United States Environmental Protection Agency
Assessment and Watershed Protection Division
Office of Water
Washington, DC 20460
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# Water Quality Program Highlights

## Ohio EPA's Use of Biological Survey Information

### BACKGROUND

The Federal Clean Water Act has been amended numerous times since it was completely rewritten in 1972, but its principal goal remains unchanged: to restore and maintain the physical, chemical, and biological integrity of our surface waters. To achieve this environmental goal, we – EPA, the States, the regulated community, and the public – need information about the aquatic environment. We need information to help us develop meaningful yet workable water quality goals, wisely direct our limited resources to those waters that will benefit most from restoration or control efforts, and ensure that our efforts result in measurable environmental improvements.

EPA and State monitoring programs have historically relied on one type of information – measurements of individual pollutants in the water column. Only slowly have chemical analyses of the water column been supplemented by other monitoring methods. There seems to be a consensus today that to manage our remaining water quality problems cost-effectively, we must employ a variety of methods capable of assessing the impact of chemicals in tissue and sediment as well as in the water column, the condition of the physical habitat as well as water column chemistry, and the response of resident biota as well as laboratory test species.

### HIGHLIGHTS OF OHIO EPA'S MONITORING PROGRAMS

The Ohio Environmental Protection Agency (Ohio EPA) uses a combination of chemical, toxicological, and ecological approaches to monitor the quality of its rivers and streams. This Highlight focuses on Ohio EPA's Biological and Water Quality Survey (BWQS) Program, and briefly discusses Ohio's long-term ambient water quality monitoring network (NAWQMN). Both programs make use of integrated chemical and biological monitoring. In the early 1980s, the highest priority in the BWQS was evaluating the need for publicly owned treatment works (POTW) to install advanced treatment; the current priority is to evaluate nonpoint sources and assess toxicity due to point sources. The main use of the NAWQMN data is to evaluate the effectiveness of selected pollution control projects.

Because the biological component of Ohio EPA's programs is likely to be of greatest interest, this Program Highlight focuses on the potential uses, advantages, and limitations of the biological survey information collected in these two programs.

Ohio EPA has found that incorporating biological survey methods into its water quality assessment program produces several benefits compared with relying exclusively on chemical-by-chemical or whole effluent toxicity monitoring. First, biological assessments can detect water quality problems that other methods might miss or underestimate. The resident biota act as continuous monitors of environmental quality, increasing the likelihood of detecting the effects of episodic events (e.g., spills, nonpoint sources) or other highly variable impacts that monthly or even weekly chemical sampling might miss. And sampling need not be conducted at critical low flow or under other worst case conditions. Second, biological surveys can detect problems such as habitat degradation that are not strictly water quality problems, but can prevent attainment of uses. Third, biological surveys directly assess biological integrity, providing information needed to identify high quality waters deserving special protection or confirm instream impacts predicted by fate and transport modeling (e.g., wasteload allocation) and toxicity testing (i.e., bioassays).

The power of biological assessments is their ability to assess aquatic ecosystem health (i.e., biological integrity). They can supplement, but not replace, chemical and toxicological methods that are necessary to predict risks (particularly to human health and wildlife) and to diagnose, model, and regulate problems once they are detected.

### USES OF THE DATA

Three major uses of the chemical and biological data derived from the BWQS and NAWQMN Programs have included:

- improving water quality standards (including refinement of stream use classifications and development of biological criteria);
- identifying impaired waters and assessing attainment/nonattainment of beneficial uses;
- evaluating the effectiveness of pollution controls.

#### Use #1: Improving Water Quality Standards

A major use of BWQS data has been to improve Ohio's water quality standards by refining existing use classifications and developing numeric biological criteria to supplement existing chemical-specific and toxicity criteria. The development of biological criteria required descriptions of the type and condition of aquatic life thought attainable in streams and rivers throughout the State. Ohio recognized that biological criteria needed to account for intrastate differences in attainable quality due to regional variation in land surface form, land use, vegetation, soils, and climate, but realized that it was infeasible to develop site-specific criteria for each of the hundreds of waterbodies in the State. Their solution was to monitor streams least affected by human activity in each of several regions of the State ("least disturbed streams") and analyze the data to establish criteria specifying attainable conditions within each region.

