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Biological Criteria for the Protection of Aquatic Life:

Volume II. Users Manual for Biological Field Assessment of Ohio Surface Waters

October 30, 1987
(Updated January 1, 1988)

Ohio Environmental Protection Agency
Division of Water Quality Monitoring and Assessment
Surface Water Section
1030 King Ave.
Columbus, Ohio 43212

NOTICE TO USERS

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

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

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

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

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

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

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

These documents can be obtained by writing:

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

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

ACKNOWLEDGMENTS

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

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

SECTION 1: INTRODUCTION

Background

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

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

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

The Biological Basis for Determining Use Attainment/Non-Attainment

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

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

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

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

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

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

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

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

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

Biological Criteria

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

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

Evaluating Biological Integrity

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

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

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

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

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

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

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

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

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

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

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

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

SECTION 2: DEFINING BACKGROUND CONDITIONS

In order to establish biological criteria that are reflective of the legislative goal of attaining biological integrity in surface waters a "calibration" of the methods used to establish the criteria is needed. The practical definition of biological integrity as the biological performance exhibited by the natural or "least impacted" habitats of a particular region provides the underlying basis for a sampling design to provide such information. It should be noted that this is not an attempt to characterize "pristine" or totally undisturbed environmental conditions as such conditions exist in only a very few places if at all (Hughes et al. 1982). Thus our expectations of how a biological community should perform are determined by the demonstrated attainability of natural communities at "least impacted" or reference sites within a particular biogeographical region.

Ecoregion Concept

The selection of control or reference sites from which attainable biological conditions can be defined is a key component in establishing biological criteria. Hughes et al. (1986) described at least seven different approaches that have been used to estimate attainable biological conditions in surface waters. Two of these include the use of forested watershed models (Vannote et al. 1980) and the classic upstream-downstream approach. Some problems with these approaches include too narrow of a focus (e.g. forested watersheds), selection of unrepresentative control sites, or a subjective selection of control sites. In some situations adequate control sites simply do not exist. Ideally, reference sites for estimating attainable biological conditions should be as "undisturbed" as possible and be representative of the watershed for which they are to serve as a control. Such sites can serve as references for a large number of streams if the sites typify the range of physical characteristics within a particular geographical region (Hughes et al. 1986). While it is recognized that all individual water bodies differ to some degree from each other, the basis for having regional reference sites is the similarity of watersheds within defined geographical regions. Generally less variability is expected among surface waters within a particular region than between regions. This is because surface waters, particularly streams, derive their basic characteristics from their watersheds. Thus streams draining comparable watersheds of a region are much more likely to be similar than those from less comparable watersheds located in a different region.

In order to accomplish the selection of reference sites it was first necessary to define "ecoregions" within the state. An ecoregion is a relatively homogenous area where the boundaries of several key geographic variables more or less coincide (Hughes et al. 1986). The delineation of ecoregions is accomplished by simultaneously examining patterns in the relative homogeneity of several terrestrial variables (Omernik 1987). This is done because several watershed variables, not just one or two, are presumed to have major and controlling influences on aquatic ecosystems (Hughes et al. 1986).

Omernik (1987) mapped the aquatic ecoregions of the conterminous United States from maps of land-surface form, soils, potential natural vegetation, and land use. These maps were then analyzed to identify areas of combined, regional homogeneity. This method seems most appropriate for classifying aquatic ecoregions because of the integrative ecological (versus technological and reductionist) way it was developed, its level of resolution, its incorporation of mapped physical, chemical, and biological information, and because it requires no further data collection (Hughes et al. 1986).

Ecoregions provide a geographical basis for estimating ecosystem responses to management action assuming that most sites within each will respond similarly to those actions (Bailey 1983). In using the ecoregion/reference site approach the reference sites serve as benchmarks for measuring the condition of other sites within the same ecoregion. Thus reference sites are used to develop expectations about surface waters that are as protective of the environment as is ecologically and socioeconomically possible. This fits well with the definition of biological integrity as the ecological performance of the least disturbed habitats within an ecoregion. This does not mean that the attainable conditions within an ecoregion cannot improve over time with changes in population, land use, progress with nonpoint pollution abatement, etc. However, it does reflect what is currently and reasonably attainable given current societal activities.

In Ohio parts of five ecoregions occur (Fig. 2-1) and the distinguishing features of each are given in Table 2-1. A detailed narrative description of these ecoregions is available in Whittier et al. (1987).

Criteria for Selecting Reference Sites

The process of selecting watersheds and reference sites is outlined in Larsen et al. (1986) and Whittier et al. (1987). While the 1983-84 Stream Regionalization Project (SRP) focused on watersheds with drainage areas of 10-300 square miles these were supplemented with additional data from sites sampled from 1981-1986. Reference sites from locations with drainage areas of 300-6000 square miles were also selected from the Ohio EPA data base (1979-1986). These latter sites include the larger streams and rivers from across the state. The lake level affected sections of Lake Erie tributaries, the Ohio River, and inland lakes and reservoirs are not included in the current analysis. However, we plan to address these areas within the next two to three years.

The SRP study design (Larsen et al. 1986; Whittier et al. 1987) was initially limited to watersheds of less than 300 square miles drainage area. Candidate watersheds were generally contained entirely within an ecoregion, but selected "cross-boundary" streams were included for comparison. Watersheds with evidence of substantial human disturbance were eliminated. This was done by examining maps of human population density, current and past land uses, compiling a watershed disturbance ranking, and noting the size and location of point source discharges. From this exercise "least-impacted" watersheds were selected. These are not "pristine" or "undisturbed" watersheds (none really

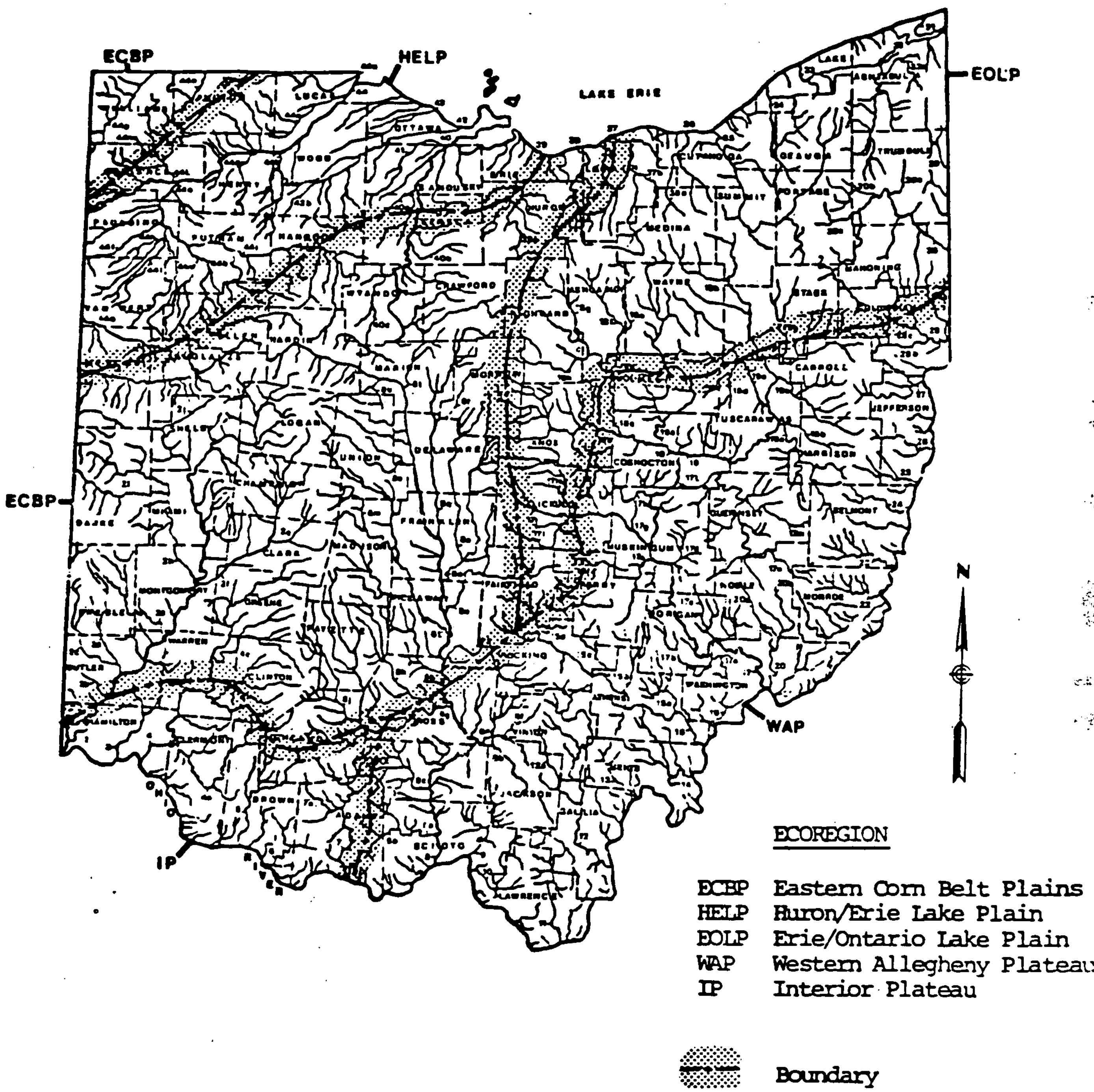

Figure 2-1. The ecoregions of Ohio as determined by methodologies developed by Omernik (1987) and used to establish attainable biological criteria in Ohio (broken line and light shading indicates ecoregion boundaries).

Table 2-1. The physical and terrestrial characteristics of the five ecoregions of Ohio.

Component	Huron/Erie Lake Plain (Northwest) HELP	Interior Plateau (S. West) IP	Erie/Ontario Lake Plain (Northeast) EOLP	Western Allegheny Plateau (E./S. East) WAP	Eastern Corn Belt Plains (W./Central) ECBP
Land Surface Form (Hammond 1970)	Flat plains	Plains with hills, open hills, tablelands with moderate relief	Irregular plains	Low to high hills	Smooth plains
Land Use (Anderson 1967)	Cropland	Mosaic of cropland, pasture, woodland and forest	Cropland with pasture, woodland, forest, and urban	Woodland, forest with some cropland and pasture; woodland, forest mostly ungrazed	Cropland
Soil (various sources)	Humic-gley, low humic gley, gray brown podzolic/humic gley	Udalfs/udults	Alfisols	Alfisols	Alfisols, gray-brown podzolic/humic gley
Potential Natural Vegetation (Kuchler 1970)	Elm/ash forest	Oak/hickory forest	Beech/maple northern hardwoods (maple, birch, beech, hemlock)	Mixed mesophytic forest (maple, buckeye, beech, tulip, oak, linden), Appalachian oak	Beech/maple forest

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exist in Ohio), but they do represent the best watershed conditions within an ecoregion given the background activities prevalent in our society (see Trautman 1981 for a description of changes during the period 1750 - present). These watersheds represent the least-impacted conditions thus they should have the least-impacted streams from an ecoregional viewpoint. The character of these streams should reflect the reasonably attainable biological conditions and water quality within a particular ecoregion given the prevailing background conditions.

Final SRP site selection was made after making an aerial and local reconnaissance of each candidate site and watershed. Factors considered in this inspection included the amount of stream channel modification (if any), the condition of the vegetative riparian buffer, water volume, channel morphology, substrate character and condition, obvious color/odor problems, amount of woody debris, and the general "representativeness" of the site within the ecoregion. Field sampling was conducted for macroinvertebrates, fish, and chemical/physical water quality at 109 sites during 1983-84 following Ohio EPA standardized methods (Ohio EPA 1987a). Detailed descriptions of the instream habitat were made by the biological field crews. Chemical water quality data were also collected; the results are described elsewhere (Larsen and Dudley 1987; Whittier et al. 1987).

Following the field sampling portion of the project several sites were deleted because watershed and stream characteristics were discovered that showed these sites to be unrepresentative of least-impacted conditions. These are listed in Appendix A. Complete avoidance of small stream (i.e. drainage areas less than 300 square miles) sites with any history of channel modification was not possible in the Huron/Erie Lake Plain ecoregion because of the extensive stream channel modification work that has been done in this area. Given the amount of the land surface that is devoted to row crop agriculture coupled with the poor drainage characteristics of this ecoregion, this condition could arguably be termed a "background" condition for the small streams of this ecoregion. This particular problem is described in more detail in Section 6. An examination of the entire Ohio EPA statewide data base (1979-1986) resulted in the addition of nearly 200 sites that also qualified as reference sites. Most of the added sites less than 300 square miles in size were sampled during 1981-1986. The location of fish and macroinvertebrate sites appear in Figs. 2-2 and 2-3.

Large stream and river sites were also selected and included sampling conducted since 1980 for fish and 1981 for macroinvertebrates. The original SRP study design did not include these areas. The criteria for choosing large stream and river reference sites was basically the same as the SRP study design, except that using some sites located downstream from urban centers and point sources could not be completely avoided. These consisted of sites located well downstream from these potential disturbances and below known biological recovery points. No sites in direct proximity to any point sources or within impounded or extensively modified areas were used.

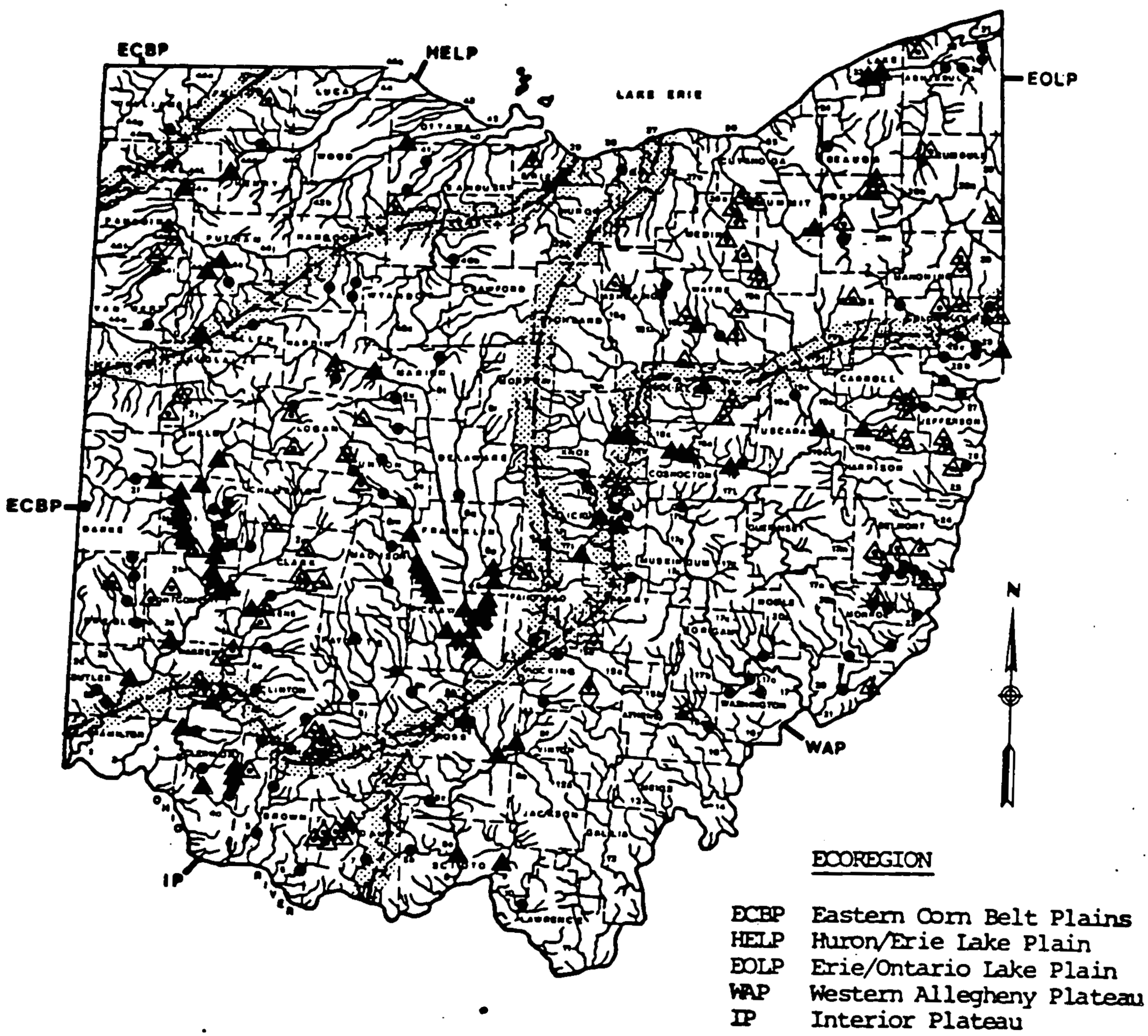

Figure 2-2. Location of Ohio reference sites for fish within each of the five ecoregions and the three principal stream and river sizes (termed boat methods, wading sites, and headwaters sites - each are indicated by different symbols; dashed lines and shading indicates ecoregion boundaries).

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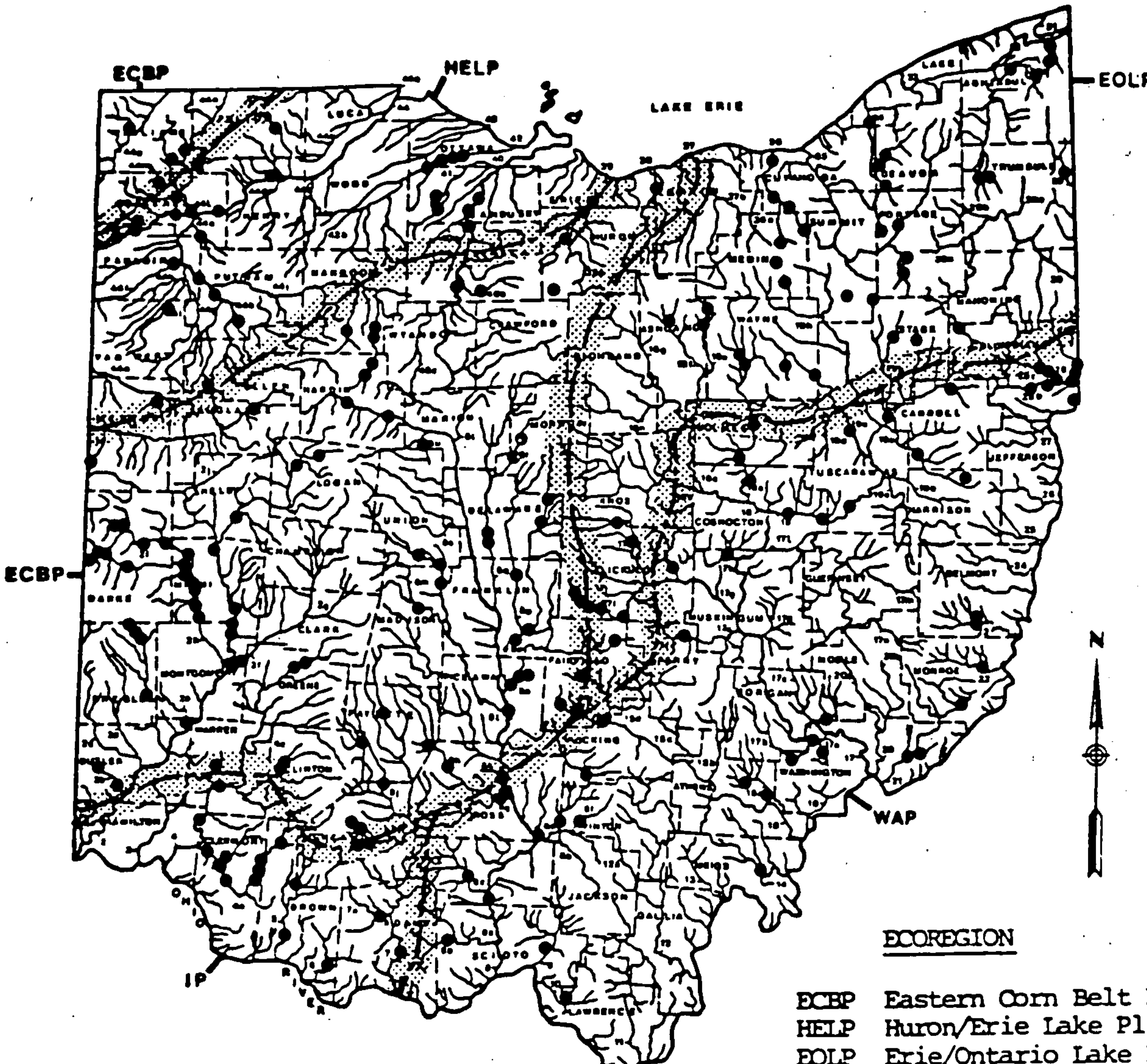

ECOREGION

ECBP Eastern Corn Belt Plains
HELP Huron/Erie Lake Plain
EOLP Erie/Ontario Lake Plain
WAP Western Allegheny Plateau
IP Interior Plateau

METHOD

• Artificial Substrate

SCALE

0 10 20 30
MILES

0 16 32 64
KILOMETERS

Figure 2-3. Location of Ohio reference sites for macroinvertebrates within each of the five ecoregions and the principal collection methods (artificial substrates sites only; dashed lines and shading indicates ecoregion boundaries).

