The Ohio EPA Bioassessment Comparability Project:
A Preliminary Analysis

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Abstract

The Ohio EPA, Monitoring and Assessment Section conducted a two-year long study to assess the comparability of alternative bioassessment methodologies to the established Ohio EPA system of biological assessment methods and biological criteria. A principal goal of this study was to evaluate the feasibility of expanding the availability bioassessment tools from the more complex, informationally robust methods used routinely by Ohio EPA to the simpler, easier to use methods such as those used by volunteer monitoring organizations. We compared the assessments yielded by the Ohio DNR Scenic Rivers Program Stream Quality Monitoring (SQM) method and the U.S. EPA Rapid Bioassessment Protocol levels II and III (for three different subsample sizes) with that of the Ohio EPA macroinvertbrate and fish community assessment protocols at 75 stream sampling locations primarily in the Eastern Corn Belt Plains ecoregion of Ohio. Using the Ohio EPA biological assessments as the arbiter of method performance none of the tested methods regularly exceeded 50% agreement in terms of rating a site as exceptional, good, fair, poor, or very poor quality. Method performance was improved somewhat if the SQM and RBP results were limited in use as a pass/fail screen for the Warmwater Habitat (WWH) use designation. In this situation, the SQM agreed with the Ohio EPA Invertebrate Community Index (ICI) in 82% of the comparisons where the WWH ICI met the ecoregion biocriterion and in 73% of the comparisons where the ICI indicated non-attainment of WWH. These rates of agreement are lower than that found in an earlier Ohio EPA/Ohio DNR cooperative study by Dilley (1991). The RBP comparisons were no better than SQM with rates of agreement ranging from 62-70% for WWH non-attainment - we were not able to evaluate WWH attainment as only three RBP samples yielded an exceptional rating. At this point (and without further modification and testing) the alternative bioassessment methods tested here (SQM, RBP) could function within the Ohio EPA monitoring and assessment program only as gross screening tools. The less accurate and less discriminating bioassessment levels carry a significant risk that the resultant assessment will either be of insufficient sensitivity and accuracy or will be less useful for some future purpose. Thus the potential consequences of limited

capabilities can be weighed ahead of time rather than discovering unwanted and potentially irreversible consequences at a later time. The potential to improve these methods is greatest for the RBP approach which is the most amenable to calibration via the regional reference site approach. Attempts to further refine the SQM method will likely have only minimal benefits due to the inherent limitations of the protocol (*e.g.,* coarse level of taxonomy, mesh size, etc.). The alternative bioassessment procedures evaluated by this study are further limited in application to wadeable streams which generally drain less than 200 mi.[2] and by the constraints implied by Table 4. Making the RBP approach useful to Ohio EPA will require significant time to modify and calibrate the methods so that accurate and reliable results can be obtained. Furthermore, the contribution of experienced and seasoned staff in this process is a must, thus there is the potential to detract from existing commitments. It may be more cost-effective for Ohio EPA to better develop existing "rapid assessment" techniques which would not require an extensive calibration process. The usefulness of a well calibrated and constructed set of bioassessment methods will benefit many Ohio EPA programs including the Five-Year Basin Approach to Monitoring and NPDES Permit Reissuance, the Voluntary Action Program (VAP), and the Watershed Approach. Key to this, however, is providing adequate technical support (training, laboratory, and equipment support) within MAS to ensure that the methods are used appropriately and within the guidelines listed in Table 4.

Recommendations

- Make better use of already existing Ohio EPA "rapid assessment" capabilities throughout the water programs, particularly for addressing short-term, site-specific and watershed management needs. This would include making maximum use of the existing fish community assessment methodologies, qualitative macroinvertbrate assessment methods, and the Qualitative Habitat Evaluation Index (QHEI) in wadeable streams (generally less than 200 mi.[2]). Examples of this already exist within selected Ohio EPA District Offices (*e.g.,* SEDO, NEDO) and increasing these capabilities is needed towards satisfying existing monitoring and assessment needs and those which will soon emerge as part of the Watershed Approach.

- Proceed further with the refinement of the RBP protocol including the development of a multimetric index (*i.e.,* Benthic Index of Biotic Integrity) calibrated to regional reference conditions in Ohio. The effect of subsample size and level of taxonomy can be further evaluated at the same time. However, extending the application of the RBP method beyond the ECBP ecoregion will require an expansion of the reference database which will take several years to complete. However, this could be accomplished at the same time RBP methods are being phased-into the overall monitoring and assessment program.

- Accomplishing the above will require a commitment to staff training, both in terms of support for tuition reimbursement and time for experienced MAS staff to act as facilitators and trainers, and equipment and laboratory resources in the District Offices and MAS (at least 1.0 FTE devoted to District support) to support the additional work load. This should not come at the expense of the DSW resources already committed to the Five-Year Basin Approach as a goal of developing and implementing rapid bioassessment methods is to increase the overall Ohio EPA monitoring output above the current 50-60% of annual needs to 80%.

- Develop refined cost estimates of each procedure including an update to the current Ohio EPA "Cost of Biological Monitoring" analysis.

- In the interim between this study and further development of rapid bioassessment procedures, we should use SQM results that are considered to be valid as evaluated level assessments for purposes of the Ohio Water Resource Inventory (305[b]) report and the Ohio Nonpoint Source Assessment.

- Continue to provide technical support within Ohio EPA and to Ohio DNR and other organizations engaged in developing and implementing volunteer monitoring methods and networks. To date MAS has provided data management support, training in stream habitat evaluation, field demonstrations, and general technical assistance.

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Introduction

Bioassessment using resident aquatic organisms is receiving increased emphasis in state and federal water quality programs, especially for reporting on designated use attainment status, trend assessment, and evaluating the effectiveness of water quality management and pollution abatement efforts. This is evident in the recommendations of contemporary working groups such as the Intergovernmental Task Force on Monitoring Water Quality (ITFM 1992, 1993, 1995), recent U.S. EPA guidance documents, and recent efforts by many states (*e.g.,* Maxted *et al.* 1992; Barbour *et al.* 1996a). However, the ability to procure and allocate sufficient resources to meet the demands for bioassessment of priority issues has lagged behind this demand, even within the state programs that are generally regarded as exemplary. For example, in the Ohio EPA Five-Year Basin Approach to Monitoring and NPDES Permit Reissuance we are currently able to address approximately 50-60% of the identified priority bioassessment needs within a given basin year. The success of the program has in fact increased the demand for this type of information which has countermanded the efficiencies gained in bioassessment during the past 10 years (Figure 1). In addition, the growing emphasis on local watershed initiatives and other new initiatives (e.g., Voluntary Action Program) will further increase the demand for bioassessment information.