Ohio EPA could not have developed biological criteria without first developing standardized biological assessment methods. Ohio has accomplished both – the development of assessment methods and criteria – through an iterative process of monitoring, the development of initial criteria, additional monitoring, and the subsequent development of more rigorous criteria. Ohio was fortunate to have a fairly extensive historical database dating back as far as 1979.

The process began in 1980, when Ohio EPA used the available database of about 150 sampling locations and the experience of its biologists to develop biological criteria for two aquatic life uses (exceptional warmwater habitat and warmwater habitat). These early criteria included both narrative and numeric requirements (e.g., a stream met the exceptional warmwater habitat use only if there were more than 30 taxa present and pollution-sensitive species were "abundant").

The process continued in 1983 and 1984, when Ohio EPA and USEPA's Environmental Research Laboratory in Corvallis, Oregon, carried out the Stream Regionalization Project. The project involved delineating the five distinct ecological regions ("ecoregions") illustrated in Figure 1, identifying "least-disturbed" watersheds in each ecoregion, and conducting extensive field work to characterize the health of fish and macroinvertebrate communities (and water quality) in the least-disturbed watersheds. Ohio chose fish and macroinvertebrates as its indicators of biological integrity because the

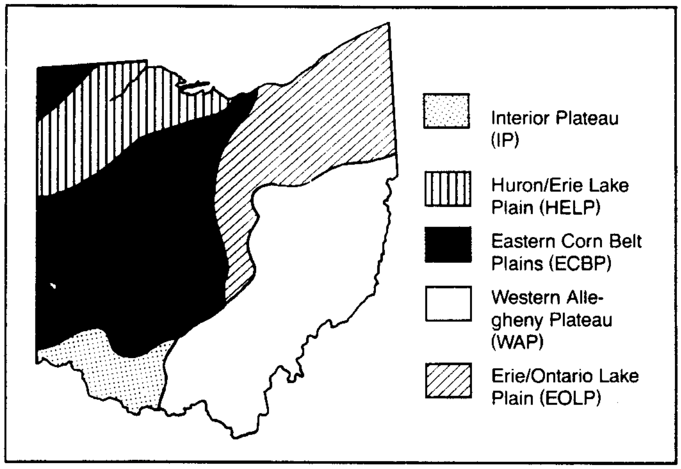
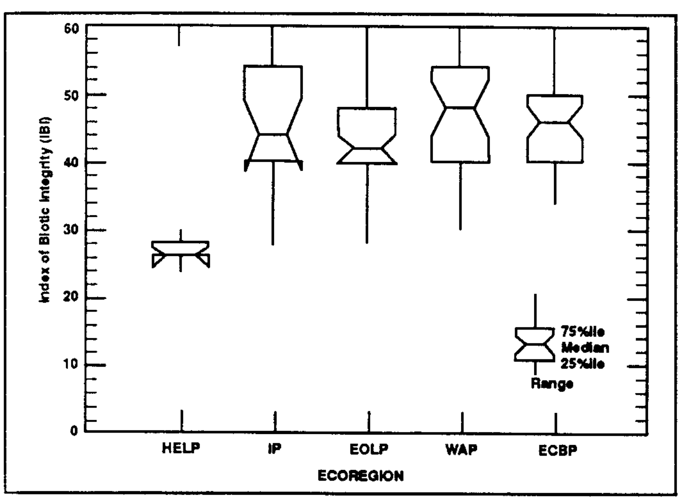



**Figure 1. Ohio's Five Ecoregions.**

distribution, environmental tolerance, and importance of these communities in lotic ecosystems were well known and because their health also reflects the health of lower trophic groups. More than 250 small stream sites and about 100 large river sites were sampled. These reference sites represent roughly the highest quality 5 percent of stream and river habitats in the State.

