach may preclude it from general use, it should be used in those circumstances in which it would provide the most useful data.

3. Multiple tests should be encouraged for problem identification including community-based and in-situ toxicity tests.

Hazardous Waste Site Discussion Group Recommendations

The discussion group leaders were Wayne Davis (USEPA Region V) and Dave Charters (USEPA, Headquarters Office of Superfund). The primary topic of discussion was the establishment of a Biological Technical Assistance Group (BTAG) in Region V to provide the Office of Superfund with expert assistance on biological assessment issues. BTAGs successfully function in EPA Region's 2 and 3 and are being encouraged by EPA Headquarters for implementation in each region. The recommendations of this discussion group were as follows:

1. Region V should establish a Biological Technical Assistance Group for Superfund. This group should be chaired by the Environmental Sciences Division and coordinated by the Office of Superfund Region V.

2. The BTAG would address the technical issues of biological assessments such as biological resources, fate and transport mechanisms that affect those resources, and mitigation design.

3. The BTAG would function as an advisory group to the Superfund Remedial Project Manager (RPM) and provide technical recommendations.

4. The RPM would have the authority to either accept or reject the BTAG recommendations.

5. The BTAG would not act as a forum for Natural Resource Trustee issues.

6. The BTAG should have representation from EPA Region V Divisions and Offices, the State regulatory agencies, Department of Interior including the Geological Survey and the Fish and Wildlife Service, and the Department of Commerce including NOAA. Other participants would be added as deemed necessary.

7. Region V's Superfund Office should address ecological concerns in a realistic and technically acceptable fashion in each project than comes to their attention.

Inland Lakes and Wetlands Discussion Group Recommendation

The discussion group leaders were Wayne Gorski (USEPA Region V) and John Schneider (USEPA Region V). The following recommendations were presented.

1. Comprehensive standards should be developed for lakes and wetlands that includes a suitable biological index for habitat assessment.

2. Local units of government/generators should be held responsible for the control of nuisance conditions that affect the proper functioning of wetlands and lakes.

3. A system of transferable development credits by local units of government should be implemented to facilitate the control of inappropriate land uses within their jurisdictional boundaries.

Participants and Meeting Abstracts

The abstracts of papers presented at the meeting but not appearing in the proceedings appear in Appendix 1. A list of the registrants and participants to the meeting (excluding the keynote and welcoming addresses) appears in Appendix 2. Plans for the next Midwest Pollution Control Biologists Meeting, in the spring of 1990, will include wide participation by private-sector biologists.

Acknowledgements

We greatly appreciated the support from all of the professionals involved in this meeting, in particular our discussion group leaders and technical session moderators. Special thanks to Mike McCarthy and his staff from Research Triangle Institute for making many of the crucial arrangements for the meeting and some of the participants. Thomas Simon provided a great deal of support for the planning and coordination of the meeting. This meeting was funded by USEPA's Assessment and Watershed Protection Division in Headquarters and hosted and coordinated by USEPA Region V's Instream Biocriteria and Ecological Assessment Committee.

Appendix 1. Abstracts of papers presented at the 1989 Midwest Pollution Control Biologists Meeting not appearing in the proceedings.

Toxicity of Sediments from the Fox River and Green Bay, Lake Michigan Gerald T. Ankley, Albert Katko, and John W. Arthur U.S. Environmental Protection Agency Environmental Research Laboratory 6201 Congdon Blvd. Duluth, MN 55804.

The Fox River/Green Bay system has been heavily impacted by pollutant inputs from both point and nonpoint sources. The objectives of this study were to evaluate the toxicity of sediment-associated contaminants from 13 sites within the system and identify causative toxic agents. Interstitial (pore) water from sediments at several sites produced both acute and chronic toxicity to Ceriodaphnia dubia, Pimephales promelas, and Selenastrum capricornutum. Manipulation of the pore water indicated that the observed toxicity was pH-dependent and could be reduced by a zeolite resin, suggesting the presence of ammonia. Measurement of ammonia in the pore water revealed concentrations sufficient to result in a significant degree of the observed toxicity. The implications of these results in terms of sediment toxicity assessment will be discussed.

Recent Water Quality in the Grand Calumet River Basin as Measured by Benthic Invertebrates. Greg R. Bright Indiana Department of Environmental Management 5500 W. Bradbury St. Indianapolis, IN 46241.