Meeting all of these needs will not only require additional (not necessarily new) resources, but a "gradient" of bioassessment methods that are available to fit both the varying complexities of a watershed setting and the variable capabilities of available staff resources. Striking a realistic balance between the need for defensible, adequate, scientifically sound, and environmentally robust bioassessments and the current shortfall in adequately trained resources will be a continuing challenge. However, the desire to expand our bioassessment capacity by using increasingly rapid and cheaper tools should not outweigh the need for scientifically credible and robust information. To better determine how to balance these oftentimes competing concepts, the Ohio EPA, Monitoring and Assessment Section (MAS) designed a study in which different levels of bioassessment could be compared and evaluated. While the issue of comparability between different chemical/physical monitoring methods is focused largely on the precision and
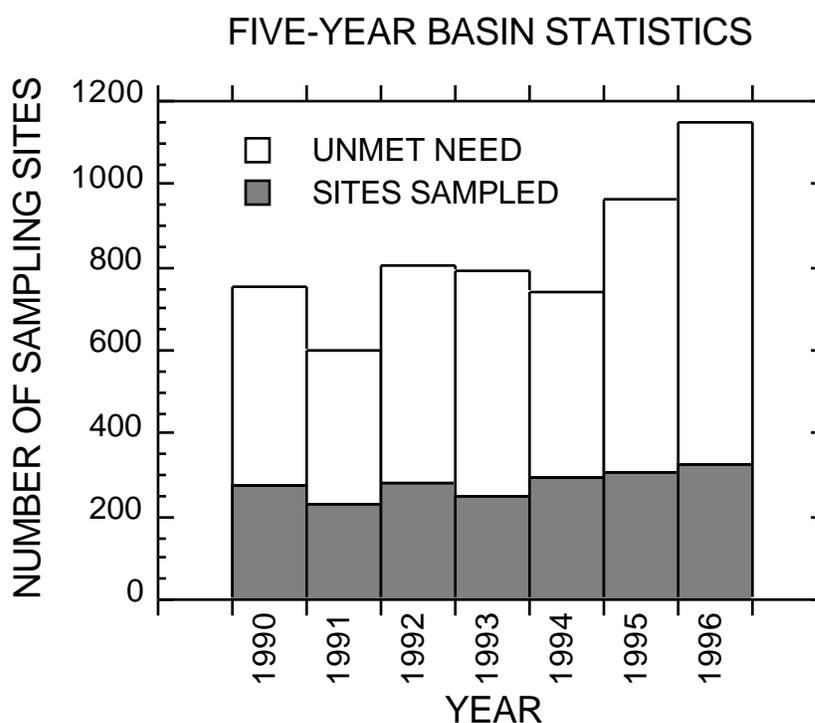

Figure 1. The number of sites sampled (dark shading) in support of the Five-Year Basin Approach compared to the needs identified (open shading) in each basin year, 1990 - 1995.

accuracy of an analytical result, the focus on bioassessment comparability is with the assessment, *i.e.*, the translation of the analytical results into a measurement or statement of condition and quality.

The need to recognize the inherent capabilities of different levels of bioassessment is illustrated by the experience of Ohio EPA in their reporting of the status of stream and river miles attaining and not attaining designated uses (*i.e.,* Clean Water Act goals) between the 1986 and 1988 Water Resource Inventories (305b report). Because of a change in the type of bioassessment used between the two 305b reporting years, the miles of streams and rivers failing to attain designated uses changed from 9% in 1986 to 44% in 1988, an *increase in non-attainment of nearly five times*. This remarkable change was due entirely to a change in assessment methodology and illustrates the important influence that the differing capabilities of various bioassessment types can exert. It also illustrates the variable levels of accuracy between different bioassessment frameworks and the need to categorize and classify each according to their respective capabilities to detect and discriminate impairments both spatially and temporally. Given the wide variability in reporting these types of statistics between states problems such as those just mentioned are compounded on a national scale (Ohio EPA 1995). The predominant error tendency is for the simpler, less robust, and cheaper bioassessment methods to over-estimate the true condition of the environment although under-estimation is a distinct possibility (Yoder 1994).

For the purposes of this study a bioassessment is defined as the assignment of a relative community condition or quality rating to a sampling site as indicated by the composition of the resident aquatic community, *i.e..,* each site is rated as exceptional, good, fair, poor, or very poor. The ratings of exceptional and good correspond directly to attainment of the Exceptional Warmwater Habitat (EWH; exceptional rating) and Warmwater Habitat (WWH; good rating) biological criteria and use designations defined in the Ohio Water Quality Standards; the remaining ratings of fair, poor, and very poor indicate increasing departures from attainment of

these aquatic life use designations. Depending on the bioassessment type, a rating may be assigned based on a qualitative, narrative interpretation of the results (*i.e,* based on best professional judgement) or a numeric index value resulting from an analysis of the raw data. The resulting statement of condition is then the basis for evaluating whether or not a water body is attaining the applicable designated aquatic life use. Thus the narrative rating produced by different bioassessments is the basis of comparison for the purposes of this study. The purpose of this study is by way of examples from Ohio streams and rivers to demonstrate the comparability of the assessments derived from different "off-the-shelf" (*i.e.,* without modification for Ohio conditions) bioassessment types. The results can then be used as a basis for defining if, when, where, and for what purposes the different bioassessment types may or may not be acceptable for use by Ohio EPA.

Hierarchy of Ambient Bioassessment Types

When the combination of field sampling techniques and laboratory methods, assessment protocols, level of taxonomy, types of indices, indicator organisms, and other attributes of different biological assessment approaches are considered a hierarchy of bioassessment types emerges (Yoder 1994, 1995). In any biological monitoring program decisions about each of these techniques and methods are made that ultimately determine the power and accuracy of the resultant assessment and the "products" and programs it supports. Practical matters such as cost, time required, and availability of operator expertise frequently are the principal considerations in making such decisions. However, the consequences of these decisions that affect data quality, environmental accuracy, and power of assessment must also be considered. Factors in addition to cost and logistical considerations may be of equal or even greater importance. For instance, can we decide *a priori* that a family level of taxonomy (in lieu of genus/species level) is adequate without considering the ramifications of such a decision? While the costs and expertise requirements of the former are less, what are the data quality and power of assessment ramifications? The "cost" and consequences of such a decision without equal

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regard to the level of bioassessment needed should be considered at least as much, if not more so, than the seemingly more prevalent economics/logistics concerns.