The field measurements were analyzed to determine various "metrics" of the health of the fish and macroinvertebrate communities such as species richness, trophic composition, diversity, the presence of pollution-tolerant individuals or species, abundance or biomass, and the presence of diseased or abnormal individuals. These metrics were in turn used to calculate values of three different biological indices: the Index of Biotic Integrity (IBI) for fish, the Modified Index of Well Being (Iwb) for fish, and the Invertebrate Community Index (ICI) for macroinvertebrates.

The next step in the analysis was to select values of each index thought attainable for each ecoregion. Figure 2 illustrates in a "box and whisker" plot the analysis conducted for one of the three indices: the IBI. The plot shows the distribution of IBI values calculated for least-disturbed streams in each of the five ecoregions. In the Huron/Erie Lake Plain ecoregion, for instance, IBI values for least-disturbed streams varied between 24 and 30. Ohio EPA established that a stream surpassing the 25th percentile value of the IBI scores of the reference streams in its ecoregion has attained the warmwater habitat use, in this case an IBI of 26. Ohio EPA established that a stream surpassing the 75th percentile value of the entire statewide reference site data set has attained the exceptional warmwater habitat use. These values serve as Ohio's numeric biological criteria. Generally, a waterbody is reported to fully attain its use only if all three index




Note: See Figure 1 for definition of acronyms.

**Figure 2. Notched Box-and-Whisker Plot of Reference Site Results for the IBI (headwater streams).**

scores (IBI, Iwb, and ICI) surpass the ecoregional criteria. Ohio reports partial use attainment if only one or two index values are met and nonattainment if none of the indices meet applicable criteria or if one organism group indicates poor or very poor performance.

Ohio has now established reference values for each of its three biological indices for each of the five ecoregions in three of its five aquatic life use categories. In addition, because attainable fish community characteristics vary with stream size and sampling method, reference values have been established separately for headwater streams (streams with drainage areas less than 20 $mi^2$), nonheadwater streams sampled by wading (drainage areas between 20 and 500 $mi^2$), and streams and rivers sampled by boat (drainage areas between 200 and 6,000 $mi^2$).

The five aquatic life uses included in Ohio EPA's refined water quality standards are: warmwater habitat, exceptional warmwater habitat, modified warmwater habitat, coldwater habitat, and seasonal salmonid habitat. Warmwater habitat is designated where waters are believed capable of supporting balanced reproducing populations of warmwater fish and associated organisms; exceptional warmwater habitat is designated where more sensitive and diverse biological communities, or rare species, are possible; coldwater habitat is designated in waters capable of supporting coldwater fish and associated organisms or where salmonids are regularly stocked; and seasonal salmonid habitat applies between October and May in tributaries to Lake Erie used by migrating salmonids. The modified warmwater habitat use designation is intermediate between the existing warmwater habitat and limited resource water categories. Limited resource waters are those that have extremely limited physical habitats due to natural limitations or extreme alterations of anthropogenic origin. The modified use was adopted after integrated assessments identified a number of stream segments where irreversible impacts precluded the attainment of the warmwater habitat use, but documented that these segments were able to sustain a semblance of a warmwater biological community. A use attainability analysis and USEPA approval are required prior to designating a stream as a modified warmwater habitat. There are, in addition, designations for aesthetics, water supply, and recreational uses, but the aquatic life use designations generally have the more stringent chemical criteria.

Ohio devoted a substantial fraction of its monitoring resources for 10 consecutive years to improving its water quality standards. Ohio expects in future years to sample about 10% of the reference sites each year to detect any broad-scale changes in background conditions that might prompt a recalibration of the biological indices, revisions of the biological criteria, or both.

Ohio EPA's approach to developing biological criteria is but one of several approaches used by State water quality agencies to define and measure achievement of biological integrity. States may choose to conduct crash efforts and monitor reference sites statewide in a year or two, or follow Ohio's example and spread the sampling over a 5- to 10-year period. The level of effort required to develop criteria varies from State to State—more ecologically homogeneous and sparsely populated States might find tens of reference sites sufficient; more heterogeneous and densely populated States might need more than the 300 or so sites monitored in Ohio. See the *Proceedings of the First National Workshop on Biological Criteria* (December 1988) for a discussion of other approaches.