Supplement to Figs. 2-2 and 2-3. Major Ohio streams and rivers (≥100 sq. mi. drainage area).

OHIO RIVER BASIN

1. Wabash R.
   a. Beaver Cr.
2. Great Miami R.
   a. Whitewater R.
   b. Indian Cr.
   c. Four Mile Cr.
   d. Sevenmile Cr.
   e. Twin Cr.
   f. Mad R.
   g. Buck Cr.
   h. Stillwater R.
   i. Greenville Cr.
   j. Loramie Cr.
3. Mill Cr.
4. Little Miami R.
   a. East Fork
   b. Todd Fork
   c. Ceasar Cr.
5. Whiteoak Cr.
6. Eagle Cr.
7. Ohio Brush Cr.
   a. West Fork
8. Scioto R.
   a. Scioto Brush Cr.
   b. South Fork
   c. Sunfish Cr.
   d. Salt Cr.
   e. Little Salt Cr.
   f. Middle Fork
   g. Paint Cr.
   h. North Fork
   i. Rocky Fork
   j. Rattlesnake Cr.
   k. Deer Cr.
   l. Big Darby Cr.
   m. Little Darby Cr.
   n. Walnut Cr.
   o. Big Walnut Cr.
   p. Alum Cr.
   q. Olentangy R.
   r. Whetstone Cr.
   s. Mill Cr.
   t. Little Scioto R.
   u. Rush Cr.
9. Little Scioto R.
10. Pine Cr.
11. Symes Cr.
12. Raccoon Cr.
   a. L. Raccoon Cr.
   b. Leading Cr.
14. Shade R.
15. Hocking R.
   a. Federal Cr.
   b. Sunday Cr.
   c. Monday Cr.
   d. Rush Cr.
16. Little Hocking R.
17. Muskingum R.
   a. Wolf Cr.
   b. West Branch
   c. Meigs Cr.
   d. Salt Cr.
   e. Moxahala Cr.
   f. Jonathan Cr.
   g. Licking R.
   h. North Fork
   i. South Fork
   j. Raccoon Cr.
   k. Wakatomika Cr.
   l. Wills Cr.
   m. Salt Fork
   n. Seneca Fork
18. Walhonding R.
   a. Killbuck Cr.
   b. Kokosing R.
   c. Mohican R.
   d. Lake Fork
   e. Muddy Fork
   f. Jerome Fork
   g. Black Fork
   h. Clear Fork
19. Tuscarawas R.
   a. Stillwater Cr.
   b. L. Stillwater Cr.
   c. Sugar Cr.
   d. South Fork
   e. Conotton Cr.
   f. Sandy Cr.
   g. Nimishillen Cr.
   h. Chippewa Cr.
20. Duck Cr.
   a. West Fork
   b. East Fork
21. Little Muskingum R.
22. Sunfish Cr.
23. Captina Cr.
24. Wheeling Cr.
25. Short Cr.
26. Cross Cr.
27. Yellow Cr.
28. Little Beaver Cr.
   a. North Fork
   b. West Fork
   c. Middle Fork
29. Pymatuning Cr.
30. Mahoning R.
   a. Mosquito Cr.
   b. Eagle Cr.
   c. West Branch

LAKE ERIE BASIN

31. Conneaut Cr.
32. Ashtabula R.
33. Grand R.
   a. Mill Cr.
34. Chagrin R.
35. Cuyahoga R.
36. Rocky R.
   a. West Branch
37. Black R.
   a. West Branch
   b. East Branch
38. Vermilion R.
39. Huron R.
   a. West Branch
40. Sandusky R.
   a. Wolf Cr.
   b. Honey Cr.
   c. Tymochtee Cr.
41. Muddy Cr.
42. Portage R.
   a. South Branch
   b. Middle Branch
43. Toussaint Cr.
44. Maumee R.
   a. Swan Cr.
   b. Beaver Cr.
   c. Cutoff Ditch
   d. S. Turkeyfoot Cr.
   e. Auglaize R.
   f. Blue Cr.
   g. L. Auglaize R.
   h. Praire Cr.
   i. Middle Cr.
   j. Blanchard R.
   k. Ottawa R.
   l. Tiffin R.
   m. Lick Cr.
   n. Bean Cr.
   o. St. Marys R.
   p. St. Joseph R.
   q. Ottawa R.

SECTION 3: FIELD METHODS AND DATA ANALYSIS REQUIREMENTS

General Guidelines

The purpose of this section is to describe the field methods and data analysis techniques that are required to use the biological criteria for the purposes of the Ohio Water Quality Standards (WQS). Standardized methods and data analysis techniques are a critical requirement and ensure the comparability of results from site to site. Some basic problems in sampling aquatic biota and using biological data that can affect the applicability and accuracy of the results are summarized, as follows:

1) The purpose for which data were collected is especially important when the use of "existing" data is being contemplated. Biological samples that were collected for the purposes of determining the presence/absence of species and/or taxa only will have little value for the purposes of the biological criteria. This is especially true if relative abundance data (which in itself implies standardization of sampling effort) is lacking.

2) "Partial" collections will not suffice because the Index of Biotic Integrity (IBI), Modified Index of Well-Being (Iwb), and the Invertebrate Community Index (ICI) require as complete a breakdown of the community as is possible with the methods used. Specific requirements are discussed later.

3) Sampling gear and water conditions affect sampling effectiveness and ultimately data analysis and interpretation. Specific fish and macroinvertebrate sampling gear are required for conformance to the Ohio WQS. Appropriate data collection conditions are also important.

4) Appropriate taxonomic refinement is important, particularly for macroinvertebrates, as "lumping" of species and taxa into larger groups makes the data unusable for the purposes of the biological indices.

5) Sampling sites must be representative of the surface water being sampled. For example, localized areas of impoundment, "bridge effect" areas, etc. should be avoided if the stream or river is predominantly free-flowing.

Persons using the biological criteria approach should be aware of these basic problems and take steps to ensure that study design, sampling methods, and data analysis conform to the procedures outlined by or refered to in this manual. Finally, the methods and techniques described here require the involvement of a trained biologist who is familiar with the field methods, laboratory techniques, data analyses, and the local fauna.

Fish Sampling Methods Summary

The fish sampling methods routinely used by Ohio EPA are summarized in Table 3-1. Detailed descriptions of these and other fish sampling gear and methods are available in Ohio EPA (1987a). The wading methods (sampler types D, E, and F) were developed by Ohio EPA. Boat methods (sampler type A) are based primarily on the work of Gammon (1973, 1976) on the Wabash River (Indiana) and the experience of the Ohio EPA. Unlike other biological monitoring disciplines, surprisingly little standardized guidance is available from state or federal agencies regarding appropriate methods. Therefore, Ohio EPA has used what can be considered a state-of-the-art approach in the development of standardized, systematic methods for sampling fish in rivers and streams. The requirements for all aspects (sampling frequency and duration, relative effort, etc.) of the fish sampling program are based on eight years of practical application in Ohio. On-going Ohio EPA monitoring programs have been designed to address fish sampling methods, gear selectivity, and sampling design.

It is apparent from the literature (e.g. Vincent 1971; Gammon 1973, 1976; Novotny and Priegel 1974) and our own experience that pulsed DC electrofishing is the most comprehensive and effective single method for collecting river and stream fishes that is currently available. Certainly a survey that employs a number of different gear types will likely yield more species than any one single method. Such surveys, however, are more costly and time consuming and do not generate equivalent information per unit of effort. Gammon (1976) emphasized this point when it was observed that one day of electrofishing was equal to 20-25 hoop-net days and included a much broader representation of the fish community. We have opted to use a sampling strategy that emphasizes methods designed to obtain a representative sample of the fish community at a particular site. This means that each site is sampled with an appropriate method (i.e. wading methods and boat methods) in a consistent and reproducible manner. Although this approach may not yield a complete inventory of all species at a site, sample sizes large enough to permit comparisons between sites are obtained. This is particularly true of the boat methods used to sample the larger streams and rivers. This is somewhat in contrast to the labor intensive "inventory" sampling procedures advocated by Karr et al. (1986) and others for these habitats.

Quantitative data includes repetitive sampling based on distance (rather than time), weighing individual fish (modified I_{wb} only), counting numbers by each species, and recording external anomalies. Two or three passes (on different dates) through each sampling zone are necessary to generate reliable catch data as specified by Gammon (1976) and Ohio EPA (1987a). The collection of biomass data is necessary for using the modified I_{wb} (restricted to sites >20 sq. mi.). We have found that using both the IBI and I_{wb} provides rigorous assessment, particularly where the evaluation includes use designations other than Warmwater Habitat (WWH), complex environmental impacts (toxics, combined sewers, multiple influences), and in larger streams and rivers. Karr et al. (1986) cite the need for biomass data as being a drawback to using the I_{wb}. However, we have found that subsampling techniques not

Table 3-1. Characteristics of electrofishing sampling methods most frequently used by the Ohio EPA to sample fish communities (see Ohio EPA 1987a for further details).

	Sampler Type		
	A	D or E	F
Gear Used:	12', 14', or 16' boat	D:Sportyak (7.5' boat) E:Longline (100m extension cord)	Backpack
Power Source:	Smith-Root Type VI-A electrofishing unit or Smith-Root 3.5 GPP generator/ pulsator unit	Model 1736 VDC T&J generator/pulsator unit	Michigan DNR battery pack unit
Current Type:	Pulsed DC	Pulsed DC	Pulsed DC
Wattage: (AC Power Source)	3500	1750	12 V battery
Volts: (DC Output)	50-1000	100-300	100 or 200
Amperage: (Output)	4-11	2-7	1.5-2
Anode Location:	Front of boom	Net hoop	Net hoop
Distance Sampled (km):	0.50	0.20	0.15-0.20
Sampling Direction:	Downstream	Upstream	Upstream
Relative Abundance:	Based on 1.0 km	Based on 0.3 km	Based on 0.3km
Stream Size:	Moderate to large streams & rivers	Wadeable streams to headwater tributaries	Headwater tributaries

only reduce potential error (compared to weighing each individual fish), but add an insignificant amount of time to overall sample processing. Each collection must be sorted and counted anyway thus weighing is a minor component of this effort. The subsampling and catch processing procedures are detailed elsewhere (Ohio EPA 1987a).

Fish sampling should generally take place between mid-June and late September and include two or three passes total. It may be necessary to conduct sampling outside of this time period (May, early October), but certain precautions should be taken to ensure data comparability. We prefer to limit this sampling to simple, small stream situations. Late fall, winter, and early spring sampling is discouraged because of the effect of cold temperatures on sampling efficiency and changes in fish distribution. If three passes are planned each individual pass should be spaced at least three or four weeks apart. If only two passes are intended (recommended for wading methods only) this time should be five to six weeks. These requirements have been experimentally determined by repetitively sampling at "test sites" for both boat and wading methods. Putting this time between passes allows the community to stabilize and recover from any temporary perturbations that may have been induced by the sampling. This is particularly important in the wadable streams. Restricting sampling to the summer season minimizes the influence of spring spawning or other seasonal occurrences. Additionally, environmental stresses are potentially at their height because controlling influences such as temperature and dissolved oxygen are nearest chronic stress thresholds.

The condition of the surface water being sampled is another important item that affects electrofishing. Since sampling efficiency is in part dependent on the ability of the sampler to see stunned fish, two conditions need to be met. The first is that the netter(s) should wear polarized sunglasses to enhance the spotting of fish stunned beneath the surface. The second is that sampling should be performed during normal water clarity and flow conditions. High flow and turbid water can reduce sampling effectiveness.

Accurate identification of fish is essential and is required to the species level at a minimum. Identification to the sub-specific level may be necessary in certain situations (e.g. banded killifish). Field identifications are acceptable, but laboratory vouchers will be required for any new locality records, new species, and those specimens that cannot be field identified. It is recommended that specimens be retained for laboratory examination if there is <u>any</u> doubt about the correct identity of a fish. The collection techniques used are not consistently effective for fish less than 15-20 mm in length therefore identification and inclusion in the sample is not recommended. This follows the reasoning of Karr *et al*. (1986).

Study design and sampling site selection are discussed further in Section 8 and Ohio EPA (1987a).

Macroinvertebrate Methods Summary

The primary sampling gear used by the Ohio EPA for the quantitative collection of macroinvertebrates in streams and rivers is the modified multiple-plate artificial substrate sampler originally described by Hester and Dendy (1962). The sampler is constructed of 1/8 inch tempered hardboard cut into three inch square plates and one inch square spacers. A total of eight plates and twelve spacers are used for each sampler. The plates and spacers are placed on a 1/4 inch eyebolt so that there are three single spaces, three double spaces, and one triple space between the plates (Figure 3-1). The total surface area of the sampler, excluding the eyebolt, is 145.6 square inches or roughly one square foot. A routine monitoring sample consists of a composite of five substrates that are colonized instream for a six week period normally falling between June 15 and September 30. Detailed descriptions of the placement, collection, and processing of the artificial substrates are available in Ohio EPA (1987a). In addition to the artificial substrate sample, routine monitoring also includes a qualitative collection of macroinvertebrates that inhabit the natural substrates at the sampling location. All available habitat types are sampled and voucher specimens retained for laboratory identification. More specific information for the collection of this sample can also be found in Ohio EPA (1987a). For the purpose of generating an ICI value, both a quantitative and qualitative sample must be collected at a sampling location.

A good source of information regarding the practical application of artificial substrates can be found in Cairns (1982). The use of artificial substrates for monitoring purposes has a number of advantages. According to Rosenberg and Resh (in Cairns, 1982) the major advantages in using artificial substrates are that they 1) allow collection of data from locations that cannot be sampled effectively by other means, 2) permit standardized sampling, 3) reduce variability compared with other types of sampling, 4) require less operator skill than other methods, 5) are convenient to use, and 6) permit nondestructive sampling of an environment. The authors also list a number of disadvantages, but, generally, these problems can be minimized by adhering to strict guidelines concerning sampler placement, collection, and analysis.

A composited set of five artificial substrate samplers has been used by the Ohio EPA in collecting macroinvertebrate samples since 1973. At this level of effort, it has been found that a consistent, reproducible sample can be collected. Results of analyzing replicate sets of five artificial substrates have shown that variability among calculated ICI values is low. Details of that analysis can be found elsewhere in this document (Appendix D).

The reliability of the sampling unit not only depends on the fact that colonization surface areas are standard, but equally important are the actual physical conditions under which the units are placed. It is imperative that the artificial substrates be located in a consistent fashion with particular emphasis on current velocity over the set. With the exception of water

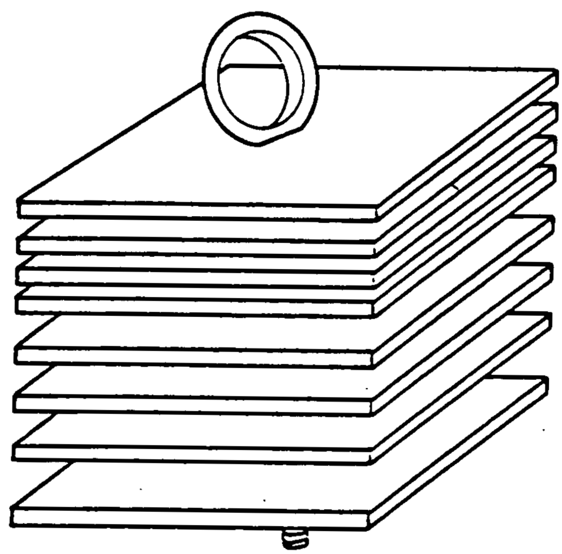

Figure 3-1. Modified Hester-Dendy multiple-plate artificial substrate sampler used by the Ohio EPA for the quantitative collection of aquatic macroinvertebrates.

quality, amount of current tends to have the most profound effect on the types and numbers of organisms collected. For a literal interpretation of the ICI, current speeds should be no less than 0.3 ft/sec under normal flow regimes. These conditions can usually be adequately met in all but the smallest of permanent streams (<10 sq mile drainage) or those streams so highly modified for drainage that dry weather flows maintain pooled habitats only. In these situations, sampling can be accomplished, but some interpretation of the ICI value may be necessary.

An additional area of some importance concerns the accuracy of identification of the sample organisms. The ICI has been calibrated to a specific level of taxonomy that is currently being employed by the Ohio EPA. It is imperative that accurate identifications to the levels specified be accomplished. Otherwise, problems may arise in many of the ICI metrics where number of kinds of a particular organism group is the parameter used. Inaccurate identifications can also be a problem in the ICI metric dealing with percent abundance of pollution tolerant organisms. As new information and taxonomic keys become available, adjustments to the ICI scoring may be necessary. A listing of current taxonomic keys and a phylogenetic table indicating level of taxonomy used for specific organism groups can be found in Ohio EPA (1987a).

SECTION 4: BIOLOGICAL DATA EVALUATION: FISH

Fish can be one of the most sensitive indicators of the quality of the aquatic environment (Smith 1971). Historically fish have received less attention than other taxonomic groups in stream surveys despite the fact that they represent upper trophic levels and the literature abounds with data on their environmental requirements and life history (Doudoroff and Warren 1957; Gammon 1976). Doudoroff (1951) emphasized the need for thorough fish population studies in connection with water quality assessments. Excepting instances of gross pollution, only fish themselves can be trusted to reliably indicate environmental conditions generally suitable or unsuitable for their existence (Doudoroff and Warren 1957). In one sense, the populations of fish in a river or stream reflect the overall state of environmental health of the watershed as a whole. This is because fish live in water which has previously fallen on the cities, fields, strip mines, grasslands, and forests of the watershed (Gammon 1976). The following are some of the advantages of using fish as indicators of water quality conditions:

1) fish are integrators of community response to aquatic environmental quality conditions; they are the end product of most aquatic food webs, thus the total biomass of fishes is highly dependent on the gross primary and secondary productivity of lower organism groups;

2) fish constitute a conspicuous part of the aquatic biota and are recognized by the public for their sport, commercial and endangered status, and represent the end product of protection for most water pollution abatement programs (i.e. many water quality criteria are based on laboratory tests using fish);

3) fish reproduce once per year and complete their entire life cycle in the aquatic environment; therefore, the success of each year class is dependent upon the quality of the aquatic environment which they inhabit; this is evident in the general condition of the fish community each summer and fall;

4) fish have a relatively high sensitivity to a variety of substances and physical conditions; and

5) fish are readily identified to species in the field and there is an abundance of information concerning their life history, ecology, environmental requirements and distribution available for many species.