In order to examine the issues of accuracy and sensitivity we examined the relationship between different bioassessment types by making direct comparisons of some commonly available approaches in terms of the respective abilities of each to accurately portray status and determine if any predominant error tendencies were evident. This included making comparisons of different field, laboratory, and data analysis techniques. In each comparison the arbiter of accuracy was the dual organism, regional reference site approach that is currently employed by Ohio EPA (Bioassessment Type 8 in Table 1). The framework for this approach is described elsewhere (Ohio EPA 1987a, 1987b, 1989a, 1989b; Rankin 1989, 1995; DeShon 1995; Yoder 1989, 1991a, 1991b; Yoder and Rankin 1995a). The error rate produced by each comparison represents the frequency at which the narrative evaluation of a particular bioassessment type agreed with that produced by the Ohio EPA assessments. A hierarchy matrix developed by Yoder (1994, 1995) demonstrates some of the key attributes and differences between the bioassessment types that were tested in this study (Table 1). The bioassessment types analyzed for the purposes of this discussion are a volunteer biological monitoring approach (Bioassessment Type 2 in Table 1), which is presently used by several organizations in Ohio, the U.S. EPA Rapid Bioassessment Protocol (unmodified; Bioassessment Types 4 and 8), and the Ohio EPA regional reference site approach (Bioassessment Type 9). While these comparisons are limited to Ohio waters, the findings should have conceptual applicability elsewhere.

Volunteer Biological Monitoring Methods
Biological monitoring techniques which are designed primarily for use by non-practitioners or lay persons are termed here as volunteer methods. In Ohio the most widely employed methodology is the Ohio DNR Stream Quality Monitoring (SQM; Kopec and Lewis 1983) method which is an adaptation of the Izaak Walton League Save Our Streams approach. This method employs a one

Table 1. Hierarchy of ambient bioassessment approaches that use information about indigenous aquatic biological communities (NOTE: this applies to aquatic life use attainment only).

BIOASSESSMENT TYPE	SKILL REQUIRED[1]	ORGANISM GROUPS[2]	TECHNICAL COMPONENTS[3]	ECOLOGICAL COMPLEXITY[4]	ENVIRONMENTAL ACCURACY[5]	DISCRIMINATORY POWER[6]	POLICY RESTRICTIONS[7]
1. Stream Walk (Visual Observations)	Non-biologist	None	Handbook[8]	Simple	Low	Low	Many
2. Volunteer Monitoring	Non-biologist to Technician	Invertebrates	Handbook[9], Simple equipment	Low	Low to Moderate	Low	Many
3. Professional Opinion (*e.g.,* RBP Protocol V)	Biologist w/ experience	None or Fish/Inverts.	Historical records	Low to Moderate	Low to Moderate	Low	Many
4. RBP Protocol I&II	Biologist w/ training	Invertebrates	Tech. Manual,[10] Simple equip.	Low to Moderate	Low to Moderate	Low to Moderate	Many
5. Narrative Evaluations	Aquatic Biologist w/training & experience	Fish &/or Inverts.	Std. Methods, Detailed taxonomy Specialized equip.	Moderate	Moderate	Moderate	Moderate
6. Single Dimension Indices	(same)	(same)	(same)	Moderate	Moderate	Moderate	Moderate
7. Biotic Indices (HBI, BCI, etc.)	(same)	Invertebrates	(same)	Moderate	Moderate to High	Moderate to High	Moderate to Few
8. RBP Protocols III&V	(same)	Fish & Inverts.	Tech. Manual,[10] Detailed taxonomy, Specialized equip., *dual* organism groups	High	Moderate to High	Moderate to High	Few
9. Regional Reference Site Approach	(same)	Fish & Inverts.	Same plus baseline calibration of multi-metric indices & *dual* organism groups	High	High	High	Few
10. Comprehensive Bioassessment	(same)	All Organism Groups	Same except all organism groups are sampled	Highest	High	High	Few

[1] Level of training and experience needed to accurately implement and use the bioassessment type.
[2] Organism groups that are directly used and/or sampled; fish and macroinvertebrates are most commonly employed in the midwest states.
[3] Handbooks, technical manuals, taxonomic keys, and data requirements for each bioassessment type.
[4] Refers to ecological dimensions inherent in the basic data that is routinely generated by the bioassessment type.
[5] Refers to the ability of the ecological end-points or indicators to differentiate conditions along a gradient of environmental conditions.
[6] The relative power of the data and information derived to discriminate between different and increasingly subtle impacts.
[7] Refers to the relationship of biosurveys to chemical-specific, toxicological (*i.e.* bioassays), physical, and other assessments and criteria that serve as surrogate indicators of aquatic life use attainment/non-attainment.
[8] Water Quality Indicators Guide: Surface Waters (Terrell and Perfetti 1989)
[9] Ohio Scenic River Stream Quality Monitoring (Kopec and Lewis 1983).
[10] U.S. EPA Rapid Bioassessment Protocol (Plafkin *et al.* 1989).

square meter kick-seine and hand-pick method to collect benthic macroinvertebrates from riffle habitats in streams and rivers. Organisms are field identified to an order/family level of taxonomy by means of visual aids and keys. Based on our experience in using this method a trained operator can complete an assessment of a sampling site in approximately one hour with data analysis taking one-half to one additional hour (Table 2). This technique is used by a variety of groups including the Ohio DNR Scenic Rivers program, one-third of the state's Soil and Water Conservation Districts (SWCD), designated planning agencies, individuals, and school programs throughout Ohio. The intended uses of volunteer monitoring information are primarily educational and citizen involvement; however, one-fourth of the SWCDs and some of the designated planning agencies are attempting to use the resultant assessments to evaluate environmental quality, particularly where no other baseline information exists.

In 1989, an effort to evaluate the SQM method by the Ohio DNR Scenic Rivers program was made by conducting a side-by-side comparison of the SQM and Ohio EPA bioassessment results at 56 locations where Ohio EPA was conducting fish and macroinvertebrate sampling following standardized methods (Dilley 1991). The SQM generates a numeric index termed the Community Index Value (CIV) which is based on the accumulated presence of intolerant taxa, intermediate taxa, and pollution tolerant taxa. The resultant assessments are organized on a narrative scale of exceptional, good, fair, and poor which correspond to CIV value ranges. The frequency of CIV narrative ratings was compared to the IBI and ICI scores obtained by Ohio EPA at the same sites. The corresponding agreement between the CIV narrative assessment was poor for either Ohio EPA index, but was better for the ICI than the IBI (Table 3). The comparison with the IBI showed the following rates of agreement: exceptional (24%), good (18%), and fair/poor (100%), and for the ICI exceptional (55%), good (50%), and fair/poor (91%). If the CIV is restricted in use to a pass/fail screen with regard to whether the stream is in attainment or non-attainment with the Warmwater Habitat (WWH) use designation (as defined in the Ohio Water Quality Standards) the performance of the SQM method improved somewhat.