**Use #2: Identifying Impaired Waters**

Biological assessments offer a powerful tool for identifying waters degraded by sources and causes of impairment that other approaches are likely to miss. In the middle segment of the Little Cuyahoga River, for example, fish and macroinvertebrate sampling indicated severe, but unexpected, impacts indicative of toxicity. These findings were unexpected because point source dischargers in the segment claimed to discharge only noncontact cooling water and small quantities of sanitary wastes. Accordingly, their permit did not require monitoring for toxic pollutants.

A followup investigation revealed that most of the dischargers in the river basin were involved in plastic and rubber manufacturing and therefore handled organic chemical products on the premises. Ohio EPA plans further work to identify the source of toxicity reaching the stream (e.g., spills, contaminated surface runoff, sewer system overflows, or unauthorized discharges).

In many other situations as well, Ohio EPA's increased reliance on biological methods has improved its ability to detect instream impacts (see Figure 3). The results of a survey of 431 stream segments found that instream chemical analyses for conventional pollutants, $NH_3$, and five heavy metals were in agreement with biosurvey results at 58% of the sites (at 17% of the sites both methods showed no impairment; at 41% of the sites both methods showed an impairment). At 6% of the sites, chemical data implied that there was an impairment while the instream biota showed no impairment. The most interesting finding, however, was that at 36% of the sites, instream chemical data implied no impairment while the instream biological communities showed impairment. The waters in this last category were degraded by "nonchemical" causes including sedimentation and/or habitat degradation (43%), subtle enrichment/dissolved oxygen impacts (31%), unknown toxicity (7%), and other causes (19%).

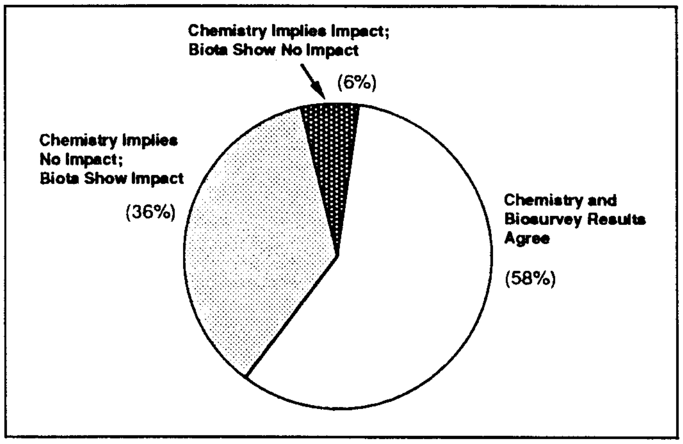



**Figure 3. Biosurvey Results Usually Agree with Instream Chemistry or Reveal Unknown Problems.**

An interesting consequence of Ohio EPA's improved ability to detect water quality problems is that the percentage of rivers and streams reported to fully support designated uses decreased between 1986 and 1988 from 61% to 32%. Ohio attributes this change to the adoption of revised biological criteria and more sensitive assessment methods, not to changes in water quality. Most of the waters newly designated in the 1988 §305(b) report as not supporting their uses experience "slight" to "minor" impairment, lending weight to Ohio's assertion that integrated assessments are capable of detecting increasingly subtle impacts.

### Use #3: Effectiveness Evaluation

Ohio EPA also monitors a network of 36 NAWQMN sites to evaluate the effectiveness of selected projects. Each year, 10 of these sites are assessed for macroinvertebrate community health. When plotted versus time (which Ohio did for 11 rivers in its 1988 §305(b) report), the trends in ICI values from these sites present a meaningful indicator of environmental improvement. Where intensive survey data are also available to interpret observed trends (e.g., to correlate trends with program actions), these plots provide a measure of program success.

Figure 4 shows the results for two of the 36 sites, on the Mohican and Olentangy Rivers. At the Mohican site, four samples were collected between 1977 and 1987. Macroinvertebrate sampling shows an improving trend in biological condition since 1978. Warmwater habitat communities have been present in all years, with the most recent data suggesting that the site has the potential to achieve the exceptional warmwater habitat use. Ohio EPA attributes these improvements to industrial waste pretreatment requirements imposed in upstream cities and wastewater treatment improvements made by several industrial and municipal treatment plants.