Changes in the relative abundance (numbers and weight), species richness, composition, and other attributes are directly influenced by the presence of water quality disturbances and/or habitat alterations. The principal measures of overall fish community health and well-being used by the Ohio EPA is the Index of Well-Being (I_{wb}) developed by Gammon (1976) and modified by Ohio EPA (Appendix C), and the Index of Biotic Integrity (IBI) developed by Karr

(1981). The Iwb is based on structural attributes of the fish community whereas the IBI additionally incorporates functional characteristics. Together both indices provide a rigorous evaluation of overall fish community condition. As stated before these are not diversity indices in the traditional sense. Both indices incorporate a much broader range of attributes of fish communities than merely species richness and the proportional relationship of fish numbers.

The presence of permanent, large populations of different fish species is generally considered to be the result of a combination of many favorable factors (Trautman 1942). Factors which account for variations in the distribution and abundance of fishes in streams and rivers include, but are not limited to, stream size, instream cover, stream morphology, depth, flow, substrate, gradient and water quality. Perturbations to the physical and/or chemical quality of a river or stream usually result in varying degrees of stress to one or more fish species. Fish species that fail to adjust to these stresses will be reduced in numbers or be eliminated via mortality, reduced reproductive success, and/or avoidance. The subsequent absence or reduced numbers of fish results in decreased community diversity and abundance, and is reflected by an association predominated by stress tolerant species. Fish can temporarily inhabit chemically or physically degraded areas (especially if refuge areas are close-by), but these are usually functionally degraded assemblages and predominated by tolerant species. Fish communities need not undergo large declines in species richness, relative numbers, or biomass to become degraded. In fact, some forms of perturbation (e.g. habitat modification, nutrient enrichment) can cause fish numbers and biomass to increase with only slight reductions in species richness. The degradation to the community in these instances is more often reflected by significant changes in trophic composition and predominant feeding guilds. The traditional tools that evaluate only community structure (e.g. diversity, numbers) can underrate these important changes.

Index of Biotic Integrity (IBI)

The Index of Biotic Integrity (IBI) uses an approach similar to that employed in econometric analyses where an array of different metrics are examined. As originally proposed by Karr (1981) and later refined by Fausch et al. (1984) and Karr et al. (1986) the IBI incorporates 12 community metrics. The value of each metric is compared to the value expected at a reference site located in a similar geographic region where human influence has been minimal. Ratings of 5, 3, or 1 are assigned to each metric according to whether its value approximates (5), deviates somewhat from (3), or strongly deviates (1) from the value expected at a reference site. The maximum IBI score possible is 60 and the minimum is 12. Further details about the underlying basis of the IBI and its application are available in Karr et al. (1986).

The individual IBI metrics assess fish community attributes that are presumed to correlate (either positively or negatively) with biotic integrity. Although no one metric alone can indicate this consistently, all of the IBI metrics combined include the redundancy that is needed to accomplish a consistent and sensitive measure of biotic integrity (Angermier and Karr 1986). IBI relies on multi-parameters, a requirement when the system being evaluated is complex (Karr et al. 1986). It incorporates elements of professional judgement, but also provides the basis for quantitative criteria for determing what is exceptional, good, fair, poor, and very poor.

The following describes the metrics of the IBI and how they were derived for headwaters, wading, and boat sites. These analyses and IBI metrics are specifically tailored to Ohio surface waters and Ohio EPA sampling methods.

IBI Metrics

Karr (1981) proposed 12 community metrics within three broad categorical groupings (species richness and composition, trophic composition, and fish abundance and condition) for calculating the IBI. Some of the metrics respond favorably to increasing environmental quality ("positive metrics") whereas others respond favorably to increasing degradation ("negative metrics"). Some respond across the entire range of perturbation whereas others respond strongly to a portion of that range (Table 4-1).

A wide variety of stream and river sizes occur in Ohio. These not only contain differing fish assemblages, but require the use of different sampling methods. Therefore it was necessary to modify the IBI for application to these different stream sizes and make adjustments for different sampling gear. The modifications were made in keeping with the guidance given by Karr et al. (1986). Three basic divisions are made; wading sites, boat sites, and headwaters sites. In Ohio, wading sites have drainage areas that are generally less than 300 square miles (range 21-475 sq. mi.; range of means within the five ecoregions 44-128 sq. mi.), but greater than 20 square miles. Boat sites include streams and rivers that are too deep and large to sample effectively with wading methods. Boat sites generally exceed 100-300 square miles in drainage area (range 117-6479 sq. mi.; range of means for the ecoregions 225-2190 sq. mi.). Headwaters sites are actually sampled with the same gear used at wading sites, but are defined as sampling locations with drainage areas less than 20 square miles (range 1-20 sq. mi.; range of means for the ecoregions 5.5-10.2 sq. mi.). These designations are followed throughout the text. Figure 4-1 provides a flow chart for determining which IBI modification (e.g. wading, headwaters, etc.) should be used to evaluate a particular site.

The IBI metrics used to evaluate wading sites closely approximates those proposed by Karr (1981) and refined by Fausch et al. (1984) and Karr et al. (1986). The minor changes are in conformity with the guidance of Karr et al. (1986). More substantial modifications were necessary for the IBI metrics used for the boat sites and headwaters sites. These changes were made in recognition of the different sampling efficiency and selectivity of the boat methods and the different faunal character of larger streams and rivers. Although headwaters sites are actually sampled with the wading methods (Ohio EPA 1987a) these habitats have a different faunal composition resulting from the strong influence of small channel and substrate size, temporal flow and

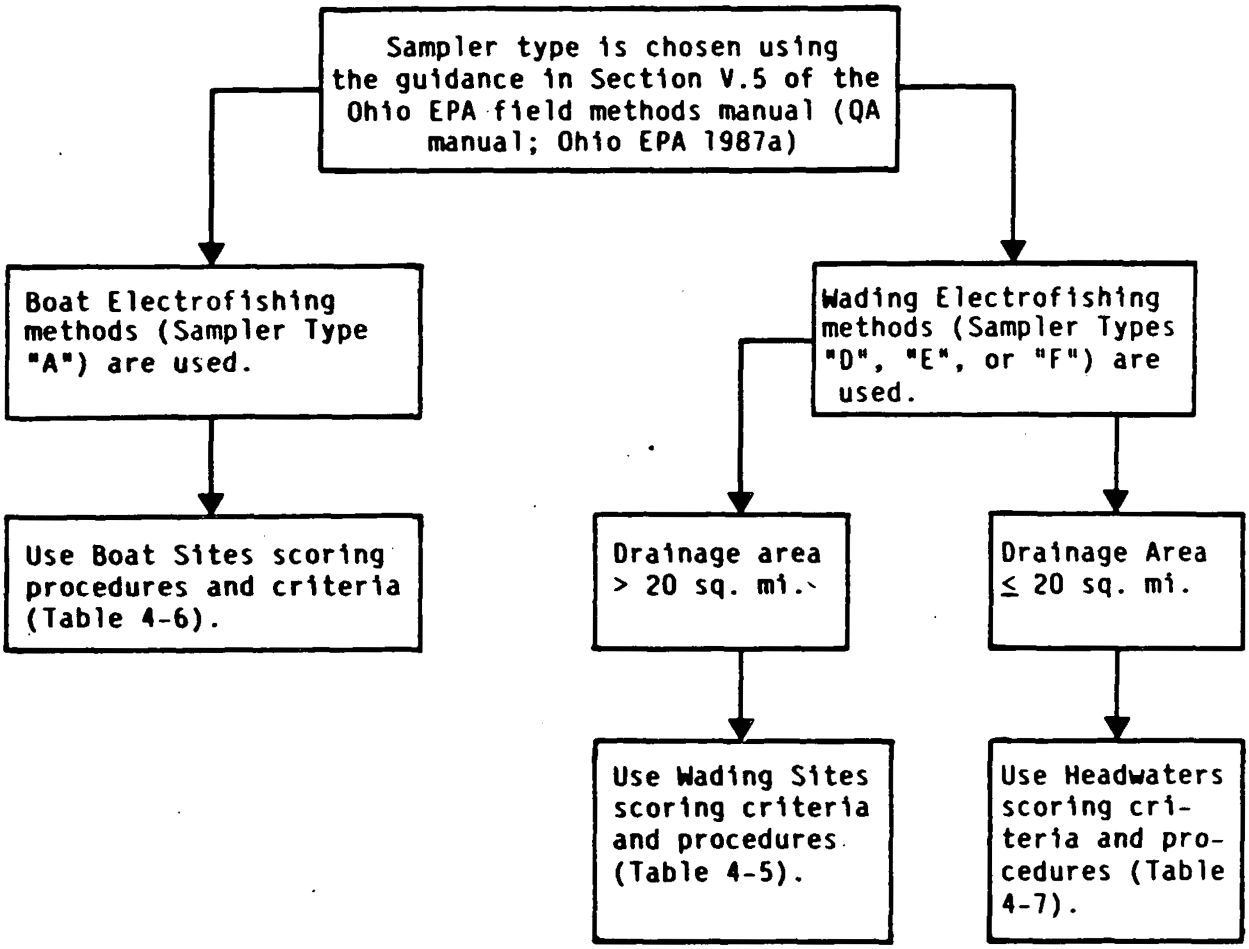

Figure 4-1. Flow chart for determining which set of IBI criteria and procedures (headwaters, wading, or boat versions) to use in calculating the Index of Biotic Integrity for a particular site.

Table 4-1. Index of Biotic Integrity metrics used to evaluate wading sites, boat sites, and headwaters stream sites. Original metrics from Karr (1981) are given first with substitute metrics following.

IBI Metric	Headwaters Sites[1,2]	Wading Sites[2]	Boat Sites[3]
1. Total Number of Species[4]	X	X	X
2. Number of Darter Species	X[5]	X	
% Round-bodied Suckers[6]			X
3. Number of Sunfish Species		X	X
Number of Headwaters Species	X		
4. Number of Sucker Species		X	X
Number of Minnow Species	X		
5. Number of Intolerant Species		X	X
Number of Sensitive Species	X		
6. % Green sunfish			
% Tolerant Species	X	X	X
7. % Omnivores	X	X	X
8. % Insectivorous Cyprinids			
% Insectivorous Species	X	X	X
9. % Top Carnivores		X	X
% Pioneering Species	X		
10. Number of Individuals[7]	X	X	X
11. % Hybrids			
% Simple Lithophils		X	X
Number of Simple Lithophilic Species	X		
12. % Diseased Individuals			
% DELT Anomalies[8]	X	X	X

1 applies to sites with drainage areas less than 20 sq. mi.
2 these sites are sampled with wading methods; 3 these sites are sampled with boat methods; 4 excludes exotic species; 5 includes sculpins.
6 includes suckers in the genera Hypentelium, Moxostoma, Minytrema, and Erimyzon; excludes white sucker (Catostomus commersoni).
7 excludes species designated as tolerant, hybrids, and exotics.
8 includes deformities, eroded fins, lesions, and external tumors (DELT).

water availability. It is important that the IBI metrics reflect the character of headwaters fish communities in relation to these critical factors. Each of the original IBI metrics are discussed including any modifications and/or substitutions that were made. A summary of the IBI metrics appears in Table 4-1.

To determine the 5, 3, and 1 values for each IBI metric the reference site data base was first plotted against a log transformation of drainage area for each of the three site designations. All of the reference site data from each ecoregion was combined for each method. Individual metric differences attributable to ecoregional differences are accounted for in the final derivation of the IBI criteria. Each metric was examined to determine if any relationship with drainage area existed. If a positive relationship was found a 95% line was determined and the area beneath trisected following the method used by Fausch et al. (1984). Wading and headwaters sites data were combined for certain common metrics to determine the slope of the 95% line even though scoring for these sites are performed separately. The IBI metric score (i.e. 5, 3, or 1) is then determined by comparing the site drainage area and metric value with the figure constructed from the reference site data base.

For some of the metrics that showed no positive relationship with drainage area an alternate trisection method was used. A horizontal 5% and 95% line was determined and the area between them trisected. A bisection method was used for the number of individuals metric. For two others (top carnivores, anomalies) the reference site data base was examined and scoring criteria established using best professional judgement. The resultant 5, 3, and 1 values are the same at all drainage areas. A similar method of trisection was used by Hughes and Gammon (1987) for the lower 280 km of the Willamette River, Oregon. A combination of the standard and alternate trisection methods were used for certain metrics, particularly for the wading sites.

Trisection was performed both separately and jointly for wading and headwaters sites, depending on the metric. All boat sites were trisected separately.

Metric 1. Total Number of Indigenous Fish Species (All Methods)

General

This metric is used with all three versions of the IBI (Table 4-1). Exotic species (Appendix B, Table B-3) are not included. This metric is based on the well-documented observation that the number of indigenous fish species in a given size stream or river will decline with increasing environmental disturbance (Karr 1981; Karr et al. 1986). Thus the number of fish species metric is expected to give an indication of environmental quality throughout the range from exceptional to poor. Exotic (i.e. introduced) species present in a system through stocking or inadvertent releases do not provide an accurate assessment of overall integrity and their abundance may even indicate a loss of integrity (Karr et al. 1986).

Wading and Headwaters Sites

The number of species is strongly affected by drainage area at headwaters and wading sites up to 100 sq. mi. (Fig. 4-2). Determining the IBI score for this metric involves comparing the resultant species richness at the drainage area for the site sampled with the resultant expectations for reference sites of the same drainage area (Figure 4-2). Scoring criteria are listed in Tables 4-5 (wading sites) and 4-7 (headwaters sites).

Boat Sites

Unlike headwaters and smaller wading sites there is no direct relationship between increasing drainage area and species richness at boat sites (Fig. 4-3). Scoring is constant at all drainage areas; criteria are listed in Table 4-6.

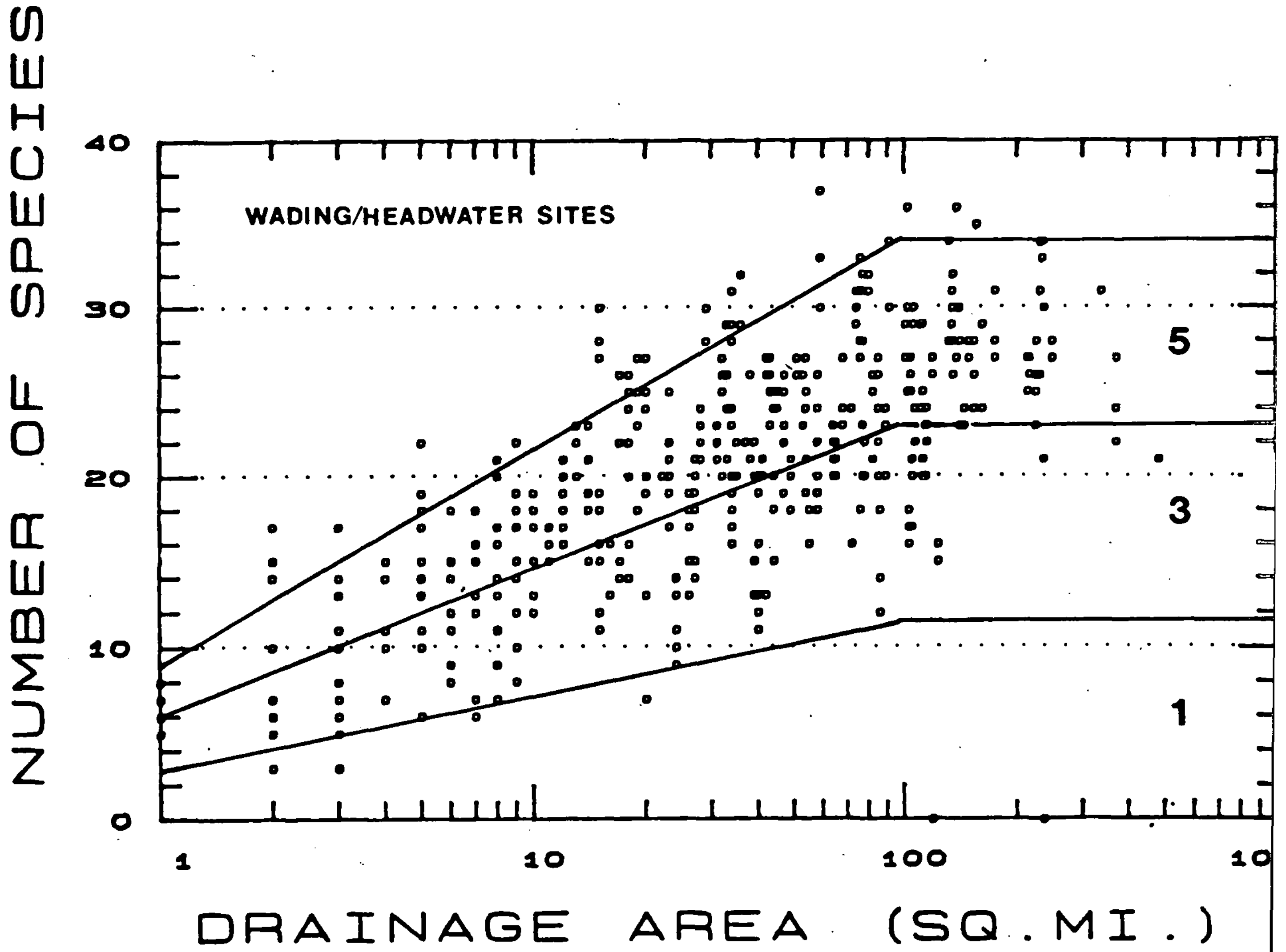

Figure 4-2. Number of species vs. drainage area (Headwaters and Wading sites) showing a combined standard and alternate trisection method for determining 5, 3, and 1 IBI scoring.