The Grand Calumet River and Indiana Harbor Canal in northwest Indiana are seriously polluted tributary and harbor areas on Lake Michigan. Biologists from the Indiana Department of Environmental Management collected benthic invertebrates from the basin during the summers of 1986-88 to document local conditions, to help determine causes of biological stress, and to provide a baseline for measuring future changes. Collections were made on artificial substrates. The benthic communities observed each year indicated stress from both low dissolved oxygen and toxic substances. Although the sediments are highly contaminated with metals, stress from metals toxicity was less likely than from cyanides and/or polycyclic aromatic hydrocarbons. The most biologically depressed site received wastewater from a large steel mill and from combined sewer overflows and generally had the most highly contaminated sediments. The benthic community appeared least stressed in 1986, when Lake Michigan water levels were at historic highs. Similar studies done since 1979 show that water quality in the Grand Calumet River Basin has improved markedly since that time.

The Ohio Lake Condition Index: Integration of Biological Parameters into an Overall Assessment of Lake Condition. Bob Davic Ohio EPA, WQM&A 2110 E. Aurora Rd. Twinsburg, OH 44087.

In order to comply with the 1988 USEPA 305(b) report, the Ohio EPA developed a multiparameter lake classification protocol to assess the overall condition of its 417 public lakes. The index is comprised of 13 parameters that represent four general categories of lake condition: biological, physical, chemical, and public perception. Biological parameters include nuisance growths of macrophytes, fecal coliform bacteria, primary production based on chlorophyll a, fish tissue contamination, and a yet to be developed fish index of biological integrity. Different sets of biological parameters are used to determine attainment of the fishable vs. swimmable Clean Water Act goals.

Superfund's Biological Technical Assessment Group (BTAG): Its Goal and Function Within Region II. Roland B. Hemmett, Chief Ambient Monitoring Section and Mark D. Sprenger Surveillance and Monitoring Branch Environmental Services Division U.S. EPA, Region II Bldg. 209, Woodbridge Ave., MS-220 Edison, NJ 08837.

The concept of using a committee of regional expertise (the BTAG) to assist hazardous waste site managers with environmental issues has been effectively used for over 1 year in Region II. The Region II BTAG activities are initiated through the Environmental Services Division, but they include representation from a number of other Divisions, along with representatives from Headquarters as well as other Federal and State agencies. The BTAG addresses environmental issues that are of concern to site managers. The BTAG will assist at State lead, fund lead, enforcement, and removal actions, with the recommendations being made directly to EPA site managers. Through a cooperative effort between participating agencies and regional personnel, consensus recommendations are made that can reduce redundant and extraneous sampling. With the implementation of the new Hazardous Ranking System and increasing attention to the costs associated with actions at hazardous waste sites, the BTAG will play an increasingly important role in assisting hazardous waste site managers.

Bioassessment of Lake Erie Harbors and the Nearshore Zone Using Benthic Macroinvertebrate Communities
Kenneth A. Krieger Water Quality Laboratory Heidelberg College 310 E. Market St. Tiffin, OH 44883.

Benthic macroinvertebrates were sampled quantitatively in 1978 and 1979 in the nearshore zone including the harbors of Lake Erie between Conneaut and Vermilion, Ohio. Significant differences between harbor and nonharbor areas, as determined by the Mann-Whitney U test applied to average abundances of the taxa, coupled with pollution indices, revealed that the harbors were severely degraded, with at most moderate degradation elsewhere. The pollution indices relied on the abundance, proportion, or species composition of the oligochaetes. Chironomids, sphaerid clams, and snails also provided some indications of environmental quality. In 1988 and 1989, the benthic community is again being sampled in Cleveland Harbor and vicinity to confirm the extent of a suspected improvement in environmental quality since the 1978-1979 study. The present study should provide a finer spatial resolution of conditions in this smaller shoreline reach than the earlier study because of enhanced sample replication at each site and sampling both in the fall and spring.

The Usefulness of Ecoregions as a Framework for Biomonitoring of Fish in Wisconsin Streams. John Lyons Wisconsin Department of Natural Resources 3911 Fish Hatchery Rd. Madison, WI 53711.