Table 2. Comparison of the time required (hours) to complete field sampling and sample analysis for each of the bioassessment techniques evaluated in this study. This applies to wadeable streams draining less than 200 mi.[2].

Bioassessment Method	Field Time	Laboratory Time	Data Processing	Other Observations
1. Stream Quality Monitoring (SQM)	1.0	NA	0.5-1.0	No laboratory work required; Level F in Table 4.
2. RBP Protocol II (100 org. Subsample)	1.0-1.5	1.8-7.9	0.5-1.0	Family level taxonomy; Level E in Table 4.
3. RBP Protocol III (300 org. Subsample)	1.0-1.5	1.9-13.5	0.5-1.0	Genus/species level taxonomy; Level C in Table 4.
4. Ohio EPA Qual.	1.0-1.5	2.0-5.0	0.5	No organism count made; Level B in Table 4.
5. Ohio EPA H-D (Quantitative)	1.5-3.0[a]	12.0-20.0	0.5-1.0	Two trips/site; qual. included; Level D in Table 4.
6. Ohio EPA One Pass Electrofishing	1.5-3.0	<0.5	0.5	Used by OEPA Districts; Level B in Table 4.
7. Ohio EPA Fish Community Assess.	3.0-6.0	0.5-1.0	0.5	Two or three passes; Level A in Table 4

[a] - time includes two separate trips to a sampling site.

For example, a CIV rating of exceptional corresponded to attainment of the WWH ICI biocriterion in 94% of the comparisons and the WWH IBI biocriterion in 76% of the comparisons. CIV ratings of fair or poor corresponded to non-attainment of the WWH ICI in 100% of the comparisons and the WWH IBI in 91% of the comparisons (Table 3). The poorest performance of the SQM was for CIV ratings of good which had 50% and 22% rates of agreement for the ICI and IBI, respectively. Dilley (1991) also found that the agreement of the CIV ratings with those based on the ICI improved for sites with a good riffle habitat and where stream size was <200 square miles. Our comparison revealed lower rates of agreement, particularly for the fair/poor correspondence to WWH non-attainment (Table 3). One possible explanation is the higher number of sites from marginally impacted sites in the ECBP ecoregion in our study with which the CIV may have had problems adequately discriminating.

The Dilley (1991) study did not provide an opportunity to examine for an important source of error - variable operator skill and experience. In order to determine this we compared SQM CIV ratings garnered by citizen participants (*i.e.,* volunteers) in the Scenic Rivers SQM and by Ohio DNR Scenic River staff coordinators with Ohio EPA results for the IBI and ICI. Although this comparison did not include the gradient of environmental impacts of the Dilley (1991) study, it did provide insights about the importance of operator variability to the relative accuracy of the SQM method. The corresponding agreement between the Scenic Rivers SQM CIV narrative and the IBI/ICI narrative ranges was better for the ICI than the IBI, but was less than that observed in the Dilley (1991) study (Table 3). Using the Scenic Rivers SQM CIV as a WWH pass/fail screen the rate of agreement was 84% and 66% for the ICI and IBI, respectively (Table 3). The Scenic River SQM results represent a range of skill levels from trained staff members to untrained lay persons. The attractiveness of the SQM method is obvious from a resource and cost standpoint (Table 2), but the ultimate usefulness to Ohio EPA and other agencies and organizations is with the accuracy of the bioassessment. At this time the SQM is, at best, a gross screening tool.

Table 3. Relative rate of agreement (accuracy) of Ohio DNR Stream Quality Monitoring (SQM) method results used by Dilley (1991), Scenic Rivers Program volunteers, and the SQM and U.S. EPA Rapid Bioassessment Protocols used in the Ohio EPA Bioassessment Comparability Project compared to corresponding narrative ratings of the Ohio EPA ICI and IBI. The aggregate percentage of exceptional ratings which correspond to the Warmwater Habitat (WWH) use designation and fair/poor ratings which correspond to WWH non-attainment are also indicated. The percentages reflect the level of agreement between the assessment yielded by the applicable method and the Ohio EPA ICI and IBI, with the latter being the arbiter of agreement. Rates of agreement $\geq$75% are highlighted.

		Narrative Rating of Community Condition				
Method	Exceptional	Good	Fair	Poor/ V. Poor	Exceptional as WWH	Fair/Poor non-WWH
ODNR SQM Dilley (1991) Study						
SQM vs. ICI	55%	50%	**91**%	-[1]	**94**%	**91**%
SQM vs. IBI	24%	18%	**100**%	-[1]	**76**%	**100**%
ODNR Scenic Rivers Volunteers						
SQM vs. ICI	38%	48%	**75**%	-[1]	**84**%	**75**%
SQM vs. IBI	27%	40%	61%	-[1]	66%	61%
Ohio EPA Bioassessment Comparability Project						
SQM vs. ICI	46%	35%	60%	44%	**82**%	73%
SQM vs. IBI	33%	41%	18%	53%	**80**%	67%
RBP II (100)[2] vs. ICI	0%	28%	36%	50%	-[3]	70%
RBP II (100)[2] vs. IBI	33%	56%	22%	**75**%	-[3]	66%
RBP III (300)[2] vs. ICI	0%	29%	38%	58%	-[3]	65%
RBP III (300)[2] vs. IBI	0%	52%	27%	60%	-[3]	62%

[1] combined with fair rated data due to insufficient samples rated as poor.
[2] sub-sample size.
[3] insufficient sample size for this category.

Rapid Bioassessment Protocols

U.S. EPA developed what are termed Rapid Bioassessment Protocols (RBPs; Plafkin *et al.* 1989) for macroinvertebrate and fish community assessments. Three method protocols are specified for macroinvertebrates and two for fish. The fish protocol (RBP V) in terms of sampling procedures and use of a multimetric index is essentially the same as the Ohio EPA methods and thus was not a subject of this study. The macroinvertebrate protocols are substantially different from the Ohio EPA methods and further represent a menu of different taxonomic resolution and sample size requirements. RBP I, like many rapid assessment techniques, requires field identifications which demands a level of technical training comparable to Ohio EPA invertebrate biologists, thus it was not considered in this study. RBP II and III employ the same sampling method (kick seine) and differ from the SQM in employing a smaller mesh size, a more structured field sampling procedure, and more refined levels of taxonomy (order/family level vs. family/genus/species level). In addition, the effect of subsample size (*i.e.,* the number of organisms actually identified) within the RBP protocols was also evaluated. The RBP method does not produce an index value comparable to the ICI or IBI. Instead the evaluation is expressed as percent of reference. For example, if the RBP result was 80% this means that the sample was 80% of the biological quality at the reference site. The lower the percent value the more the sampled site departs from the reference site which is intended to emulate the goal of designated aquatic life uses. Our comparison used the "off-the-shelf" version of the RBP procedure (Plafkin *et al.* 1989) and no effort was made to modify metrics or depart from the single reference site approach. In addition, U.S. EPA recently published an update to the 1989 RBP document which post-dated the initiation of this project.