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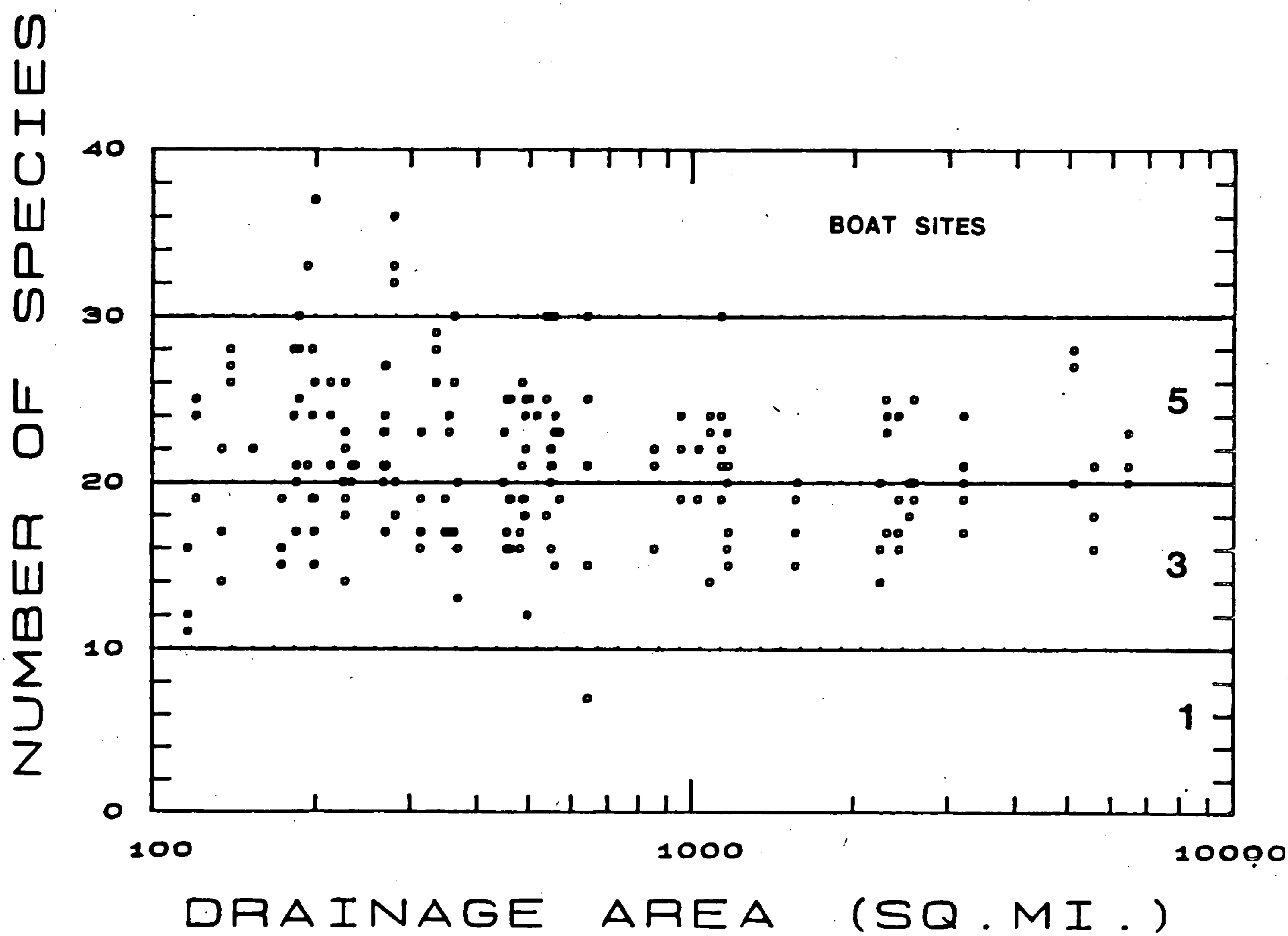

Figure 4-3. Number of species vs. drainage area (Boat sites) showing alternative trisection method (no drainage area relationship) for determining 5, 3, and 1 IBI scoring.

Metric 2. Number of Darter Species (Wading, Headwaters)
Proportion of Round-bodied Catostomidae (Boat Method)

General

The darter species metric is reflective of good water quality conditions (Karr et al. 1986). None of the species in this group have been found to thrive in degraded stream conditions (Appendix B). Eleven of the twenty-two Ohio species have been found to be highly intolerant of degraded conditions based on the Ohio EPA intolerance criteria (Appendix B, Table B-1). Life history data on this group show darters to be insectivorous, habitat specialists, and sensitive to physical and chemical environmental disturbances (Kuehne and Barbour 1983). These factors make darter species reliable indicators of good water quality and habitat conditions.

Of the 22 darter species recorded in Ohio seven are commonly found and are not restricted to a particular stream size (Trautman 1981). Nine species are confined to Ohio River basin streams; six are strongly associated with medium and/or large rivers. The Iowa and least darters are restricted primarily to the glaciated areas of Ohio, particulary lakes and swamp habitats. Three species are associated with large water conditions (either rivers or Lake Erie) and can be found in both the Ohio and St. Lawrence River basins. The orangethroat darter (Etheostoma spectabile) is associated with western Ohio prairie or low gradient small streams.

Wading Sites

The darter metric as proposed by Karr (1981) is used for wading sites only (Table 4-1). The method for determining the scoring of the darter species metric follow those recommended by Karr (1981) and Karr et al. (1986). Ohio data were used to derive maximum species richness lines and IBI scoring criteria (Fig. 4-4).

Headwaters Sites

For headwaters sites (i.e. less than 20 square miles drainage area) this metric also includes the mottled sculpin (Cottus bairdi). This species is a benthic insectivore and functions much the same as darters. This results in a greater level of sensitivity in streams that naturally have fewer darter species. The headwaters stream data base was used to define the IBI scoring criteria which vary with drainage area (Fig. 4-5).

Boat Sites

The proportion of "round-bodied" suckers is substituted for the number of darter species metric for the boat sites. This is done because darter species are not sampled consistently or effectively with the boat methods, although they can occur in the catch. Round-bodied suckers include species of the genera Hypentelium (northern hog sucker), Moxostoma (redhorses), Minytrema (spotted sucker), and Erimyzon (chubsuckers). These species are sampled effectively with the boat electrofishing methods and they comprise a sensitive component of larger stream and river fish faunas, much the same as darters do in the wadable streams. The feeding and spawning requirements of both groups are similar as are their sensitivity to environmental perturbations. Round-bodied suckers are intolerant of high turbidity and siltation, marginal and poor chemical water quality, and the elimination of their riffle-run spawning and feeding habitats. Round-bodied suckers are an important component of midwestern streams and rivers and their abundance is a good indication of good to exceptional water and habitat quality. The white sucker (Catostomus commersoni) is not included in this metric since it is a highly tolerant species (Appendix B, Table B-3) and not reflective of the intent of this metric. This metric does not change with drainage area (Fig. 4-6); scoring criteria are listed in Table 4-6.

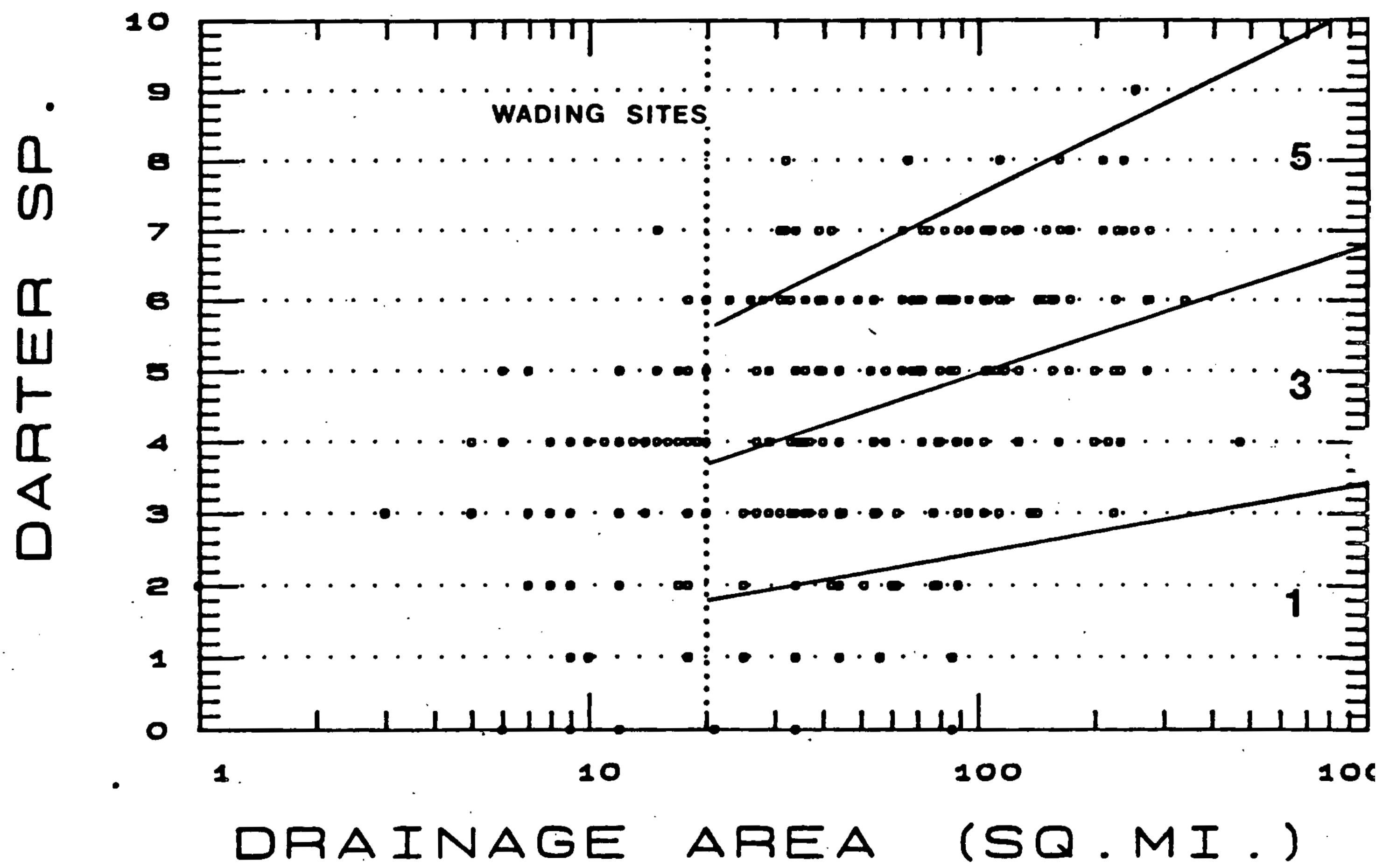

Figure 4-4. Number of darter species vs. drainage area (Wading sites) using the standard trisection method (positive relationship with drainage area) for determining 5, 3, and 1 IBI scoring.

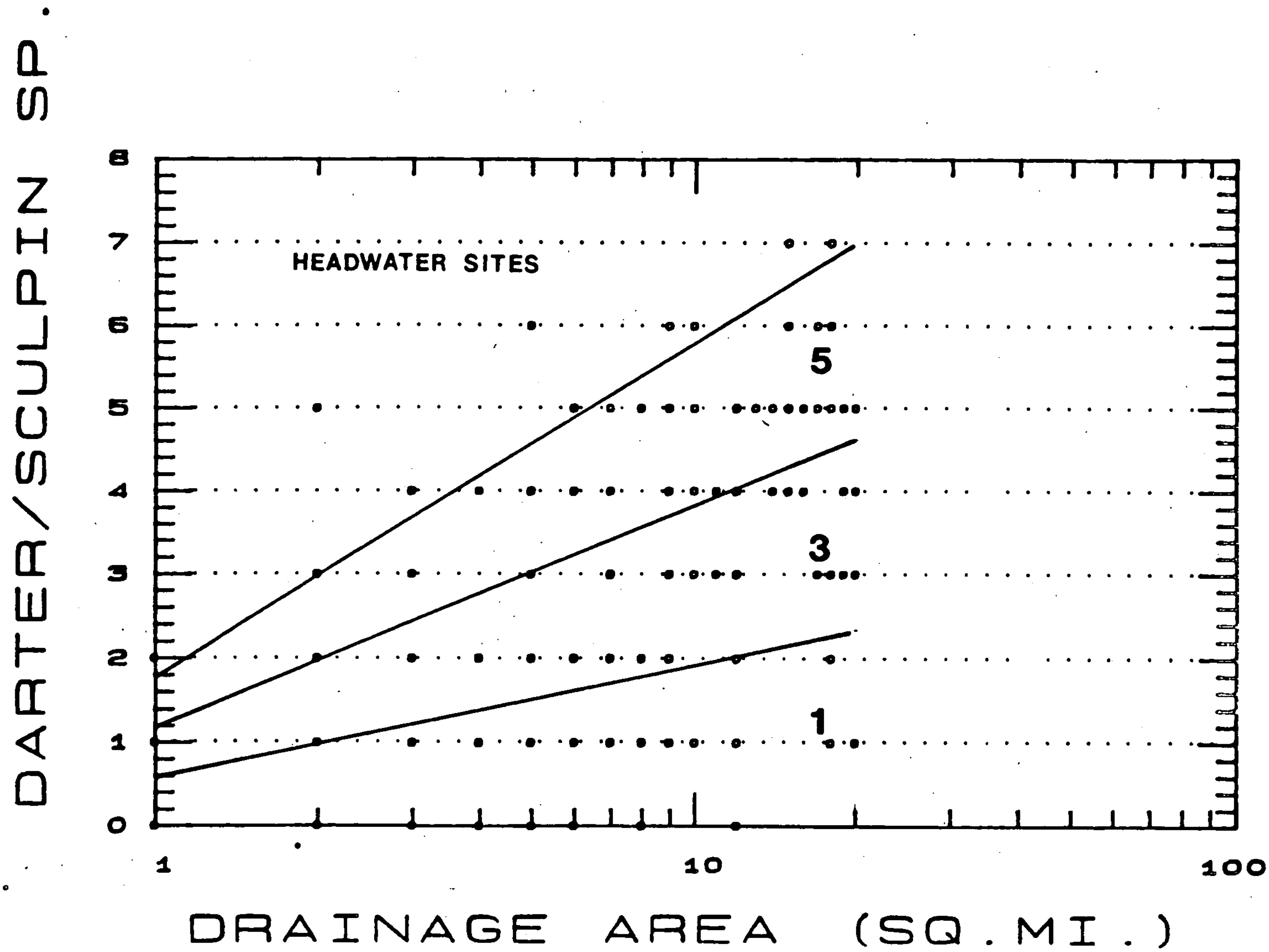

Figure 4-5. Number of darter/sculpin species vs. drainage area (Headwaters sites) using the standard trisection method (positive relationship with drainage area) for determining 5, 3, and 1 IBI scoring.

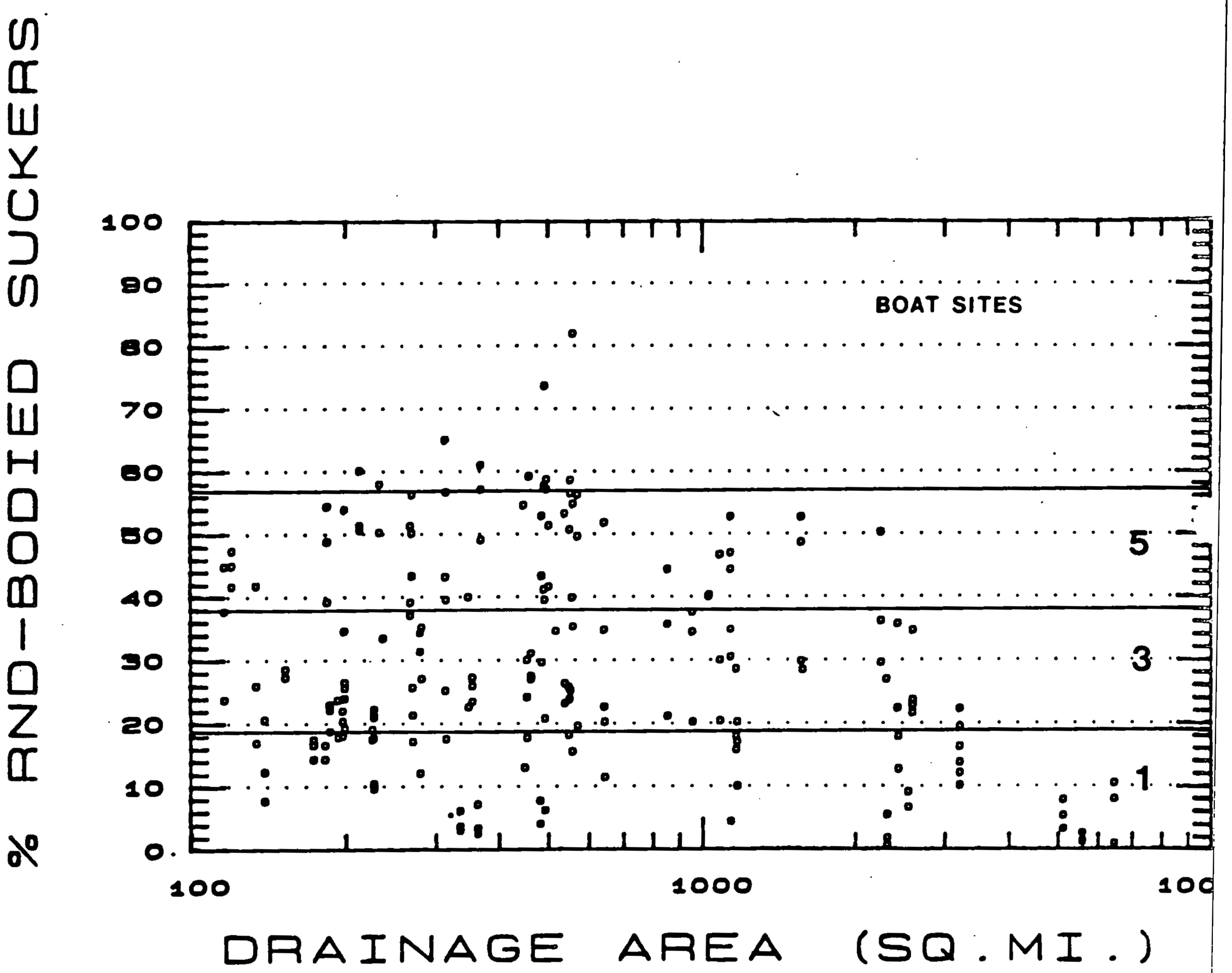

Figure 4-6. Percent of round-bodied suckers vs. drainage area (Boat sites) using the alternate trisection method (no drainage area relationship) for determining 5, 3, and 1 IBI scoring.

000041

Metric 3. Number of Sunfish Species (Wading, Boat)
Proportion of Headwaters Species (Headwaters)

General

This metric follows Karr (1981) and Karr _et al_. (1986) by including the number of sunfish species (Centrachidae) collected at a site, excluding the black basses (_Micropterus_ spp.). The redear sunfish (_Lepomis microlophus_) is not included because, in Ohio, it is introduced and only locally distributed. The nine species which are included are listed in Appendix B (Table B-3). Hybrid sunfish are also excluded from this metric.

This metric is included as a monitor of ecosystem degradation. Specifically, it is a measure of the degradation of their preferred habitats and food items. Differing from suckers and darters, preferred habitats are generally located in quiet pools where sunfish spend much of their time near some form of instream cover (Pflieger 1975). As such they are sensitive to the degradation of pool habitats. Preferred food items include midwater and surface invertebrates in addition to benthic forms (Pflieger 1975; Becker 1983). Other attributes which make this metric well suited for Ohio streams are: conditions described by early settlers were apparently conducive for sunfish (Trautman 1981), there are a number of species which are widely distributed in all stream and river sizes (Trautman 1981), and they are effectively captured by electrofishing. The primary range of sensitivity for this metric is from the middle to high end of the index (Karr _et al_. 1986).

Wading and Boat Sites

The number of sunfish species is not affected by increasing drainage area at wading and boat sites (Figures 4-7 and 4-8). Scoring criteria for the wading and boat sites are listed in Tables 4-5 and 4-6.

Headwaters Sites

The number of sunfish species metric is replaced with the number of headwaters species at sites with drainage areas less than 20 square miles. The number of sunfish species in headwater streams tends to be quite low and may be controlled more by pool quality alone than overall stream quality. A group of nine species are classified as headwaters species (see Appendix B, Table B-3). Headwaters species indicate permanent habitat (i.e. water availability) with low environmental stress. They do not show a trend associated with drainage area (Fig. 4-9). The headwaters species criteria are listed in Table 4-7.