Efforts to use biotic communities to monitor environmental degradation require a framework in which ''natural'' differences (i.e., differences not caused by degradation) among communities are taken into account. A landscape classification that divides the United States into ecoregions has been proposed by the U.S. EPA as such as framework. To evaluate the usefulness of this classification, I examined the correspondence between ecoregions and fish distribution in Wisconsin streams. Cluster and ordination analyses indicated that correspondence was better than expected by chance, and that different ecoregions tended to have different fish assemblages. However, the ecoregion classification was fairly imprecise, and within-ecoregion heterogeneity and among-ecoregion overlap in assemblage composition were substantial. A more precise classification of stream fish assemblages could be achieved using maximum summer water temperature, stream gradient, substrate, and riparian vegetation. This alternate classification requires detailed site-specific data and may not be valid for other States. I conclude that the ecoregion classification is useful as a broad-scale framework for monitoring stream fish assemblages over large geographic areas of Wisconsin, but that a different framework is needed for smaller areas.

USEPA's Biological Criteria Guidance: An Update. Suzanne K. Macy Marcy, Ph.D. U.S. Environmental Protection Agency, Headquarters Criteria and Standards Division, Office of Water Regulations and Standards 401 M St., SW Washington, DC 20460.

The Criteria and Standards Division, within the Office of Water Regulations and Standards, is developing preliminary program and technical guidance documents on biological criteria development. Both documents will draw heavily from the experiences of States currently using and/or developing biological criteria. The program guidance document will outline alternative approaches for developing and implementing biological criteria within States; the technical guidance document will synthesize and describe research techniques used for assessing and comparing the biological integrity of surface waters. Subsequent work will entail revising and updating these documents based on new research; academic, State, and Regional review; and comments from those developing and/or implementing biological criteria.

Use of Hyalella azteca (Amphipoda) in Fresh and Saltwater Toxicity Testing Marsha Kelly Nelson and C. G. Ingersoll Department of the Interior U.S. Fish and Wildlife Service National Fisheries Contaminant Research Center Rt. 2, 4200 New Haven Rd. Columbia, MO 65201.

Bioassessment of contaminants associated with fresh and saltwater sediments and effluents can be determined using the amphipod Hyalella azteca. This euryhaline species is found naturally in freshwater, at H5 ppt estuarine salinity, and inland bodies of saltwater up to H22 ppt. This broad salinity tolerance facilitates testing a continuum of contaminated sediments and effluents from freshwater wells into saltwater environments. H. azteca is easily cultured, reproduces continually, and grows rapidly. Successful H. azteca cultures range in salinities from 0 to 15 ppt, and tests have been conducted in salinities from 0 ppt to 23 ppt (H30,300 ppm total water hardness as $CaCO_3$). The biological endpoints developed for acute and chronic exposures include survival, growth, and instar development. In solid-phase sediment exposures, H. azteca burrows into the sediment surface and is tolerant of a wide range of sediment textures. Laboratory static and flow-through, partial or full line cycle, sediment exposures provide useful toxicity information for a hazard assessment in pollution-degraded areas.

Development of a National Policy on the Use of Biological Criteria and Integrated Assessments in the Water Quality Program. James L. Plafkin U.S. Environmental Protection Agency, Headquarters Assessment and Watershed Protection Division 401 M St., SW Washington, DC 20460.

The draft National Policy on the Use of Biological Criteria and Integrated Assessments is outlined. Principal applications of biological assessments are identified and compared to their limitations. Information is presented on States using biosurveys in their base programs, those already interested in developing biocriteria, current State capabilities, and projected needs. Estimates of EPA Regional personnel needed to support the States are also summarized. Related activities involving revision of the Agency Operating Guidance, development of program and technical guidance, and proposed R&D initiatives are also discussed.

Ecological Assessment of Hazardous Waste Sites. Ronald Preston U.S. Environmental Protection Agency Region III 303 Methodist Bldg., 11th & Chopline Wheeling, WV 26003.

A thorough assessment of the environmental impacts from hazardous waste sites requires the collection and evaluation of ecological data characterizing effects to the biota associated with the site. While chemical analysis is an essential first step of hazardous waste site characterization, ecological data are also needed to assess impacts of the site on living resources, to allow future monitoring of cleanup effectiveness as a result of Superfund remedial actions, and to meet the information needs of responsible natural resource agencies. In order to address the need for ecological evaluations at Superfund sites in Region III, representatives from USEPA and Federal natural resource agencies have formed a ''Bioassessment Work Group'' that meets monthly to provide technical recommendations to Superfund project managers on biological studies that may be needed at specific sites. The review process performed by the work group includes evaluations of the contaminants of concern, characteristics of the site, and recommended ecological endpoints required to describe environmental impacts.