The results of the comparison of the RBP II (100 organism subsample) and RBP III (300 organism subsample) results with the Ohio EPA ICI and IBI showed some significant discrepancies when compared to results based on Ohio EPA methods (Table 3). The levels of agreement were poor being generally less than 50% within each narrative evaluation category.

Because of the basic design of the RBP being contingent on a *single* reference site it was difficult to equate the RBP results to the exceptional/good/fair/poor/very poor evaluation hierarchy inherent to the Ohio EPA biological criteria. This was especially true for the exceptional category which we assigned only if the RBP result scored >100% of reference - only 3 sites scored >100%. Thus using an exceptional RBP rating as a screen for WWH attainment was seriously hampered by this result. Using a fair/poor RBP result as a screen for WWH non-attainment resulted in less than 75% agreement with the ICI and IBI, no better than the SQM performance in our study and less than that found by Dilley (1991). The results further indicated little difference between the RBP II and III methods with the exception that a poor rating by the RBP III method always indicated WWH non-attainment. While these results would seem to indicate little or no improvement in using the RBP over the SQM, the potential to improve the RBP approach is much greater as evidenced by such efforts elsewhere (Maxted *et al.* 1992; Barbour *et al.* 1996a,b). Obviously this will need to done for further application to Ohio streams.

The logistical requirements of the RBP methods result in minimal field time (1.0-1.5 hours), but a significant expenditure of effort in the laboratory depending on the subsample size (Table 2). Times ranged from just under two to nearly eight hours for a 100 organism subsample and up to more than 13 hours for a 300 organism subsample. The RBP method is vulnerable to extremes as one sample required nearly two weeks to process. In addition, the staff have some serious concerns about the subsampling procedure which is possibly a factor in the relatively poor performance of the unmodified RBP method. Despite these deficiencies, the potential to improve the method exists, but doing this may result in little or no time savings over the current Ohio EPA approach. In addition, the time required to modify and calibrate the RBP methods so that accurate and reliable results can be obtained will be significant. Furthermore, the contribution of experienced and seasoned staff in this process is a must, thus there is the potential to detract from existing commitments. Given this it may be more cost-effective for

Ohio EPA to better develop existing "rapid assessment" techniques which would not require an extensive calibration process.

Biossessment Capabilities

Presently, the Scenic Rivers SQM is used by the Ohio DNR, Scenic Rivers Program staff and volunteers as an environmental education, awareness, and training tool and secondarily as a general interpretation of water resource quality. The potential value of the SQM as a monitoring tool is to indicate potential problems when used as a general screen. Based on our analyses, the Scenic Rivers SQM would be most useful to the Ohio EPA when the CIV rating is either exceptional or fair/poor and only for WWH designated streams draining less than 200 mi.^{2}. The factors which seem to most limit a broader applicability of the SQM are the reliance on a single organism group, the comparatively coarse level of taxonomy employed, the single habitat sampled, the lack of calibration to regional reference conditions, and the potential bias induced by variable operator skill and experience. In a review of volunteer methods Penrose and Call (1995) were skeptical about the usefulness of these methods based on rather poor comparisons with other state agency bioassessment program results. One precautionary note to observe about volunteer programs - they are appealing from a pure cost and resource standpoint and they tend to be oversold by various advocacy organizations. While we need to remain open minded, the evidence available thus far suggests taking a "buyer beware" attitude.

The surprisingly poor agreement between the RBP II and III results and the Ohio EPA ICI and IBI could likely be improved with further developmental work. This would include testing other multimetric indices such as the Benthic Index of Biotic Integrity (BIBI; Kerans and Karr 1992) or the approach used by the state of Florida (Barbour *et al.* 1996a,b), both of which require the development of a set of regional reference sites using the RBP sampling method. This would allow the tailoring of the general RBP technique to Ohio specific conditions which should result in a more usable and reliable assessment technique. While generating the needed reference

database may take 3-4 years, this could be accomplished as the method is used for assessing streams statewide. However, serious consideration of the worthwhileness of this effort should first take place, especially if a decision to make better use of existing Ohio EPA "rapid bioassessment" methods is made.

The comparison of the Scenic Rivers SQM, U.S. EPA RBP, and Ohio EPA methods of biological assessment revealed some important findings, not the least of which was initially defining the bounds within which the SQM and RBP might be used as supplements to Ohio EPA efforts. The SQM and RBP have varying possibilities for use as a screen for *potential* non-attainment of the WWH use designation, particularly if operator error can be controlled and minimized. While some improvements can be made in how the SQM is used and applied, the methodology has some fundamentally inherent limitations. Because of the coarse level of taxonomy employed in the SQM, and to an extent the collection technique, these types of data have little if any utility for discerning different impact types as previously described by Yoder (1991) and Yoder and Rankin (1995b). SQM would not be useful in discriminating between different use designations because of the inability to consistently discriminate exceptional from good quality. Organizations presently using the SQM that wish to upgrade their bioassessment approach should focus more on advancing to an RBP or Ohio EPA level of bioassessment rather than attempting to further refine the SQM. Although RBP field methods are similar to SQM in terms of field sampling techniques, RBP requires some *a priori* expertise. Thus upgrading SQM to an RBP level of assessment is much more than a matter of improving taxonomic resolution. The habitat assessment component of the RBP is also more complex and requires the intuitive and on-site recognition of key factors, thus training and expertise is a must. In addition, both the SQM and RBP lack the discriminatory power needed to differentiate attainment/non-attainment of the Exceptional Warmwater Habitat (EWH) use and it is not sufficiently reliable for any purpose if the resultant bioassessment rating is good. Furthermore, evaluating the EWH use usually requires data on both the fish and macroinvertbrate assemblages, thus a single organism

group method will be insufficient for this purpose. It is also doubtful that volunteers could take on the difficult sampling areas with complex combinations of industrial and urban impacts and a large number of sampling sites. Thus efforts to upgrade and implement the SQM technique will eventually reach a limit of feasibility and practicality.