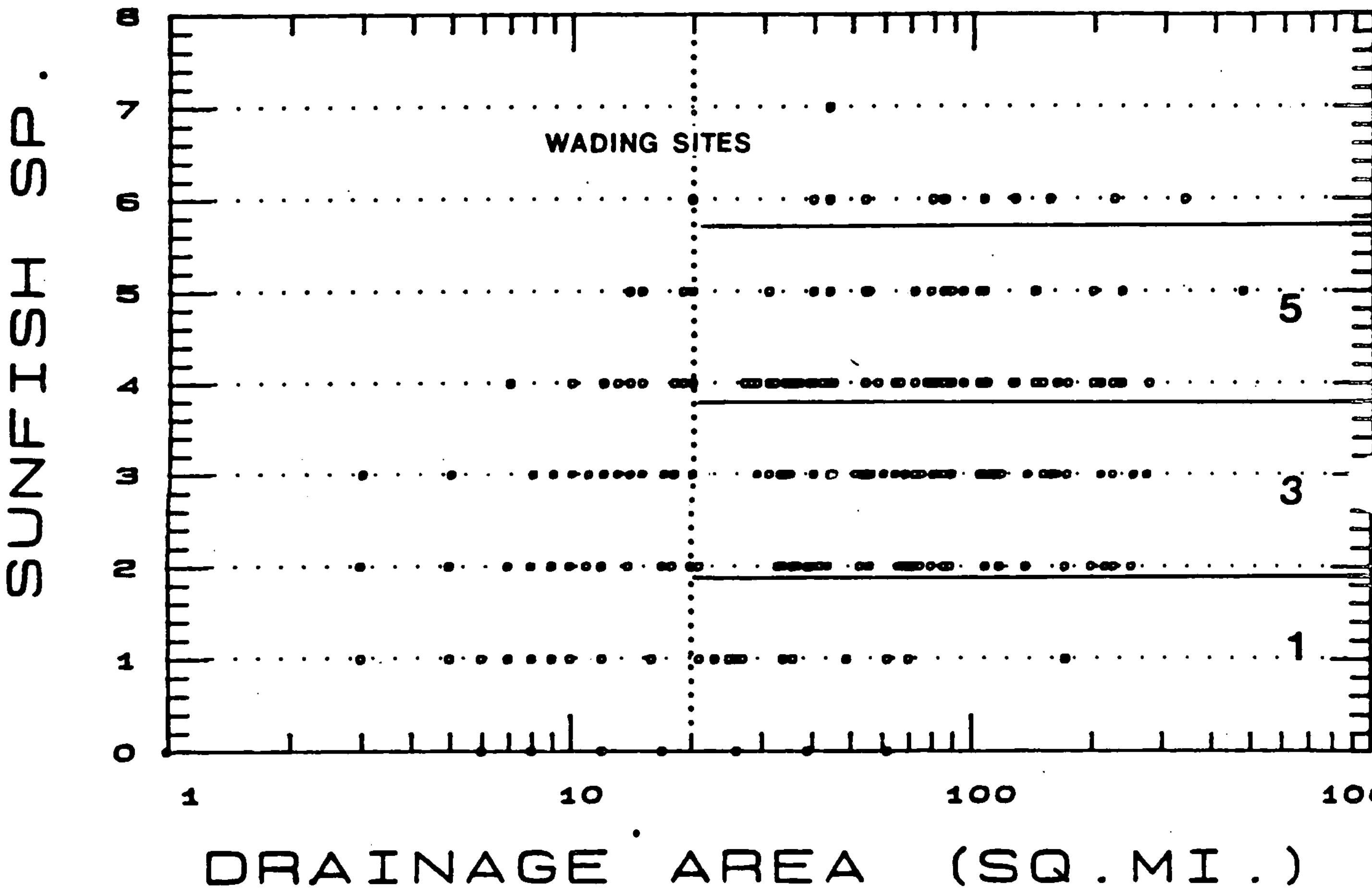

Figure 4-7. Number of sunfish species vs. drainage area (Wading sites) using the alternate trisection method (no relationship with drainage area) for determining 5, 3, and 1 IBI scoring. Values at sites draining less than 20 square miles are included for reference.

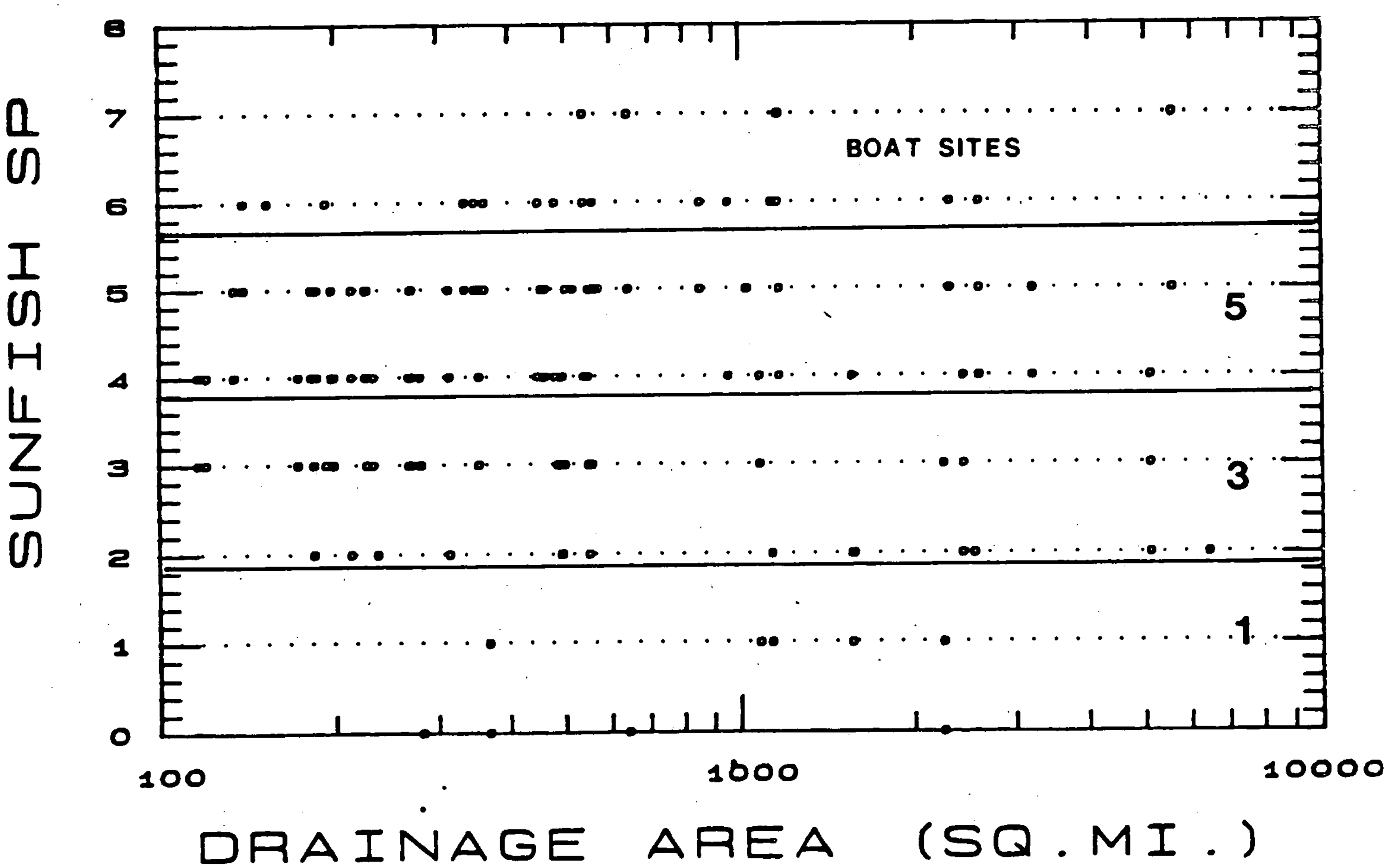

Figure 4-8. Number of sunfish species vs. drainage area (Boat sites) using the alternate trisection method (no relationship with drainage area) for determining 5, 3, and 1 IBI scoring.

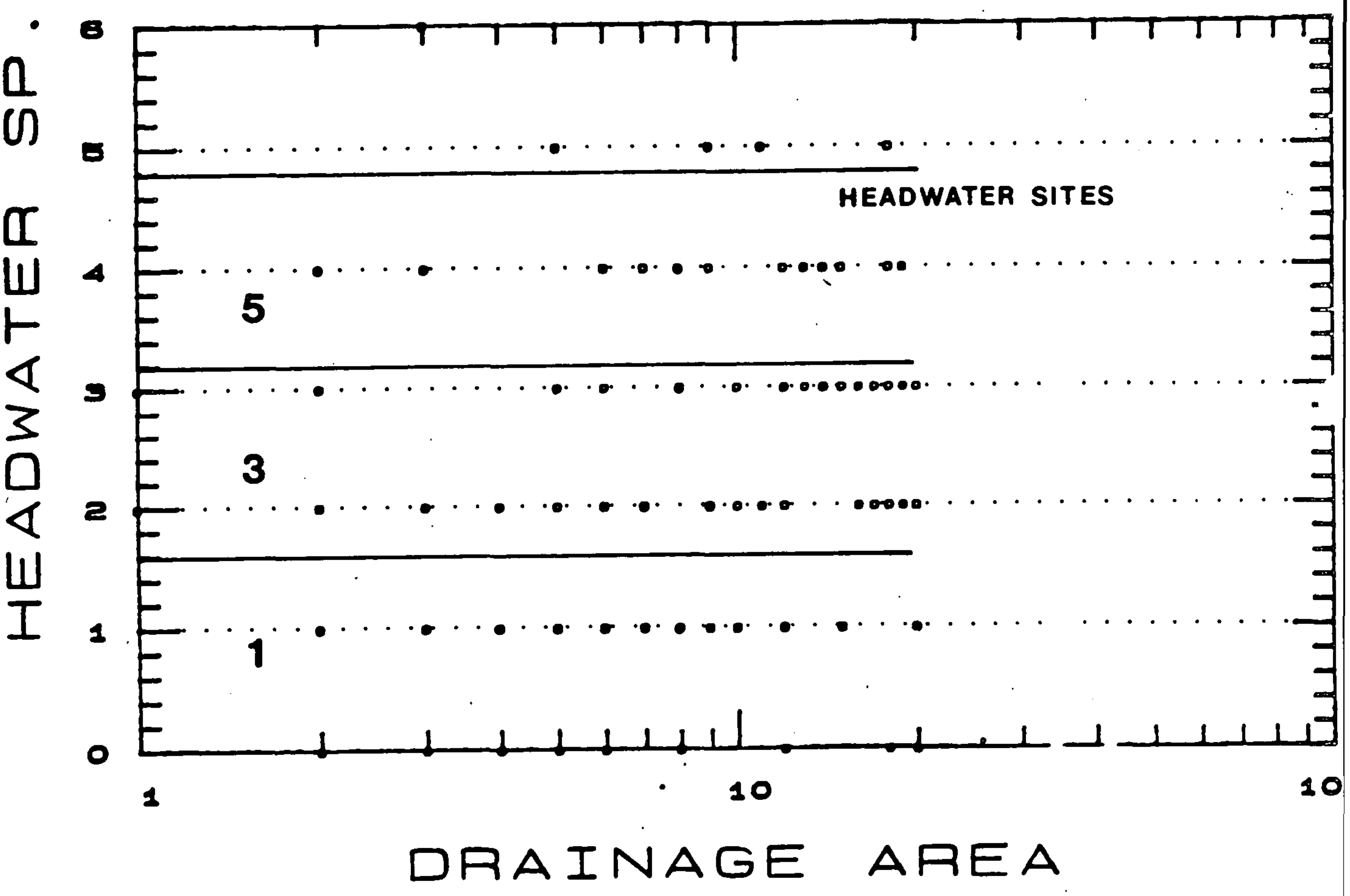

Figure 4-9. Number of headwaters species vs. drainage area (Headwaters sites) using the alternate trisection method (no relationship with drainage area) for determining 5, 3, and 1 IBI scoring.

Metric 4. Number of Sucker Species (Wading, Boat)
Number of Minnow Species (Headwaters)

General

All species in the family Catostomidae are included in this metric (Appendix B, Table B-3). Suckers represent a major component of the Ohio fish fauna with their total biomass in many samples surpassing that of all other species combined. The general intolerance of most sucker species to habitat and water quality degradation (Karr 1981; Trautman 1981; Becker 1983; Karr et al. 1986) results in a metric with a sensitivity at the high end of environmental quality. In addition the relatively long life spans of many sucker species (10-20 years; Becker 1983) provides a long-term assessment of past and prevailing environmental conditions. Of the 19 species still present in Ohio (one is extinct) seven are widely distributed throughout the state (Table 4-2).

Wading and Boat Sites

There is a definite relationship between the number of sucker species and drainage area at wading sites (Fig. 4-10). Scoring is thus dependent on the drainage area of the site and is accomplished using Fig. 4-10. No relationship between drainage area and the number of sucker species is evident at the boat sites (Fig. 4-11). The compilation of reference site data results in the criteria listed in Table 4-6.

Headwaters Sites

The number of minnow species is substituted for the number of sucker species at headwaters sites because of the inherently low number of sucker species in small streams. The number of sucker species decreases rapidly with declining drainage area at sites with less than 20 square miles (Fig. 4-10). Examination of the headwaters sites data base revealed that the number of minnow species would serve as a suitable substitute for this metric. As many as 10 different minnow species have been observed at sites as small as 5 square miles. The number of minnow species also is positively correlated with environmental quality. Species such as the redside dace (Clinostomus elongatus), bigeye chub (Hybopsis amblops), and bigeye shiner (Notropis boops) are examples of the sensitive minnow species that should occur in high quality headwaters streams. Other species such as creek chub (Semotilus atromaculatus), bluntnose minnow (Pimephales promelas), and fathead minnow (P. promelas) are tolerant of both chemical degradation and stream dessication. Thus both ends of the environmental tolerance spectrum are covered by this metric. There is a definite relationship between the number of minnow species and drainage area at the headwaters sites (Fig. 4-12). Scoring is thus dependent on the drainage area of the site and is accomplished using Fig. 4-12.

Table 4-2. The distributional characteristics of Ohio's sucker species (family Catostomidae).

Species	Widely Distributed	Small Streams	Large Rivers	Rare or Limited
Quillback carpsucker	X		X	
River carpsucker			X	
Highfin carpsucker			X	
Silver redhorse	X		X	
Black redhorse	X		X	
Golden redhorse	X		X	
Shorthead redhorse			X	
River redhorse			X	X
Greater redhorse				X
Blue sucker			X	X
Bigmouth buffalo			X	
Smallmouth buffalo			X	
Black buffalo			X	
Northern hog sucker	X	X	X	
White sucker	X	X	X	
Spotted sucker	X		X	
Creek chubsucker		X		X
Lake chubsucker				X
Harelip sucker (extinct)				
Longnose sucker				X

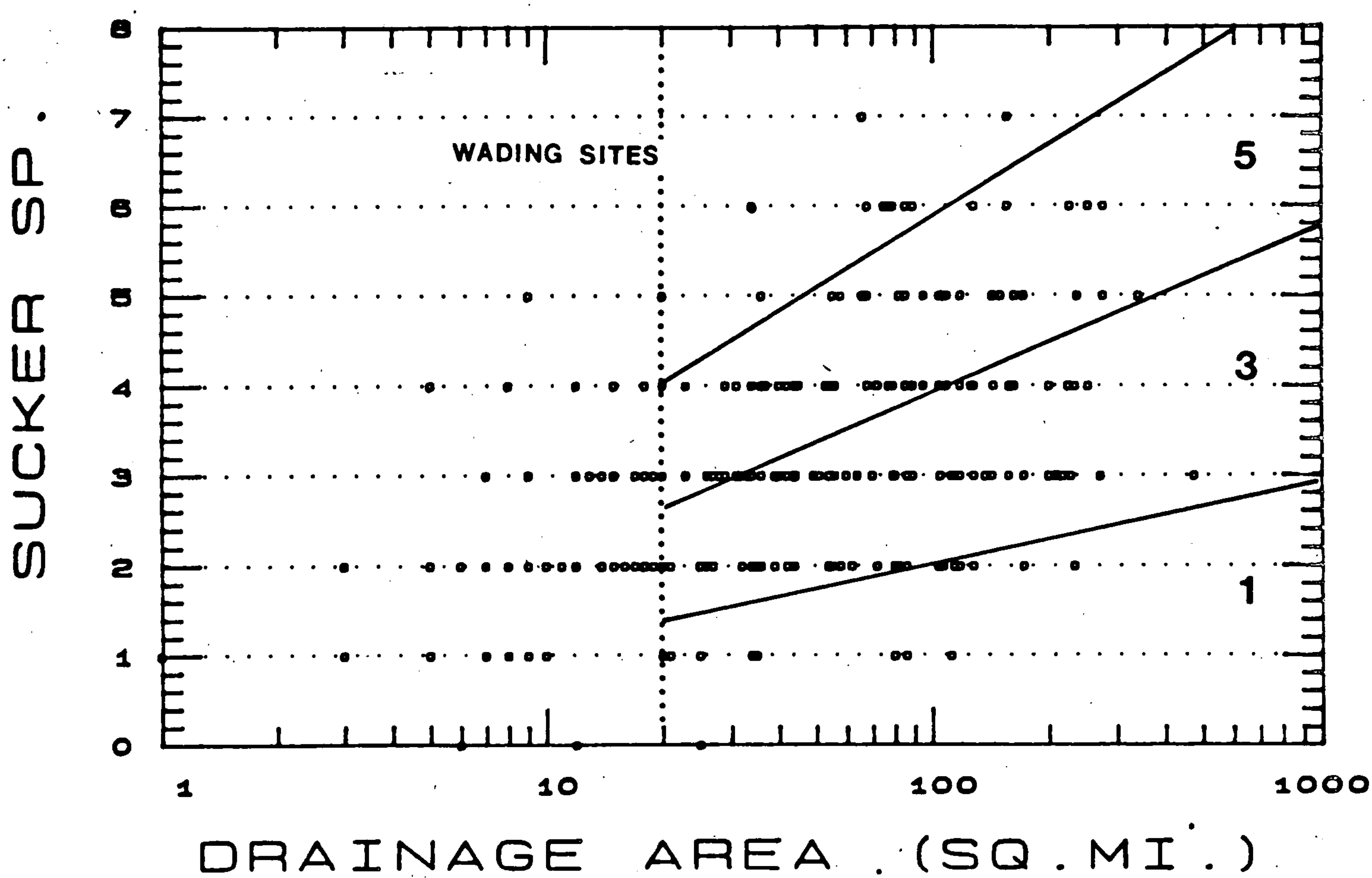

Figure 4-10. Number of sucker species vs. drainage area (Wading sites) using the standard trisection method (positive relationship with drainage area) for determining 5, 3, and 1 IBI scoring. Values at sites draining less than 20 square miles are included for reference.