At the Olentangy site, five samples were collected between 1977 and 1986. Biological condition at the site has steadily improved through this period. The most dramatic increase in ICI values occurred between 1977 and 1979 when an ICI value reflecting nonattainment of the warmwater habitat aquatic life use improved to an ICI value reflecting full attainment. The ICI improved further in 1983 when the macroinvertebrate community was scored exceptional or near exceptional, but this improvement may have been an artifact of moving the sampling location upstream. Construction of a new advanced treatment plant and improvements at several existing plants are the most likely explanations of the overall improvement.

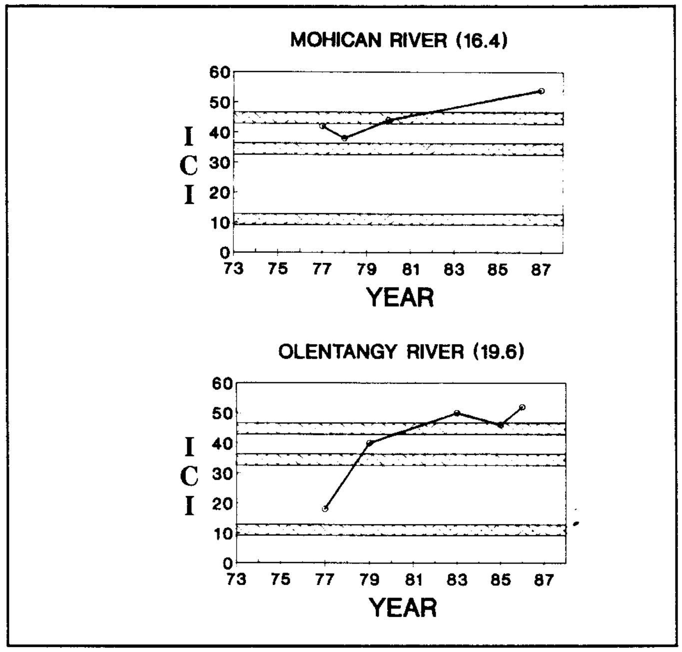



**Figure 4. Long-term Trend of the Invertebrate Community Index (ICI) at Ohio EPA Annual Monitoring Stations.**

### DESIGN CONSIDERATIONS RELEVANT TO ALL USES OF MONITORING DATA

Ohio EPA conducts 12 to 15 intensive surveys per year during the June to October sampling season. Intensive surveys can be as short as 1 week, but usually last several months. They include chemical analyses of samples collected at between 3 and 80 sites at frequencies ranging from three times during the survey to once each week. They typically include fish sampling at each site between one and three times during the survey. Macroinvertebrate sampling is typically conducted at between 6 and 80 sites, with artificial samplers remaining instream for 6 weeks at each site sampled.

Where monitoring data are needed to calibrate and validate water quality models, more intensive sampling is done for selected physical/chemical parameters.

Ohio's biocriteria describe attainable conditions. In addition, one or more reference sites located upstream of all known sources of pollution are typically sampled to sort out the effects of multiple dischargers, but not as an arbiter of attainable condition. In a typical point source evaluation, one site is located upstream from the outfall, another site is located within the mixing zone, and additional sites are located at intervals downstream to determine the extent and severity of impact.

### Fish Sampling Methods

The Ohio EPA has developed and documented standardized procedures for fish sampling. Pulsed DC electrofishing is used to obtain a representative sample of the fish community, either by wading into the stream or using a boat, depending on the size of the waterbody. In a survey, field personnel conduct repetitive sampling based on distance (rather than time) to avoid bias that would result where fish differ in spatial distribution due to differences in available habitat. Field personnel also weigh fish, identify each fish to the species level, and record external abnormalities. A three-person crew is required. Analysis of data collected at test sites indicates that spatial and temporal variability are low if standardized procedures are followed.