Monitoring and Assessment Program Implications

Our analyses reveal that the power and ability of a bioassessment technique to accurately portray biological community performance, and therefore biological integrity, and discriminate ever finer levels of aquatic life use impairments, is directly related to the useful data dimensions produced by each. For example, techniques that include the identification of macroinvertebrate taxa to the genus and species level will produce a greater number of useful data dimensions than a technique that is limited to an order/family level of taxonomy (Yoder and Rankin 1995b). Similarly, an approach that employs two organism groups is more likely to be capable of accurately detecting a broader range of impairments than will reliance on a single group. Approaches that rely on multimetric indices will yield greater information than a reliance on single dimension indices, and so on. In addition, the modification of multimetric indices to reflect regional-specific conditions and the organization and stratification accomplished through the use of a regionalization/reference site scheme further adds to the accuracy and sensitivity of a bioassessment technique.

Of the ten different bioassessment types included in Table 2, we have directly tested volunteer monitoring (Level 2), RBP II (Level 4), narrative evaluations (Level 5), single-dimension indices (Level 6), RBP III (Level 8), and the regional reference site approaches (Level 9). The other assessment types were inserted into this hierarchy based on ours and others use and knowledge of each method in terms of the relative complexity of information generated (*i.e.,* data dimensions), expertise required, and other factors. For example the Stream Walk assessment type (Level 1) is classified as the simplest and least powerful approach on the basis that no or

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very little data on biological assemblages is collected and the procedure is intended to be used by relatively untrained and unskilled personnel. The handbook entitled *Water Quality Indicators Guide: Surface Waters* (Terrell and Perfetti 1989), published by the Natural Resources Conservation Service, is one such approach which is placed in this category. While this manual provides much valuable information, drawings of plants and organisms, and other guidance, a bioassessment is not required except for the ranking of some fairly simple and visually apparent indicators (*e.g.,* turbidity, presence of fish, algae, etc.). Thus it is not only difficult to generate the data dimensions needed to provide an adequate level of discrimination, there is no framework by which the method can be tailored to produce narrative or numerical assessments which have been previously calibrated against regional specific peculiarities. Further into the hierarchy (Table 1) the U.S. EPA Rapid Bioassessment Protocols (Plafkin *et al.* 1989) were placed according to the same criteria used to judge the other bioassessment types based on the potential of the method, despite the preliminary findings of this study. RBP protocol IV is essentially a "professional opinion" type of assessment which may or may not include a reliance on actual data. In any case it does not involve the collection of "new" information on which the assessment is based. RBP protocol I is not much different from the SQM method with the exception that the level of taxonomy is more refined and the field procedures and manual are more detailed. However, as is common with many field screening methods, the RBP I protocol requires a highly trained operator who can reliably make identifications and other important field observations. Biotic indices such as the Hilsenhoff HBI and the Biotic Condition Index (BCI; Winget and Mangum 1979) present other approaches which emphasize different categories of the tolerance of macroinvertebrate taxa to environmental disturbances. The BCI in particular integrates chemical and physical parameters into the overall assessment of stream condition. The RBP levels II and III could be implemented in a manner similar to the Ohio EPA Regional Reference Site approach with the exception of some key differences in the macroinvertebrate index and whether or not it is tailored to local or regional conditions. These protocols can either closely approximate the Regional Reference Site approach or can be made less complex and

presumably less accurate depending on whether adjustments are made to reflect regional peculiarities. It is apparent from our initial results that further work needs to accomplished for the RBP approach to reach parity with the Ohio EPA approach.

The predominant error tendency observed for the less complex bioassessment levels seems to be in over-estimating the condition of the environment, *i.e.,* indicating attainment when it in fact does not exist (a Type II error). This inherent error tendency initially presented some problems to Ohio EPA in the initial stages of adopting numerical biocriteria (*i.e.,* based on the Ohio EPA Regional Reference Site approach) in that the regulated community felt they potentially could be penalized by the new, more discriminating numerical biocriteria. Our view is that the natural progress in the science of bioassessment will lead to more sensitive and more accurate assessment frameworks which result in changes in both directions, some more restrictive, some less so (*e.g.,* MWH use developed by Ohio EPA, Cuyahoga navigation channel redesignation). In this sense the process will be analogous to the progress that has been made by analytical chemists in lowering chemical detection levels from the mg/l level to the ug/l and even lower levels of quantification. However, the results of our study also suggest the possibility that true condition or quality can also be under-estimated by the lower levels of bioassessment (a Type I error) although this is a less frequent occurrence. The issue here is to sufficiently refine each method so that both the degree and direction of error is known ahead of time. Methods which continue to show a propensity for both type I and type II errors should be discarded.

The results of this study should provide program managers and administrators benchmarks by which judgements can be made about the potential effectiveness of different levels of bioassessment as ambient monitoring tools and the level of bioassessment in which to invest resources. Table 4 provides a qualitative assessment of the potential applicability and usefulness of some of the different bioassessment levels depicted in Table 2. The less accurate and less discriminating bioassessment levels carry a significant risk that the resultant assessment will

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either be of insufficient sensitivity and accuracy or will be less useful for some future purpose. Thus the potential consequences of limited capabilities can be weighed ahead of time rather than discovering unwanted and potentially irreversible consequences at a later time. This is not to say that the less complex levels of bioassessment will not be useful for *any* purposes. The SQM method in particular yields tangible values beyond the resulting bioassessment which includes education, awareness, ownership, grass roots involvement, etc. The value of participation and ownership of the local aquatic resources to long term protection and restoration efforts cannot be overstated. In addition, with the appropriate demonstration of interest by local groups, the lower levels of bioassessment could be upgraded adding credibility and usefulness to the process.

At the same time a decision to opt for a less complex level of bioassessment at Ohio EPA cannot be made *a priori* without some validation or prior knowledge of comparable accuracy and sensitivity of the new method. Practical considerations dictate that different levels of bioassessment are inevitable, thus ways to determine the appropriate use of less powerful bioassessments are needed. In part MAS has already accomplished this as evidenced by an existing hierarchy of bioassessment techniques. However, the comparison of different bioassessment levels is an activity which should be maintained much in the way analytical chemical methods are continually developed, refined, and improved. Thus further examination of the RBP types of bioassessment seems prudent.