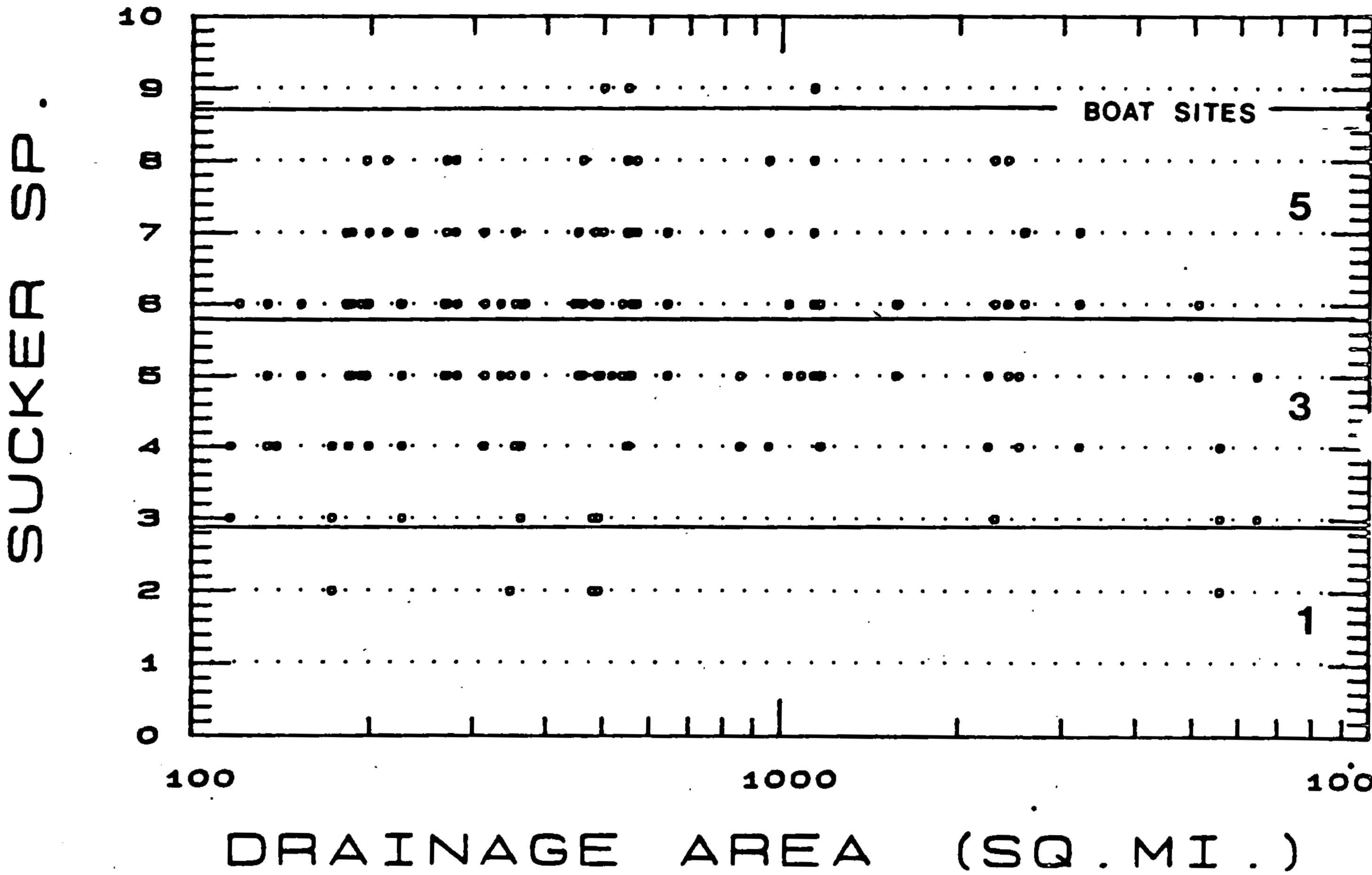

Figure 4-11. Number of sucker species vs. drainage area (Boat sites) using the alternative trisection method (no drainage area relationship) for determining 5, 3, and 1 IBI scoring.

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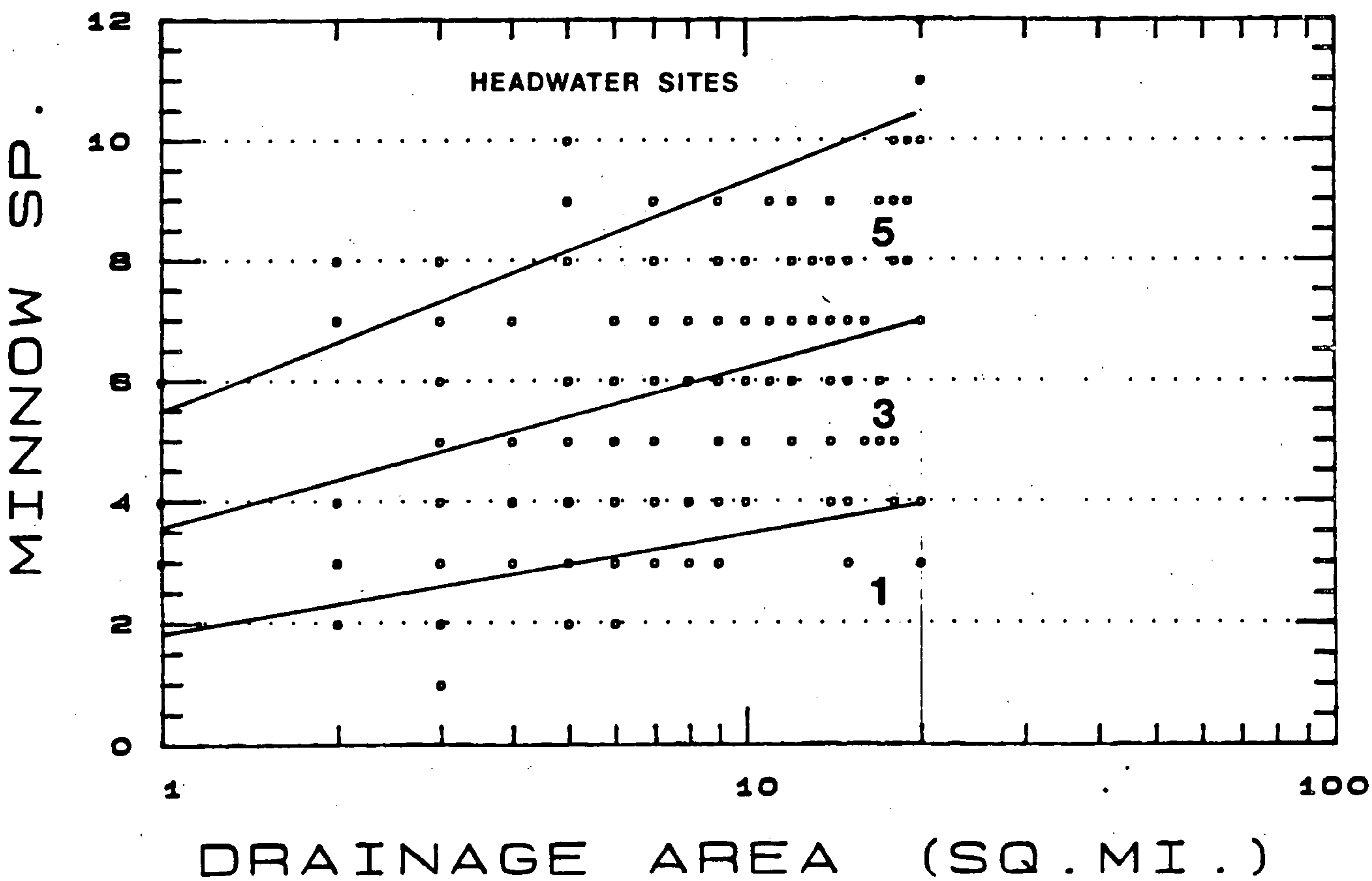

Figure 4-12. Number of minnow species vs. drainage area (Headwaters sites) using the standard trisection method (positive relationship with drainage area) for determining 5, 3, and 1 IBI scoring.

Metric 5: Number of Intolerant Species (Wading, Boat) Number of Sensitive Species (Headwaters)

General

The number of intolerant species metric is designed to distinguish streams of the highest quality. As a result, the sensitivity of this metric is at the highest end of biotic integrity. Designation of too many species as intolerant will prevent this metric from discriminating among the highest quality streams. Only species that are highly intolerant to a variety of disturbances were included in this metric so that it will respond to diverse types of perturbations; species intolerant to one type of disturbance, but not another were not included (Appendix B).

The criteria used for determining intolerance (Table 4-2) are based on numerical and graphical analysis of Ohio EPA's statewide data base from 1979 through 1985 (Appendix B), Trautman's (1981) documentation of historical changes in the distribution of species within Ohio, and supplemental information from regional ichthyological texts (e.g. Plieger 1975; Becker 1983). Intolerant species are those that decline with decreasing environmental quality and disappear, as viable populations, when the aquatic environment is degraded to the "fair" category (Karr et al. 1986). The intolerant species list was divided into three categories all of which are included in scoring this metric as follows:

1) common intolerant species (designated I in the TOL column of Appendix B, Table B-3) - species that are intolerant, but are still widely distributed in the best streams in Ohio;

2) uncommon or geographically restricted species (designated R) - species that are infrequently captured or that have restricted ranges; and,

3) species that are rare or possibly extirpated (designated S) - intolerant species that are rarely captured or for which we have little recent data.

The list of commonly occurring intolerant species (i.e. those designated I) is within the 5-10% guideline of Karr (1981) and Karr et al (1986). Although the addition of species designated R and S collectively inflates the number of intolerant species above the 10% guideline, no where in the state do these species all occur together at the same time. In the vast majority of cases only one or two usually occur in the same collection.

Wading and Boat Sites

The expected number of intolerant species increases with drainage area among the wading sites (Figure 4-13); however, such a direct positive trend is not evident in the boat sites data (Figure 4-14). In fact intolerants seem to level off and decrease at the larger boat reference sites. Intolerant species in large rivers have likely been reduced (see Appendix B, Table B-3, TOL categories R and S); nevertheless, a score of "5" for this metric has been observed at the best large river reference sites. Large river intolerant species still exist in areas of high integrity in large rivers and are catchable with the boat electrofishing methods. Therefore, scoring criteria remain constant with increasing drainage area for the boat sites (Fig. 4-14 and Table 4-6).

Headwaters

The number of intolerant species metric is modified to include moderately intolerant species for application at headwaters sites. This combination is termed sensitive species (Appendix B, Table B-3). This is done because few or no intolerant species are expected in these streams (Fig. 4-13). The moderately intolerant species meet most of the criteria in Table 4-3. Sensitive species also require permanent pools thus this metric will also aid in distinguishing permanent streams from those with ephemeral characteristics. An absence of these species would indicate a severe stress caused by man-induced perturbation or loss of habitat due to a lack of water. This metric varies with drainage area and scoring is accomplished using Fig. 4-15.

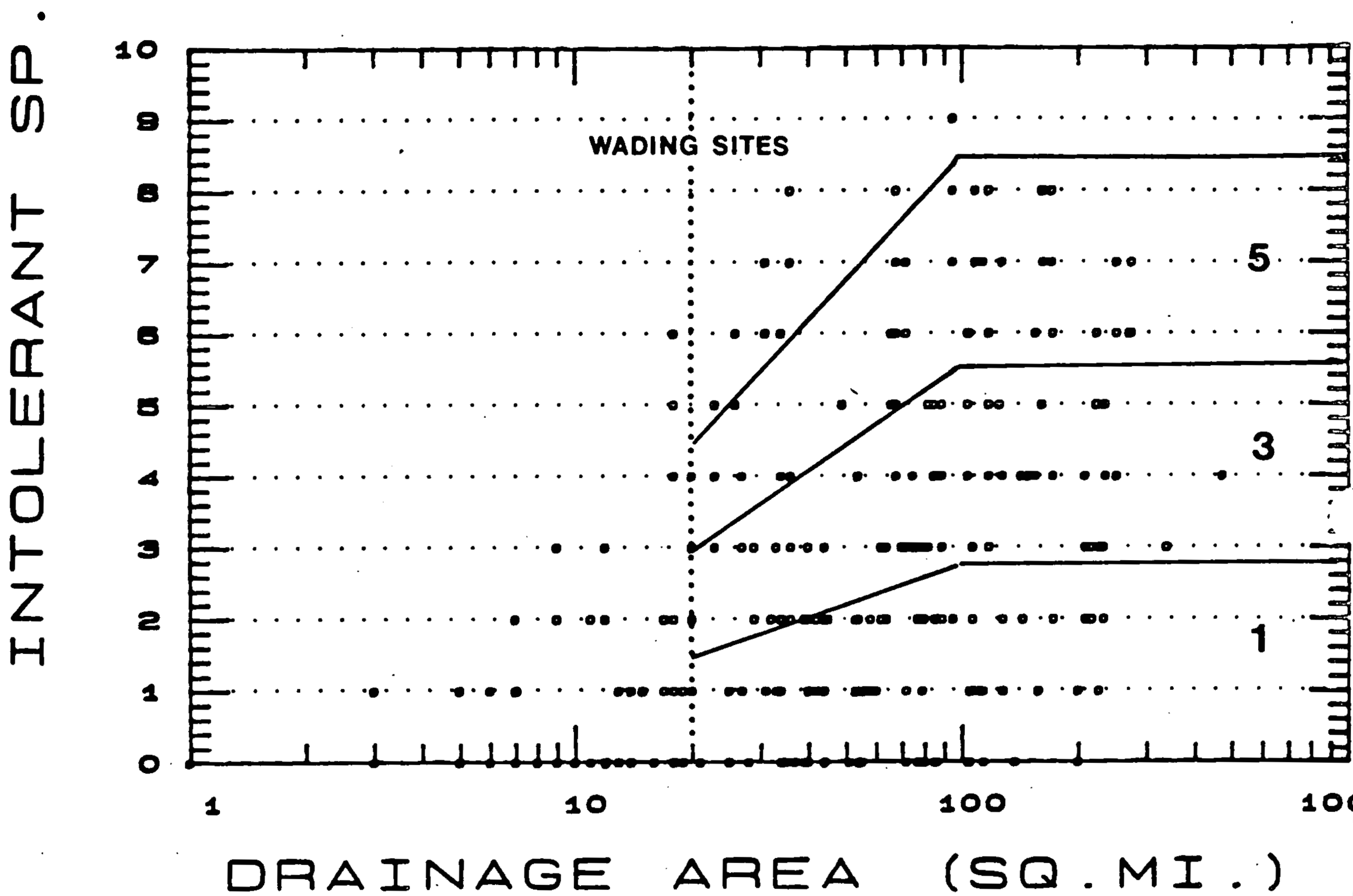

Figure 4-13. Number of intolerant species vs. drainage area (Wading sites) using both the standard and alternate trisection method (limited positive relationship with drainage area) for determining 5, 3, and 1 IBI scoring. Values at sites draining less than 20 square miles are included for reference.

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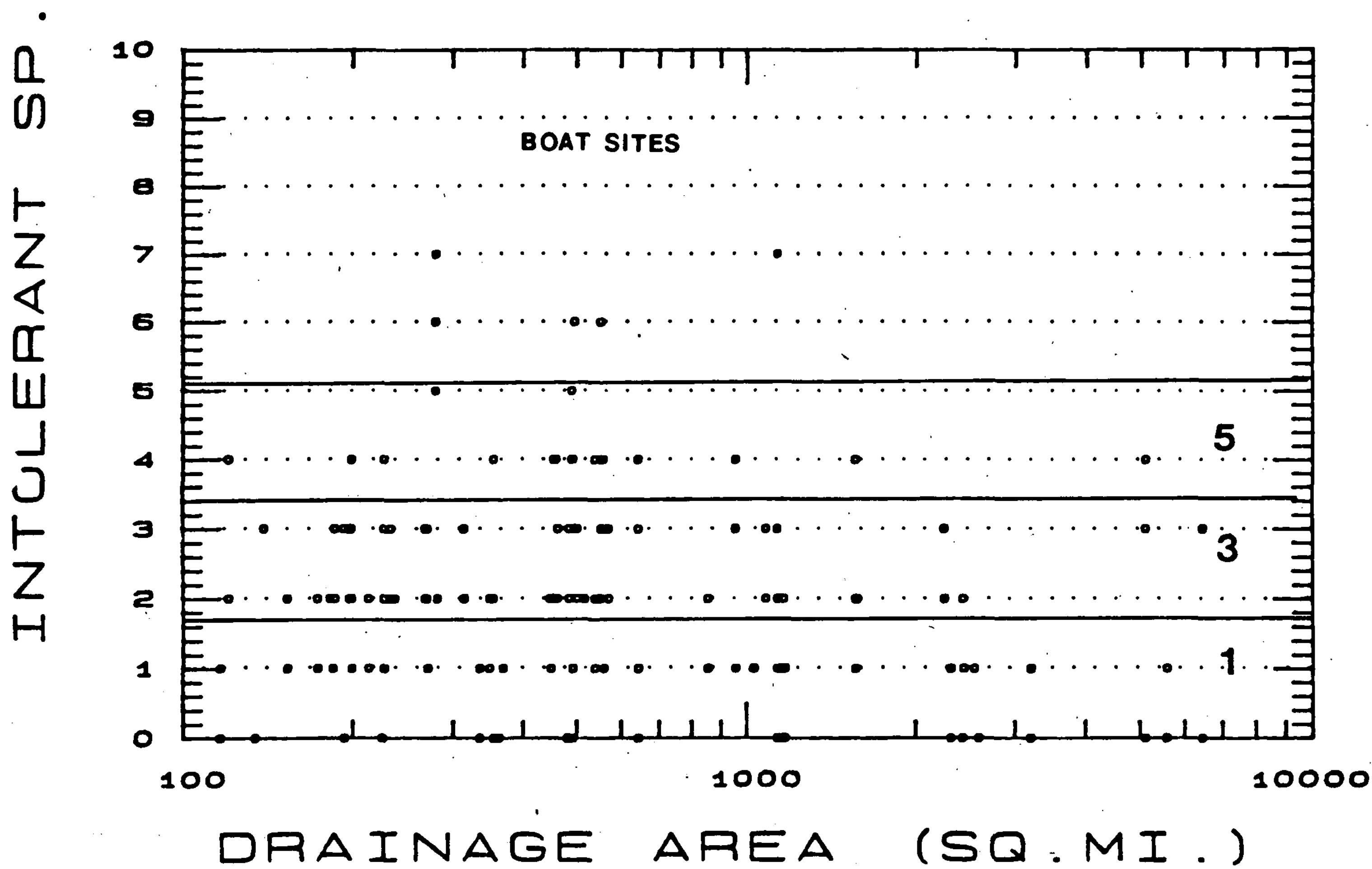

Figure 4-14. Number of intolerant species vs. drainage area (Boat sites) using the alternate trisection method (no positive relationship with drainage area) for determining 5, 3, and 1 IBI scoring.