**Macroinvertebrate Sampling Methods**
Ohio relies primarily on a modified Hester-Dendy multiplate artificial substrate sampler for quantitative sampling of macroinvertebrates in streams and rivers. The Ohio EPA uses a composite set of five samplers, supplemented with a qualitative sample from the natural substrate that provides a more complete inventory of all taxa present. The Ohio EPA prefers artificial substrate samplers because they work in locations that cannot be sampled effectively by other means, require lower operator skill requirements, are nondestructive to the environment, and reduce the influence of the natural substrate. Results collected over the past 15 years confirm that sampling variability is low if there is strict adherence to standardized procedures.

**Chemical Analyses**
Ambient water samples (usually grab samples) are collected during integrated surveys. These samples are analyzed for dissolved oxygen, nutrients, solids, oil and grease, total organic carbon (TOC), methylene blue activated substances (MBAS), fluoride, organics, metals, pesticides, cyanides and phenols, as appropriate. Effluent and sediment samples are collected as necessary.

**Quality Assurance**
Quality assurance is of paramount importance to the Ohio BWQS Program. In September 1989, the Ohio EPA published an updated version of *Biological Criteria for the Protection of Aquatic Life.* This document, published in three volumes, details all aspects of sample collection and analysis of biological samples including:

- minimum staff training in sample collection and species identification needed to ensure adequate data quality;
- methods for selecting and evaluating sampling sites;
- sampling procedures including the design and use of sampling equipment, species identification, field counting and weighing procedures, sample preservation, and "chain-of-custody" procedures;
- habitat evaluation procedures;
- laboratory procedures for handling and identifying preserved specimens;
- data management and storage procedures;
- data analysis methods (including statistical tests and calculation of metrics).

Ohio EPA uses the USEPA's STORET database to manage its chemical data and its own Fish Information System (FINS) and Macroinvertebrate Data Gathering and Evaluation System (MIDGES) for its biological community data. Personal computers are used extensively to analyze data and prepare reports.

**PROGRAM RESOURCE REQUIREMENTS**
Out of an estimated 52 workyears available for Ohio EPA's monitoring activities in FY88 (field sampling, field and laboratory analyses, data analyses, and reporting), 9.5 workyears (18.4%) went toward BWQS (surveys), 0.2 workyears (0.3%) went toward the biological portion of Ohio EPA's NAWQMN, and 0.8 workyears (1.6%) went toward the chemical portion of the NAWQMN. The remaining monitoring program resources went toward wasteload allocation modeling/permitting, toxic contaminant monitoring, compliance/enforcement monitoring, water quality criteria, §401 certifications, and other needs.

Collection of biological data has the reputation of being resource-intensive and too costly for routine application in State monitoring programs. In 1989, Ohio EPA compared the cost of different approaches assumed to provide the same analytical and evaluative "power." Ohio EPA believes that, on a per-site basis, sampling fish and macroinvertebrate communities can be equal to or lower in cost than chemical sampling or toxicity testing. More comprehensive chemical monitoring, such as priority pollutant scans and sediment analyses, further increases costs for chemical data.

**THE FUTURE**
Improving the ability of its monitoring program to produce the type of monitoring information needed to support water quality program decisions has, in turn, increased the demand for Ohio EPA's biological monitoring resources. Managers of Ohio EPA's permits, nonpoint source, hazardous waste, and other environmental programs now compete for limited monitoring resources. In its most recent 5-year monitoring strategy (Ohio EPA 1985), Ohio estimated that at current staffing levels it would take 13 years to satisfy its outstanding monitoring needs.

*Material for this report was furnished primarily by Chris Yoder, Ohio EPA. Figures 1 and 3 were prepared using data from Ohio EPA's 1988 §305(b) report. Figures 2 and 4 were taken from* Biological Criteria for Protection of Aquatic Life, *February 28, 1988, Ohio EPA, Division of Water Quality Monitoring and Assessment, Surface Water Section, Columbus, Ohio. For more information, contact Chris Yoder.*

*This report is produced by EPA to highlight EPA and State monitoring activities. Contributions of information for similar reports are invited. Please contact: Monitoring Branch, EPA, AWPD, WH-553, 401 M Street S.W., Washington, DC 20460 (202) 382-7056.*