Conclusions

The results of our study indicate that further detailed work will be needed to make the RBP methods useful to Ohio EPA and others. At the same time, more effort needs to be expended in acquiring an increased capability to conduct bioassessments within Ohio EPA. The implementation of bioassessments at Ohio EPA is not a dogmatic application of the highest level (*i.e.,* Level A in Table 3) everywhere. Effort is economized whenever possible such as using qualitative tools in lieu of quantitative ones whenever possible, but doing so only in recognition

Table 4. The relative capabilities of different levels of bioassessment to fulfill and/or satisfy various nee within of major surface water program areas at Ohio EPA. Designations of E (excellent), G (good), (fair), P (poor), etc. indicate the relative capability and power of the bioassessment method to provide defensible, scientifically adequate, cost-effective, and sufficiently comprehensive assessment for ea program area based on the results obtained in this study.

| | MAJOR PROGRAM AREAS | | | | | | | | | | | | |
| | Basic/WQS -------- Reporting ------- | | | --------- Watersheds/NPS ---------- | | | | | ---------- NPDES Permits -------- | | | | |
LEVEL OF BIOASSESS.	5 Yr. Basin Surveys	305b/ NPSA	General Screen	WQS/ Uses	Edu- cation	Nonpt. Source	Habitat	Problem Disc.	NPDES Terms	Priority Setting	CSO/ Storm	Toxic Impacts	Mix Zon
A - Full Scale: (Fish, Macroin- vertebrates based on multimetric indices)	E	E	E	E	E	E	E	E	E	E	E	E	E
B - Partial Bio- assess ments (Fish **o**r Macro- invertebrates)	G/E[2]	G/E[2]	G/E[2]	G/E	G/E	G/E	G/E[2]	G/E	G/E	G/E	G	G	G
C - EPA Rapid Bioassessment[3] Protocol III (Macroinvertebrates, lowest level of taxonomy)	F	G/F	G/F	F/P	G	F	F/P	F	F/P	P	F	F	F
D - Qualitative Bioassessment (Macroinvertebrates based on narrative criteria)	F	G[2]	G/F	P[4]	G	F[1]	F	G[2]	G[2]	F	G/F	G[2]	G
E - EPA Rapid Bioassessment Protocol II (Macroinvertebrates, family level of taxonomy)	F	F[5]	P	P	G[1]	F[5]/P	F[5]/P	G/F[5]	F/P	P[4]	F[5]/P	F[5]/P	F
F - Volunteer Methods (Macroinvertebrates based on SQM procedure)	P[6]	F[7]/P	P[6]	P[6]	F[7]	G/F	F[7]/P	P[6]	F[7]/P	P[6]	P[6]	P[6]	P

1 - Fair because the complexity of data makes interpretation by untrained persons difficult; good because lower level of taxonomy i easier to attain.
2 - Good or exceptional only if macrohabitat is not a major limiting factor or if the Exceptional Warmwater Habitat or Modified Warmwater Habitat use designations are not at issue.
3 - Based on results of this study; improvement potential is high.
4 - Poor because quantitative indices are lacking; can be strengthened with addition of Qualitative Habitat Evaluation Index results (not normally part of this level).
5 - Fair because family level of taxonomy limits the interpretation power and utility of the resulting assessment.
6 - Poor because the inherent methodology lacks sufficient resolution or reproducibility even with fine tuning and training.
7 - Fair only if the assessment has been sufficiently calibrated against the A-C levels of bioassessment; otherwise the rating is poo
8 - Excellent rating because the method can be used by unskilled volunteers.

of the information needs dictated by the issues at stake. For example, in complex situations involving a

basin or subbasin scale and where use designations are likely to be scrutinized and complex NPDES permit

issues exist, the more complex levels of bioassessment (level A in Table 4) are needed and used. For

issues of a "lesser" magnitude on small streams where the "landscape" permits, a less rigorous protocol

(levels B, C, or D) may suffice. MAS has already demonstrated an increased use of partial

bioassessments (levels B and D) during the past six years and this has increased the number of samples

collected and hence the number of stream and river miles evaluated (Figures 2 and 3). For example, an

increased reliance on qualitative macroinvertebrate evaluations (level D) in lieu of quantitative sampling

(which produces the ICI score) has been evident (Figure 2). Reducing the number of sampling passes for

fish community assessment from three to two passes in large rivers and from two to one pass (level B) in

smaller streams has had a like result (Figure 3). These measures were taken in an attempt to stretch and

maximize the existing monitoring and assessment resources. Unfortunately, the steadily increasing

demand for this type of assessment (Figure 1) has effectively canceled out the effect of increased

production in terms of the proportion of annual monitoring and assessment needs that can be met in any

one basin year. More attention to increasing this type of capability both within and outside of Ohio EPA

will have more immediate benefits than attempting to use less powerful "off-the-shelf" bioassessment

tools, particularly without modification and calibration to Ohio conditions. The challenge remains to

develop the more promising bioassessment methods in order to increase the number of stream and river

miles assessed annually by Ohio EPA and others. For example, level C is a method the Districts could use

for site evaluation purposes in addition to the level B and D bioassessments that some Districts are

already performing. Our concern in all of this should be for cost-effectiveness which takes into account

the "weight" of the decision-making that the bioassessment results will be required to support. To be

successful, we must be anticipatory regarding the level of information needed as there is rarely time for

redoing a bioassessment. Thus making choices about which levels of bioassessment to use must transcend

simple cost concerns.