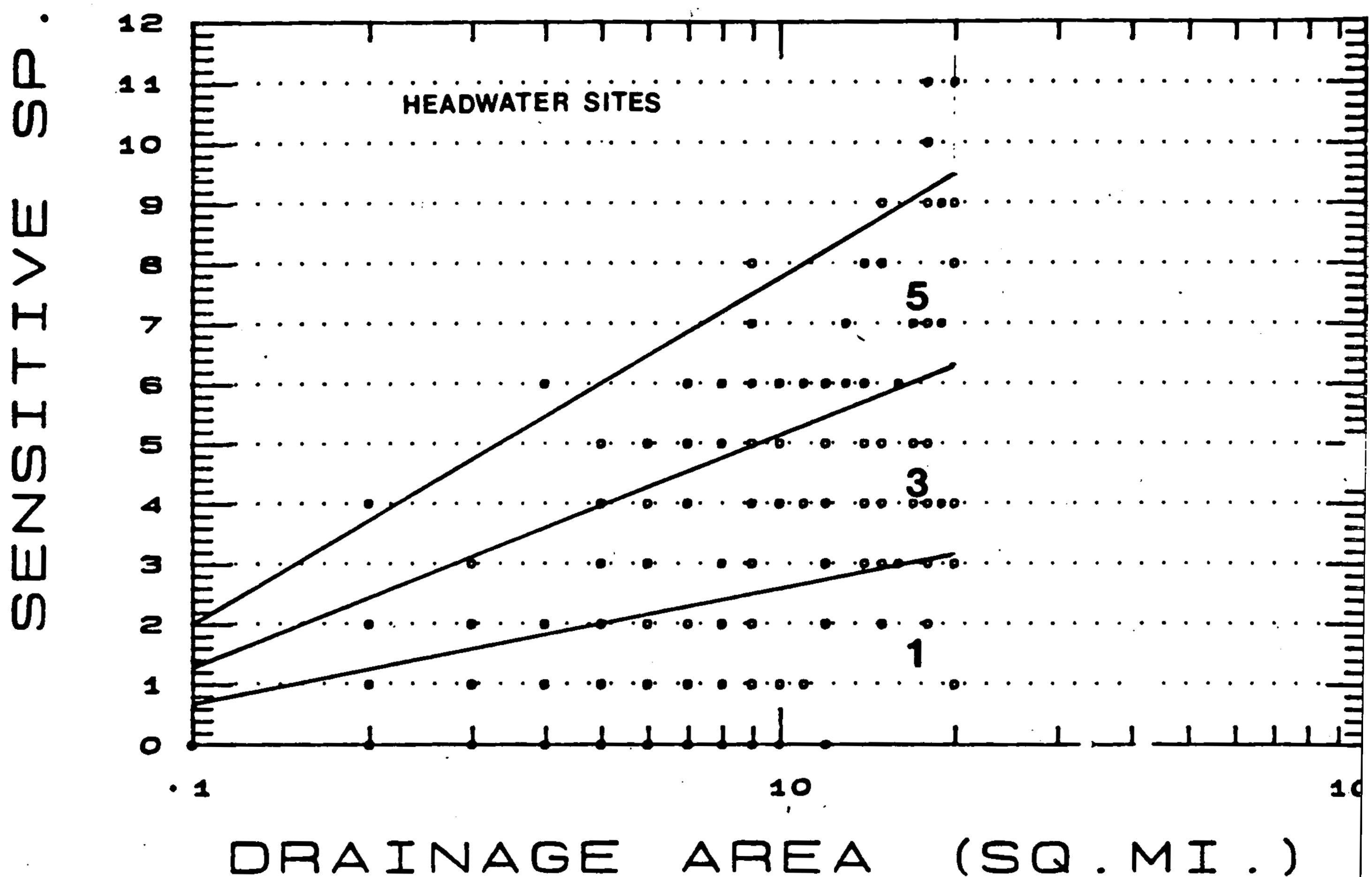

Figure 4-15. Number of sensitive species vs. drainage area (Headwaters sites) using the standard trisection method (positive relationship with drainage area) for determining 5, 3, and 1 IBI scoring.

Metric 6: Percent Abundance of Tolerant Species (All)

General

This metric is a modification of one of Karr's original IBI metrics, the percentage of the fish community comprised by green sunfish (Karr 1981). This metric was designed to detect a decline in stream quality from fair to poor. The green sunfish (Lepomis cyanellus) is a species that is often present in moderate numbers in many Midwest streams and can become a predominant component of the community in areas with degraded habitat and/or water quality. This ability to survive and reproduce in disturbed environments makes this species sensitive to changes in environmental quality in severely impacted areas. Although green sunfish are one of the most widely distributed and numerically abundant fish species found in the Midwest they show a decided preference towards smaller sized and low gradient streams. This limits their utility in assessing impacts in larger streams and rivers. Karr et al. (1986) suggested that other species could be substituted for the green sunfish if they respond in a similar manner, i.e., they increase as a proportion of the community in degraded environments. Several species meeting this criterion were included to give this metric an improved sensitivity for the range of stream and river sizes encountered in Ohio. Since individual species have habitat requirements that are keyed to stream size, composition of the tolerant species metric shifts with drainage area and this metric remains useful among small, medium, and large streams and rivers.

Ohio's tolerant species are listed in Table 4-4 (also see Appendix B, Table B-3). This list was based on a numerical and graphical analysis of Ohio EPA's catch data from 1978 through 1985 (Appendix B) and historical changes in the distribution of fish species throughout Ohio (Trautman 1981). Tolerant species are those that 1) are present at a substantial number of sites with original I_{wb} values <6.0 (i.e. fair and poor sites), 2) show either no decline or a historical increase in abundance or distribution (Trautman 1981), and 3) shift towards community predominance with decreasing water and habitat quality (Table 4-3; also see Appendix B).

Wading and Headwaters

Data for headwaters and wading sites were plotted and scored together for this metric (Figure 4-16). No relationship with drainage area was evident up to 10 sq. mi., but became inverse for sites greater than 10 sq. mi. Scoring criteria are given in Tables 4-5 (wading) and 4-7 (headwaters).

Boat Sites

The expected percentage of tolerant species remains constant with increases in drainage area at boat sites (Figure 4-17). Scoring criteria are given in Table 4-6.

Table 4-3. Criteria for inclusion of species on the Ohio EPA intolerant and tolerant species lists.

Intolerant Criteria

1) A distinct and rapid decreasing trend in abundance with decreasing water and habitat quality (based on graphical analysis; Appendix B, Fig. B-1).

2) Abundance skewed towards sites with high I_{wb} scores (which is reflected in high weighted I_{wb} scores; Appendix B, Table B-2).

3) The species is absent from sites with I_{wb} <6.0, occurs at a few sites <7.0, and is present at the majority of sites >8.0 (Appendix B, Table B-2).

4) A significant historical decrease in distribution (based on Trautman 1981).

Tolerant Criteria

1) Present in a substantial number of sites with I_{wb} values <6.0 (Appendix B, Table B-2).

2) No change or a historical increase in abundance or distribution (based on Trautman 1981).

3) A shift towards community predominance with decreasing water and habitat quality (Appendix B, Fig. B-1).

Table 4-4. List of Ohio fish species considered to be highly tolerant (for calculating IBI and modified I_{wb} values) to a wide variety of environmental disturbances including water quality and habitat degradation.

Tolerant Species - All Sampler Types	
Common Name	Scientific Name
Central mudminnow	Umbra limi
White sucker	Catostomus commersoni
Carp	Cyprinus carpio
Goldfish	Carassius auratus
Golden shiner	Notemigonus crysoleucas
Blacknose dace	Rhinichthys atratulus
Creek chub	Semotilus atromaculatus
Bluntnose minnow	Pimephales notatus
Fathead minnow	Pimephales promelas
Green sunfish	Lepomis cyanellus
Yellow bullhead	Ictalurus natalis
Brown bullhead	Ictalurus nebulosus
E. banded killifish	Fundulus diaphanus diaphanus

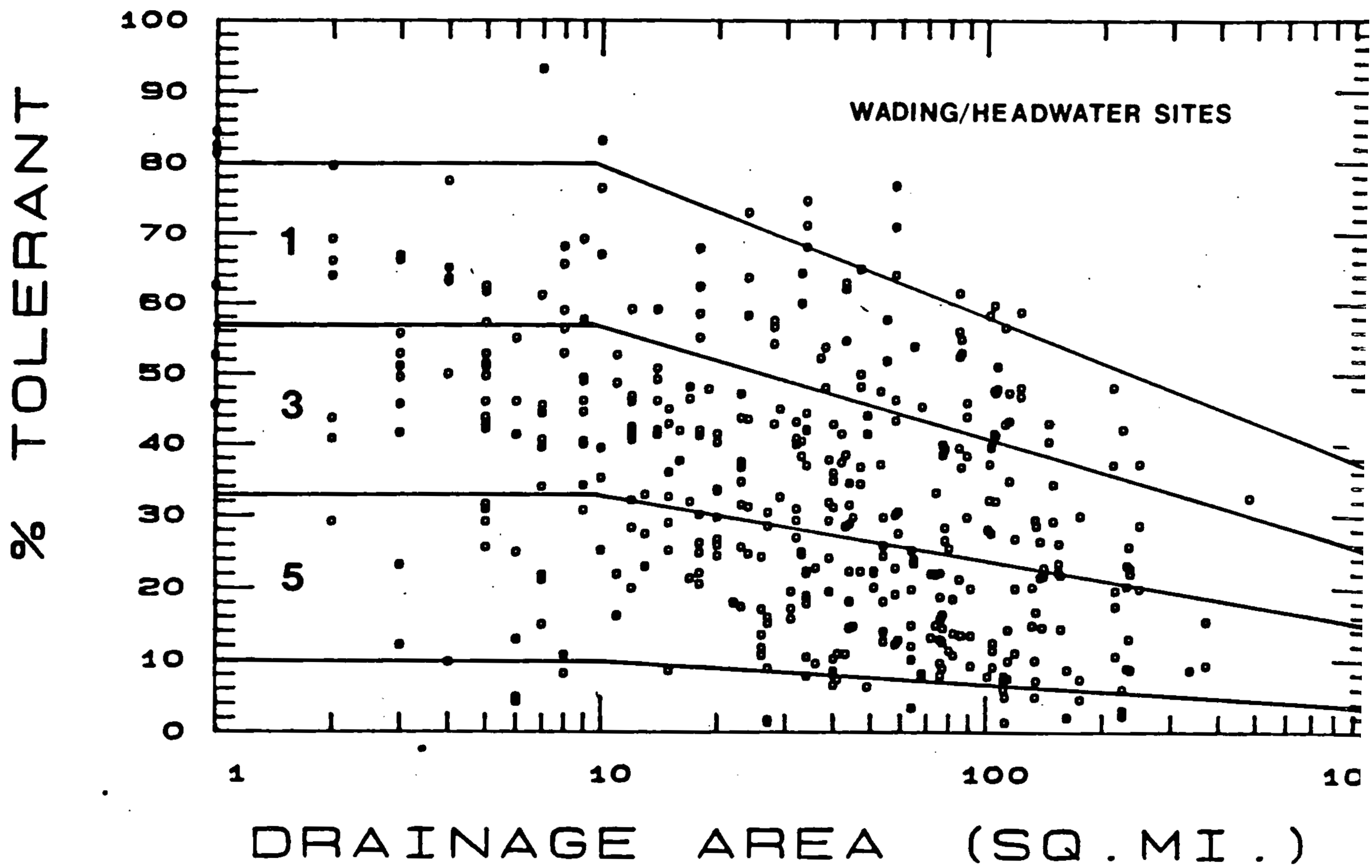

Figure 4-16. Percent of tolerant species vs. drainage area (Headwaters and Wading sites) using the alternate trisection and standard methods for determining 5, 3, and 1 IBI scoring.

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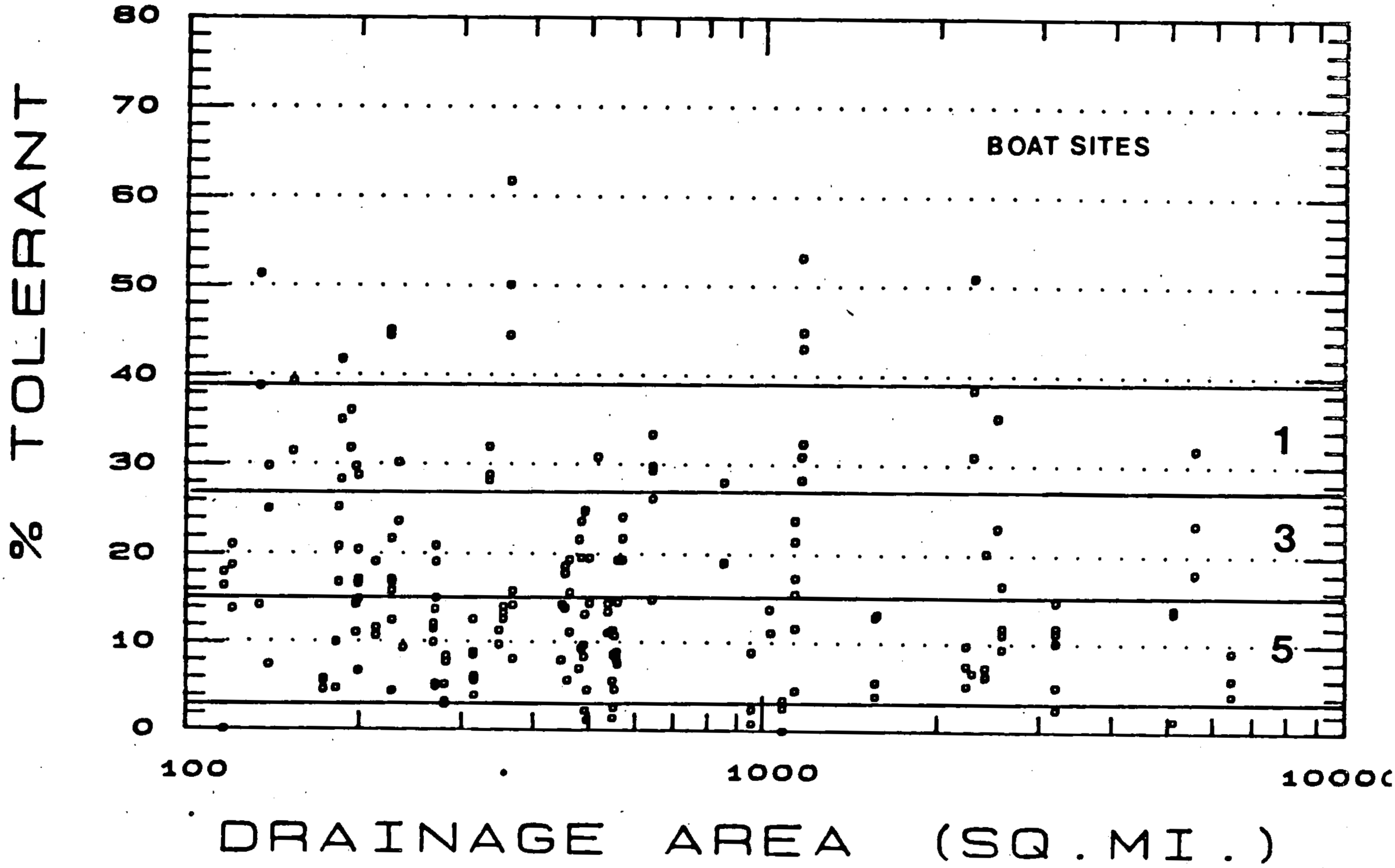

Figure 4-17. Percent tolerant species vs. drainage area (Boat sites) using the alternate trisection method (no drainage area relationship) for determining 5, 3, and 1 IBI scoring.

Metric 7. Omnivore Metric (All)

General

The Ohio EPA definition of an omnivorous species follows Karr (1981) and Karr et al. (1986) with two important distinctions added. Specialized filter-feeding species which technically are omnivorous are not included. Specialist filter feeders are represented in Ohio by the paddlefish (*Polyodon spathula*) and brook lamprey ammocoetes. These species are generally sensitive to environmental degradation. Since the omnivore metric is designed to measure increasing levels of environmental degradation due to a disruption of the food base it is not appropriate to include these sensitive, filter feeding species in this metric. This metric was further restricted to those species that did not show feeding specialization and were reported primarily as omnivores in all studies reviewed. This removes such species as channel catfish (*Ictalurus punctatus*) which may or may not feed as an ominivore under different environmental conditions. Species considered as omnivores are listed in Appendix B, Table B-3.

Wading and Headwaters Sites

The effect of these restrictions limits the omnivore metric to those species that consistently feed as omnivores. Consequently, overall percentages of omnivores are different from Karr (1981) and Karr et al. (1986). To determine appropriate criteria for 5, 3, and 1 IBI scores the Ohio EPA reference sites data base was examined. Furthermore a relationship with drainage area was found for sites less than 30 sq. mi. (Fig. 4-18). Scoring criteria for the wading and headwaters sites is given in Tables 4-5 and 4-7.

Boat Sites

No relationship with drainage area was found for the proportion of omnivores at boat sites (Fig. 4-19). Scoring criteria are given in Table 4-6.

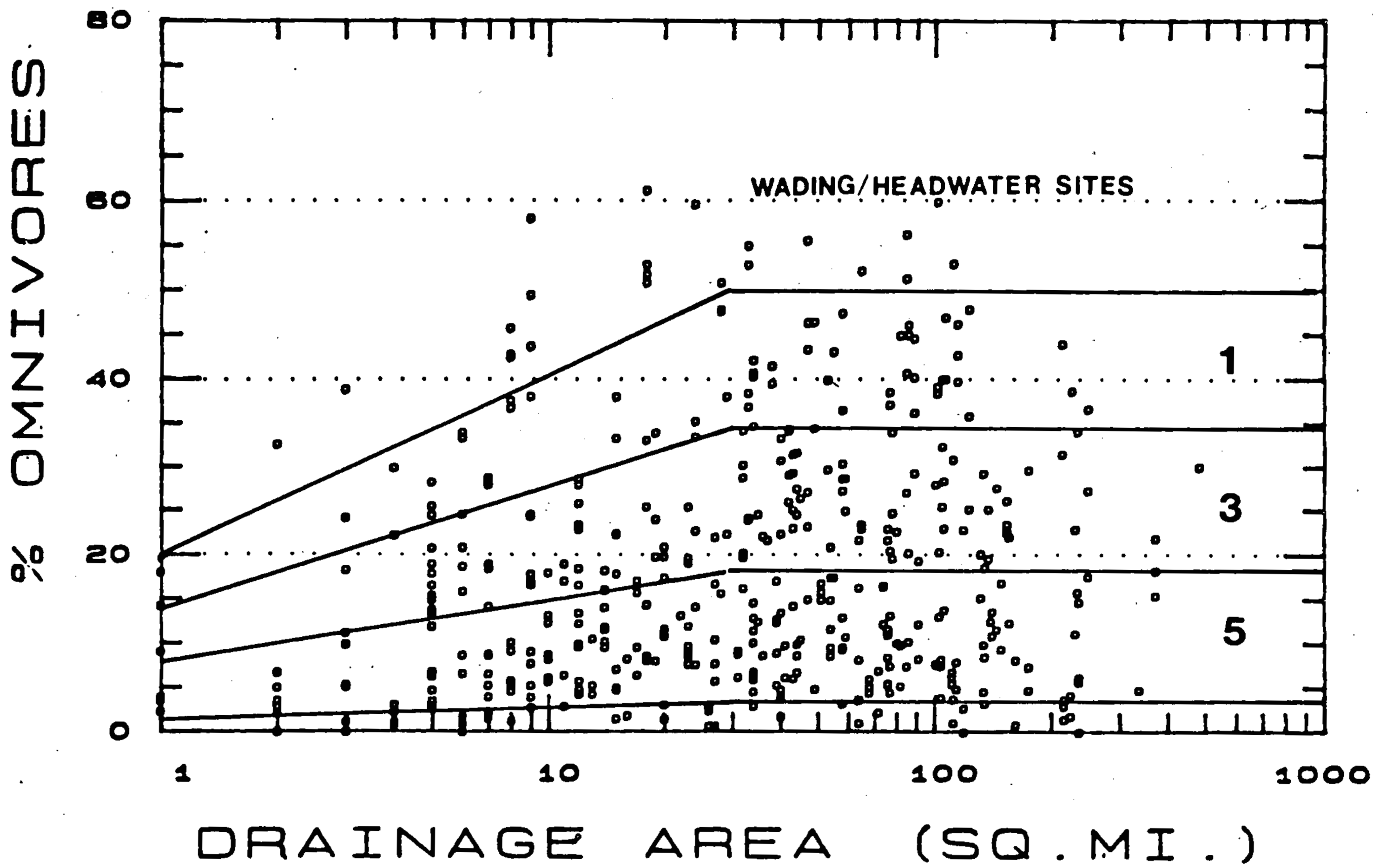

Figure 4-18. Percent of omnivores vs. drainage area (Headwaters and Wading sites) using the standard and alternate trisection methods for determining 5, 3, and 1 IBI scoring.