Assessing Sediment Contamination in Great Lakes Areas of Concern.
Philippe Ross Associate Aquatic Toxicologist Illinois Natural History Survey 607 E. Peabody Dr. Champaign, IL 61820-6970.

Section 118(c)(3) of the Clean Water Act of 1987 calls for the USEPA's Great Lakes National Program Office (GLNPO) to undertake a 5-year study and demonstration program for the assessment and removal of contaminants from Great Lakes Areas of Concern (AOCs), with emphasis on sediment pollutants. The program, called ''Assessment and Remediation of Contaminated Sediments (ARCS), represents a new direction in that in-place source contamination, rather than dredged material disposal, is the principal consideration driving the research. The main objectives of the program are to: (1) assess the nature and extent of contamination at key AOCs; (2) evaluate the potential efficacy of remedial technologies; (3) conduct field demonstrations of the most promising clean-up methods; and (4) provide cost and efficiency information for various remedial alternatives. The assessment phase of the project will have physical, chemical, and biological components. The biological work will entail both toxicological testing (a suite of bioassays recommended by the International Joint Commission) and in situ studies (benthic community structure, fish health, and abnormalities). The resulting data set will be suitable for use in integrative evaluation approaches.

The Role of Exotic and Indigenous Species in Wetland Bioassessment. John P. Schneider U.S. Environmental Protection Agency Region V 536 S. Clark St. Chicago, IL 60605.

Ecosystems subjected to exogenous stressors often respond with a change in species diversity. Diversity may decrease due to the loss of indigenous species or increase due to the invasion of species exotic to the ecosystem. The Index of Innate Diversity (IID) is a new index that sensitively measures such a shift in species composition. Suburban development is a major cause of wetland loss and degradation in the United States. In the New Jersey Pine Barrens, suburban engineering features alter the hydrology and water chemistry of adjacent cedar swamp wetlands. Quantitative measurements of species composition and community structure were collected, and the IID provided the most sensitive measurement of the wetland response to a gradient of stressors associated with suburban development.

Use of Integrated Ecological Assessment Techniques in Assessing Environmental Impacts at a Hazardous Waste Site. Mark D. Sprenger, David W. Charters, and Richard G. Henry U.S. Environmental Protection Agency Region II, Environmental Response Team and REAC/Roy F. Weston Bldg. 209, Woodbridge Ave., MS-220 Edison, NJ 08837.

Benthic invertebrate surveys, toxicity testing, and chemical analysis were conducted in concert to present an integrated assessment of the ecological impact of a hazardous waste site in New Jersey. Initial assessments of the site utilizing traditional techniques of chemical analysis in combination with literature toxicity values proved unable to distinguish the subtle changes occurring at the site. The integrated technique was able to distinguish subtle, but significant changes in the benthic community structure. Laboratory solid-phase toxicity tests run on sediment collected from the benthic survey stations also supported the conclusions of adverse impacts. Utilization of traditional techniques resulted in the erroneous indication that several miles of stream bed required remediation. The integrated approach showed that the remedial action could be restricted to the area adjacent to the site and an area only encompassing several hundred yards downstream.

A Preliminary Assessment of Biological Conditions in Lake Erie Estuary Areas of Ohio. Roger F. Thoma Ohio Environmental Protection Agency 1030 King Ave. Columbus, OH 43212.

At the present date, a total of 12 estuary areas of streams tributary to Lake Erie in Ohio have been sampled for fish community data at a total of 68 sites. The data collected have been analyzed using the Ohio EPA's Iwb (Index of well-being) and IBI (Index of Biotic Integrity) as delimited in the Ohio EPA's Users Manuals, Vols. I, II, and III. Conditions have ranged from an IBI of 14 on the Cuyahoga River (heavily impacted by municipal and industrial discharges) and Little Muddy Creek (a shallow mud flat area) to 41 on the Grand River (an exceptional warmwater habitat stream), with the Grand River having the highest average IBI score of 33.6. Index of well-being scores have ranged from 3.4 in the Cuyahoga River and Chagrin River (a shallow mud flat channel) to 8.9 on the Sandusky River, with the Portage River having the highest average Iwb score of 7.9. In general, biological conditions are most affected by water quality conditions and habitat. Those streams with the higher municipal and industrial discharge loadings had the lowest average IBI and Iwb scores (the Cuyahoga River had 16.3 and 3.9, respectively), while nonpoint problems were not as strongly expressed.

Appendix 2. List of the participants and registrants of the 1989 Midwest Pollution Control Biologists Meeting.

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