CORE MACROINVERTEBRATE SITES VS.
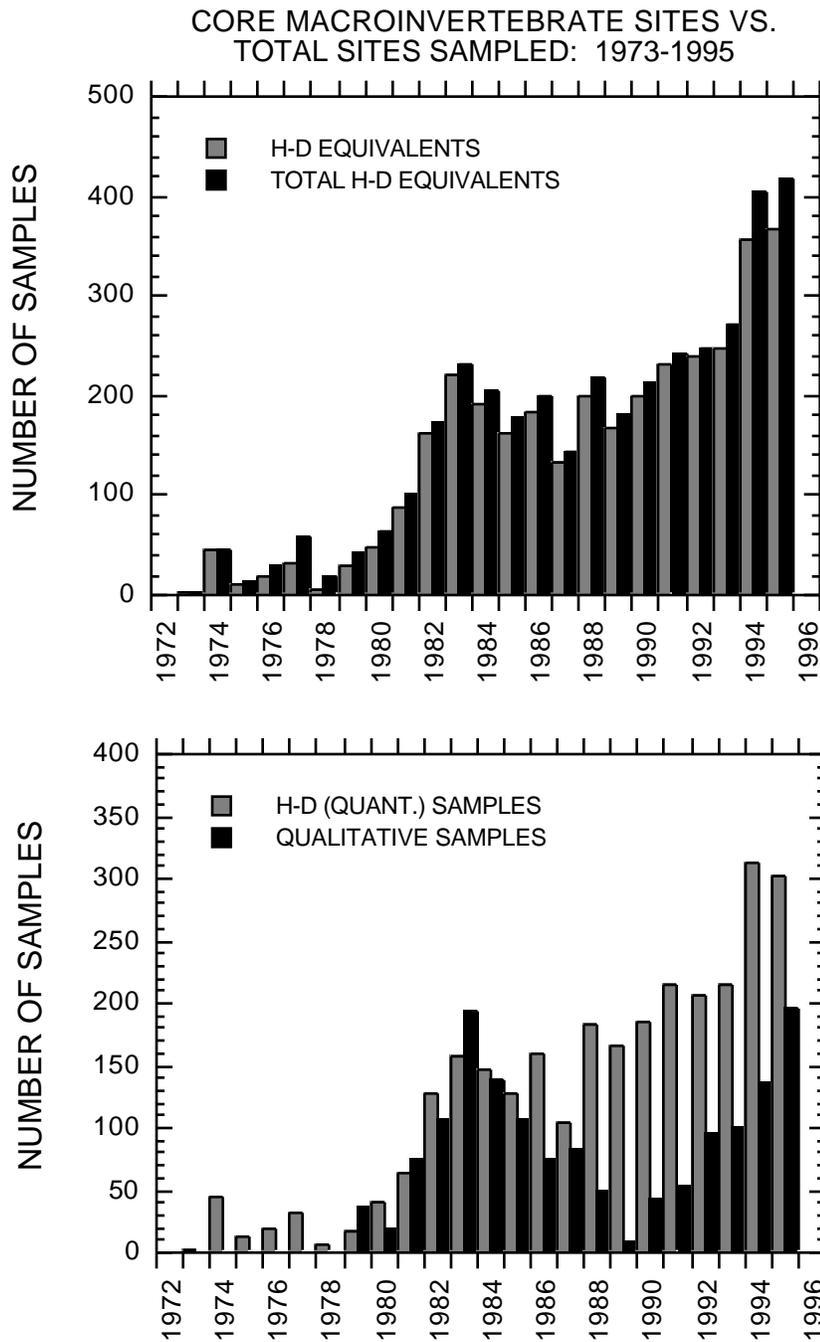TOTAL SITES SAMPLED: 1973-1995

Figure 2. Number of macroinvertebrate samples (Hester-Dendy equivalents;
    upper) collected by Ohio EPA by year during the period 1973-1995 and
    the increased number of qualitative samples collected compared to
    quantitative samples during the same period (lower).

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CORE PROGRAM FISH SITES VS.
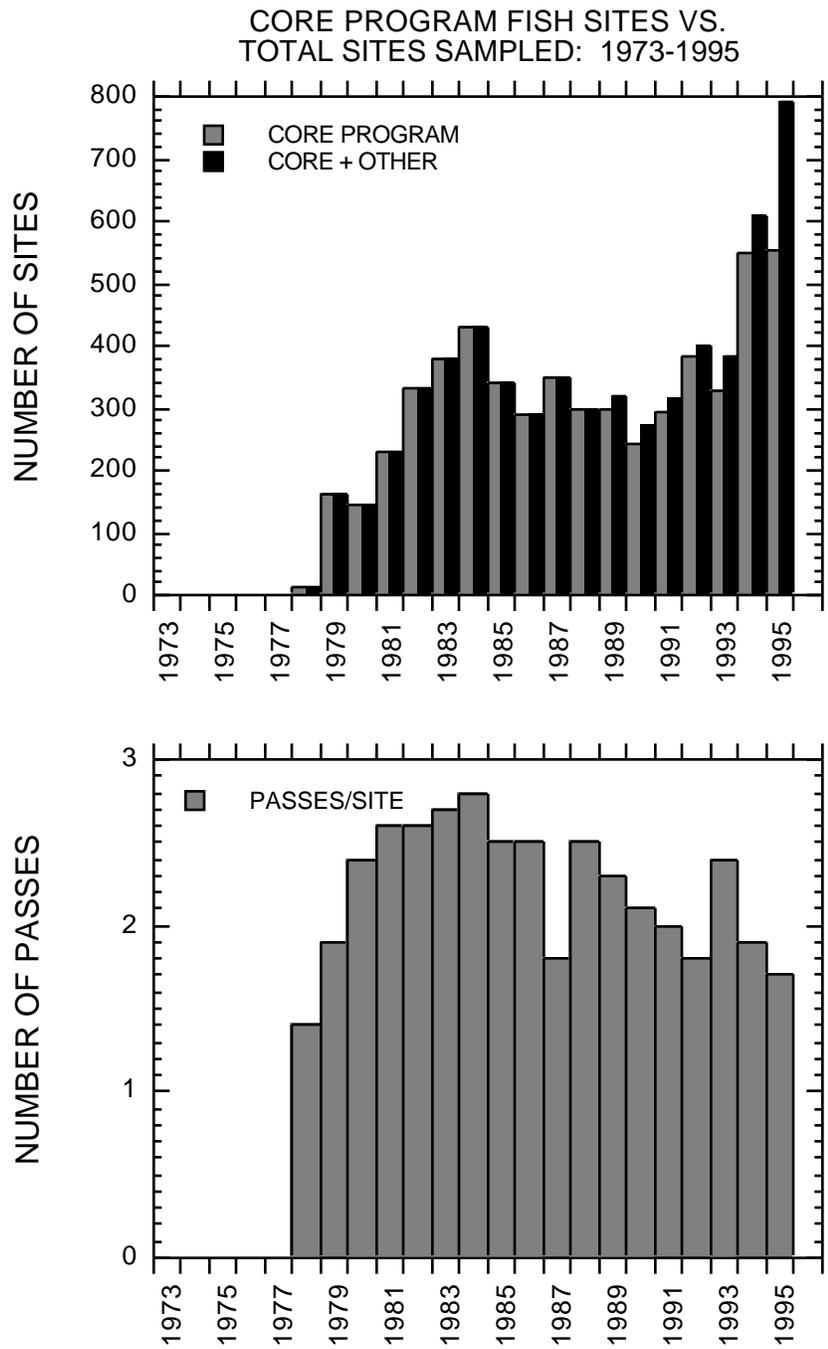## TOTAL SITES SAMPLED: 1973-1995

Figure 3. Number of electrofishing samples (upper) collected by Ohio EPA
          by year during the period 1973-1995 and the reduced number of passes
          per site (lower) during the same period.

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