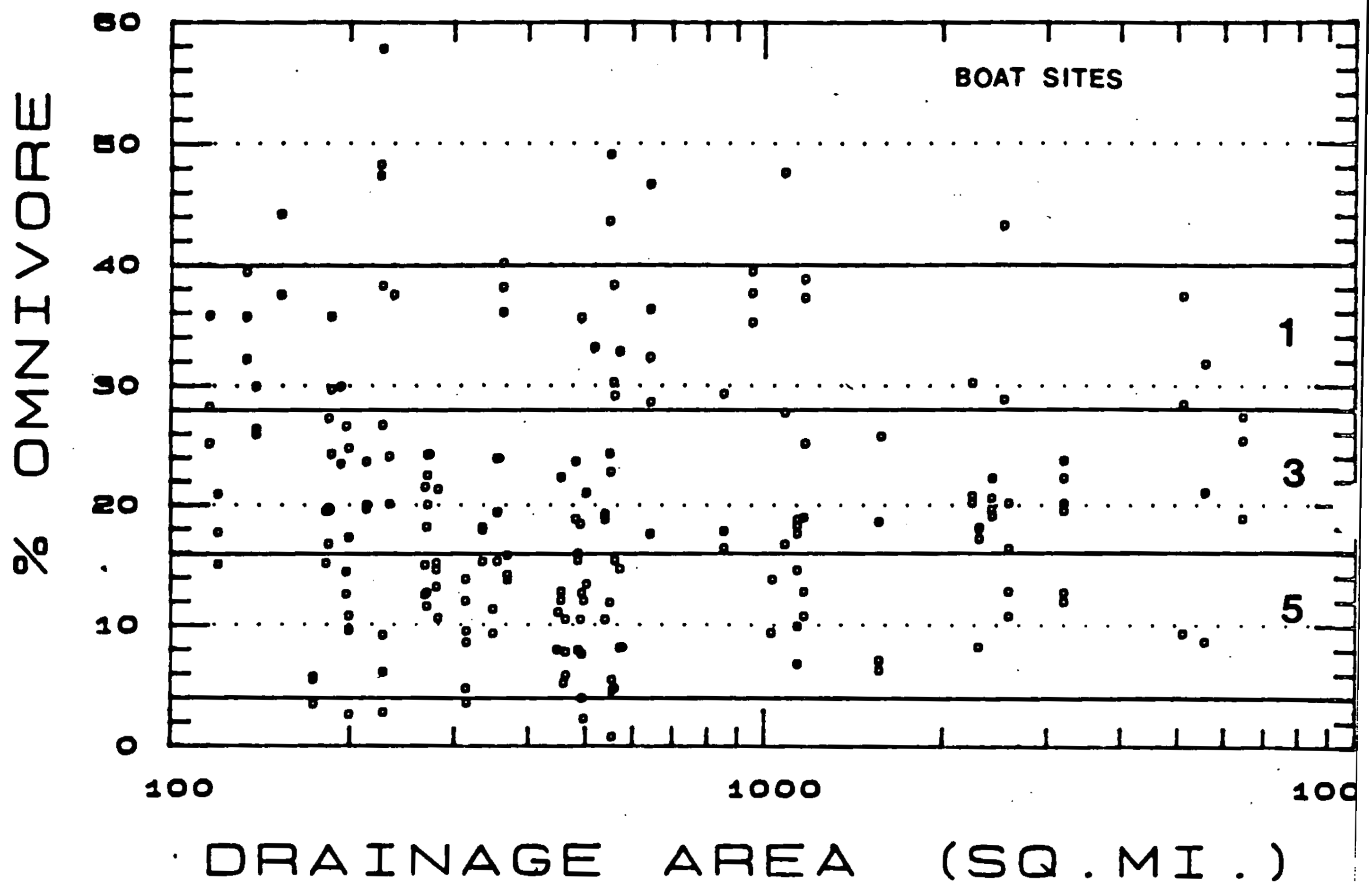

Figure 4-19. Percent omnivores vs. drainage area (Boat sites) using the alternate trisection method (no drainage area relationship) for determining 5, 3, and 1 IBI scoring.

Metric 8. Proportion as Insectivores (All)

This metric is designed to be sensitive over the middle range of biotic integrity. A low abundance of insectivorous species can reflect a degradation to the insect food base of a stream (Karr et al. 1986). As disturbance increases the diversity of benthic insects decreases, production becomes more variable, and the community often becomes predominated by a few taxa (Jones et al. 1981). Thus, specialist feeders such as specialist insectivores will decrease and be replaced by generalist feeders such as omnivores. This represents a modification from Karr et al. (1986) using insectivorous Cyprinids alone.

Wading and Headwaters Sites

We differ from Karr et al. (1986) by excluding two species that are generalized and opportunistic in their feeding habits; creek chub and blacknose dace. Inclusion of these two species as insectivores in a West Virginia study resulted in a negative correlation between insectivores and the IBI (Leonard and Orth 1986), when the relationship should have been positive (Angermier and Karr 1986). Exclusion of these generalist feeders follows the reasoning of Leonard and Orth (1986) who felt that the current definitions of trophic groupings were often arbitrary. The ecological function scored by these metrics was best served by describing species as specialist (e.g. specialized insectivores) or generalist feeders (Appendix B, Table B-3).

Scoring criteria for this metric show a positive relationship with drainage area up to 30 sq. mi. for the headwaters and wading sites (Figs. 4-20). Scoring criteria are listed in Tables 4-5 and 4-7.

Boat Sites

Insectivores show no drainage area effect (Fig. 4-21) and criteria were established using the alternate trisection method.

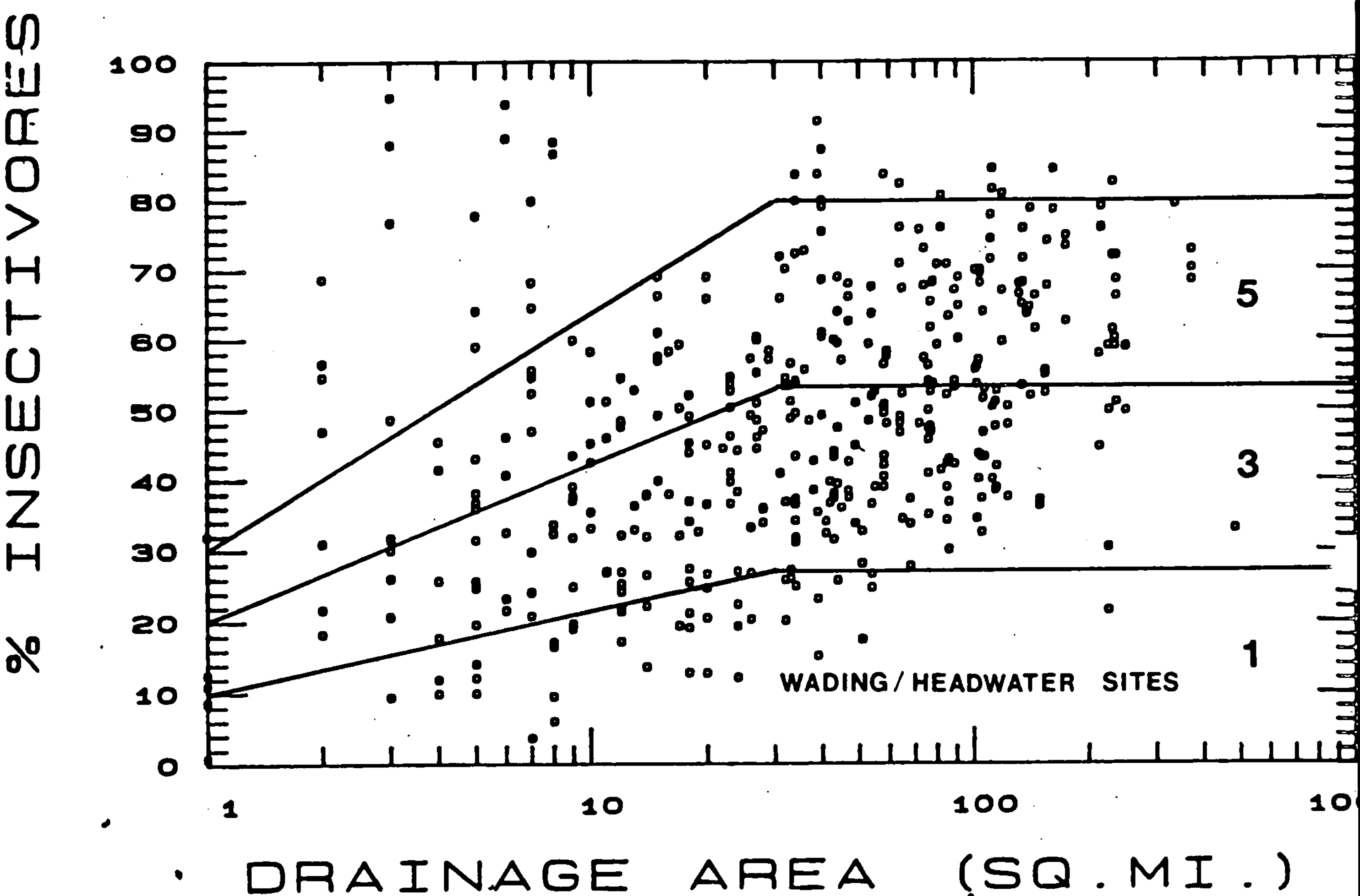

Figure 4-20. Percent of insectivores vs. drainage area (Headwaters and Wading sites) using the standard and alternate trisection methods for determining 5, 3, and 1 IBI scoring.

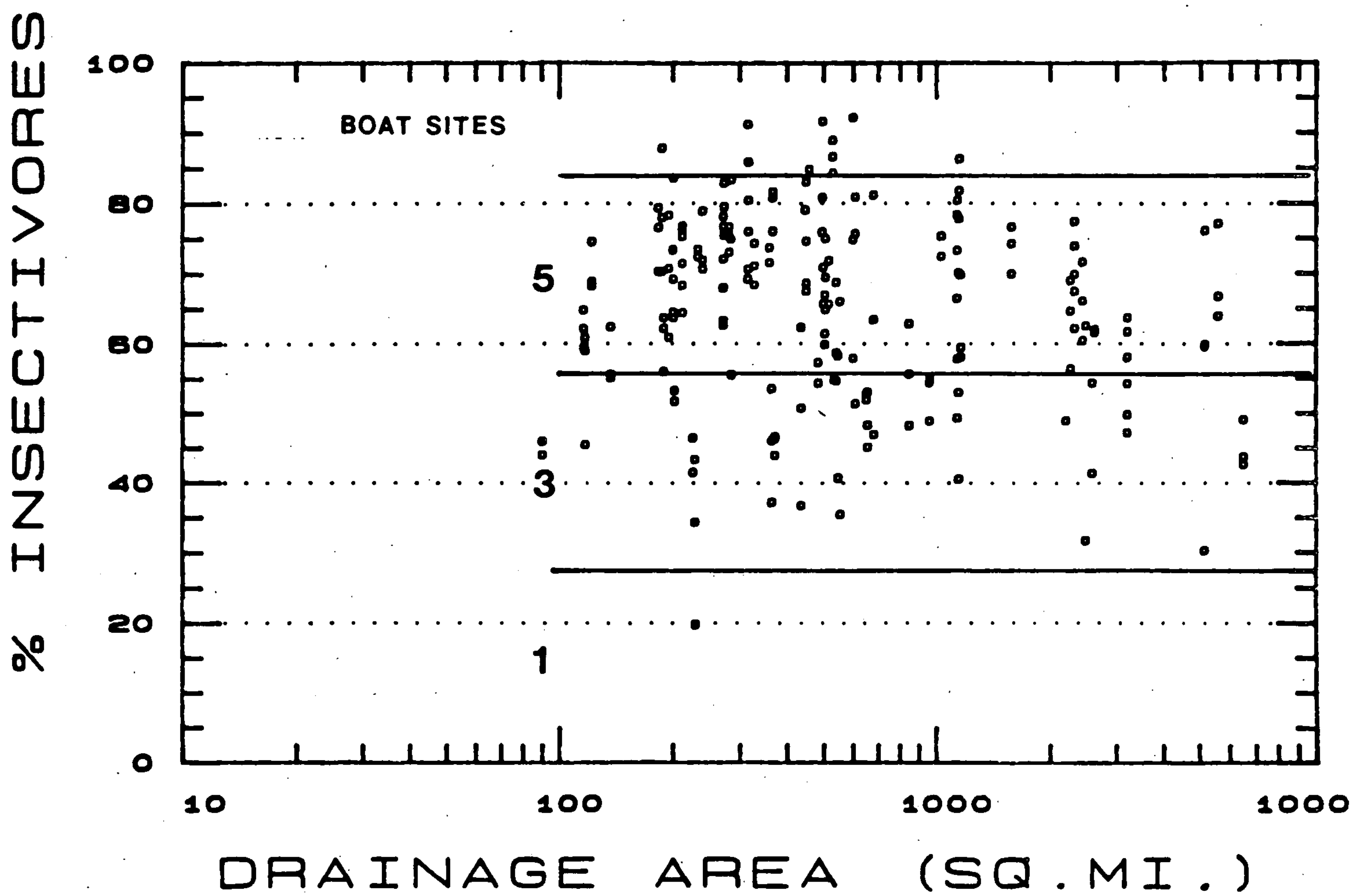

Figure 4-21. Percent insectivores vs. drainage area (Boat sites) using the alternate trisection method (no drainage area relationship) for determining 5, 3, and 1 IBI scoring.

Metric 9. Top Carnivores (Wading, Boat)
Proportion of Pioneering Species (Headwaters)

General

Karr (1981) developed the top carnivore metric to measure community integrity in the upper functional levels of the fish community. In designating a species as a top carnivore we followed Karr (1981) and Karr et al. (1986). Species which feed primarily on other vertebrates or crayfish are included in this metric (Appendix B, Table B-3). As with the omnivore metric, species which display feeding plasticity are excluded (e.g. channel catfish).

Wading Sites

Karr (1981) indicated that expectations for the proportion of top carnivores should change with drainage area. An examination of the Ohio EPA data base reveals that no relationship exists between the proportion of top carnivores and drainage area at sites greater than 20 sq. mi. An examination of the Ohio data base for wading sites yielded the same criteria as that proposed by Karr et al. (1986; Fig. 4-22; Table 4-5). No trisection method was employed in deriving the scoring criteria.

Boat Sites

No drainage area related trend was observed for boat data which displayed consistent and higher top carnivore proportions for all drainage areas (Fig. 4-23). The criteria listed in Table 4-6 were derived using best professional judgement in examining the reference sites data base. No trisection procedure was used in deriving the scoring criteria.

Headwaters

An examination of the headwaters stream data base revealed that top carnivores are virtually absent or in very low abundance at headwaters sites. A metric is needed for the headwaters sites that reflects the degree to which the community may be temporal thus reflecting the permanence of the headwater stream habitat. Smith (1979) identified certain small stream species in Illinois as "pioneering" species. These are species which are the first to reinvade sections of headwater streams that have been dessicated by prolonged periods of dry weather. These species also predominate in unstable environments that have been affected by temporal desication and/or anthropogenic stresses. Thus a high proportion of pioneering species is an indication of a habitat that is temporally not available, under stress, or both. Scoring criteria for this method are listed in Table 4-7 as determined by trisection (Fig. 4-24).

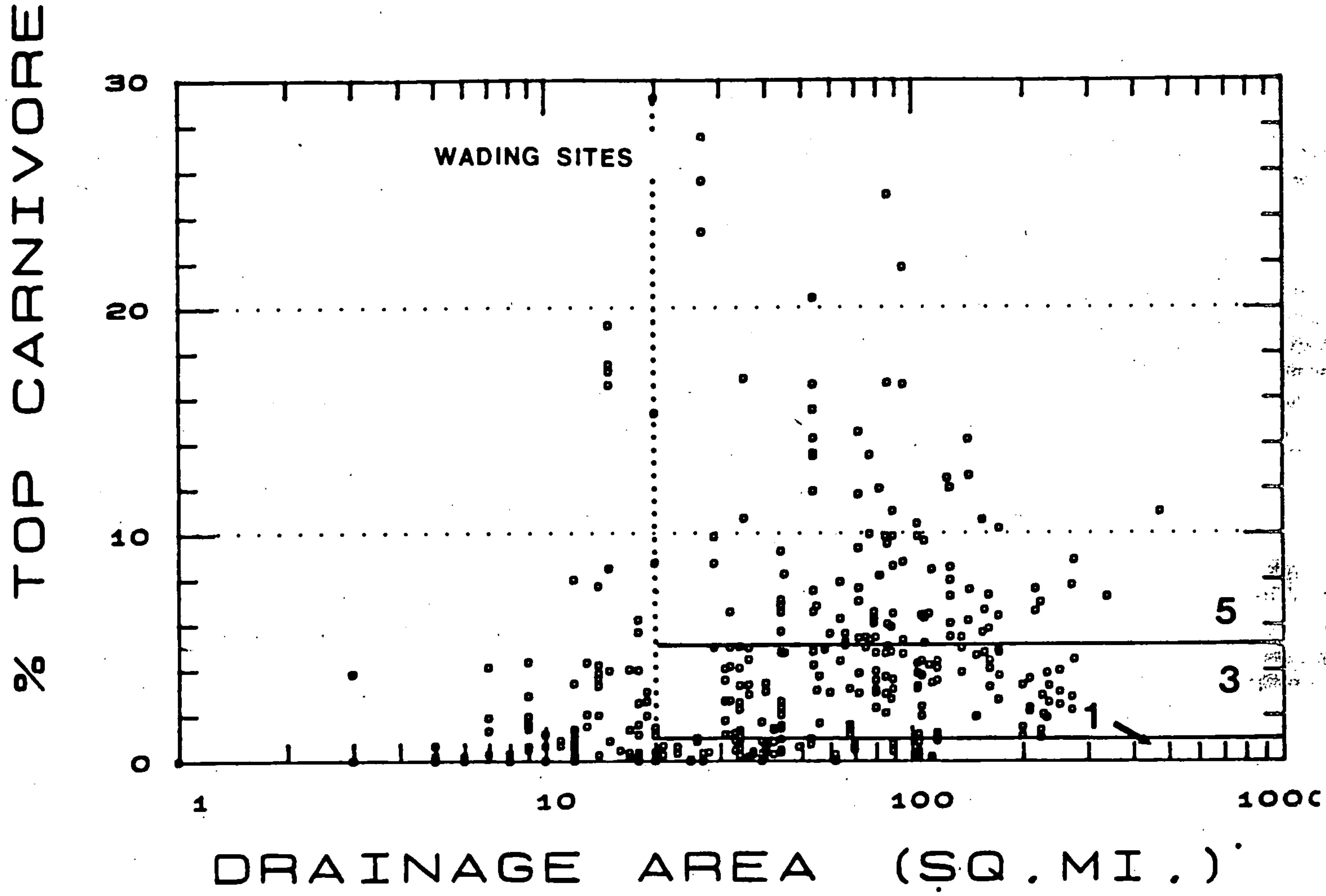

Figure 4-22. Percent of top carnivores vs. drainage area at wading sites. The horizontal lines indicate the 5, 3, and 1 scoring boundaries and do not represent any trisection method.

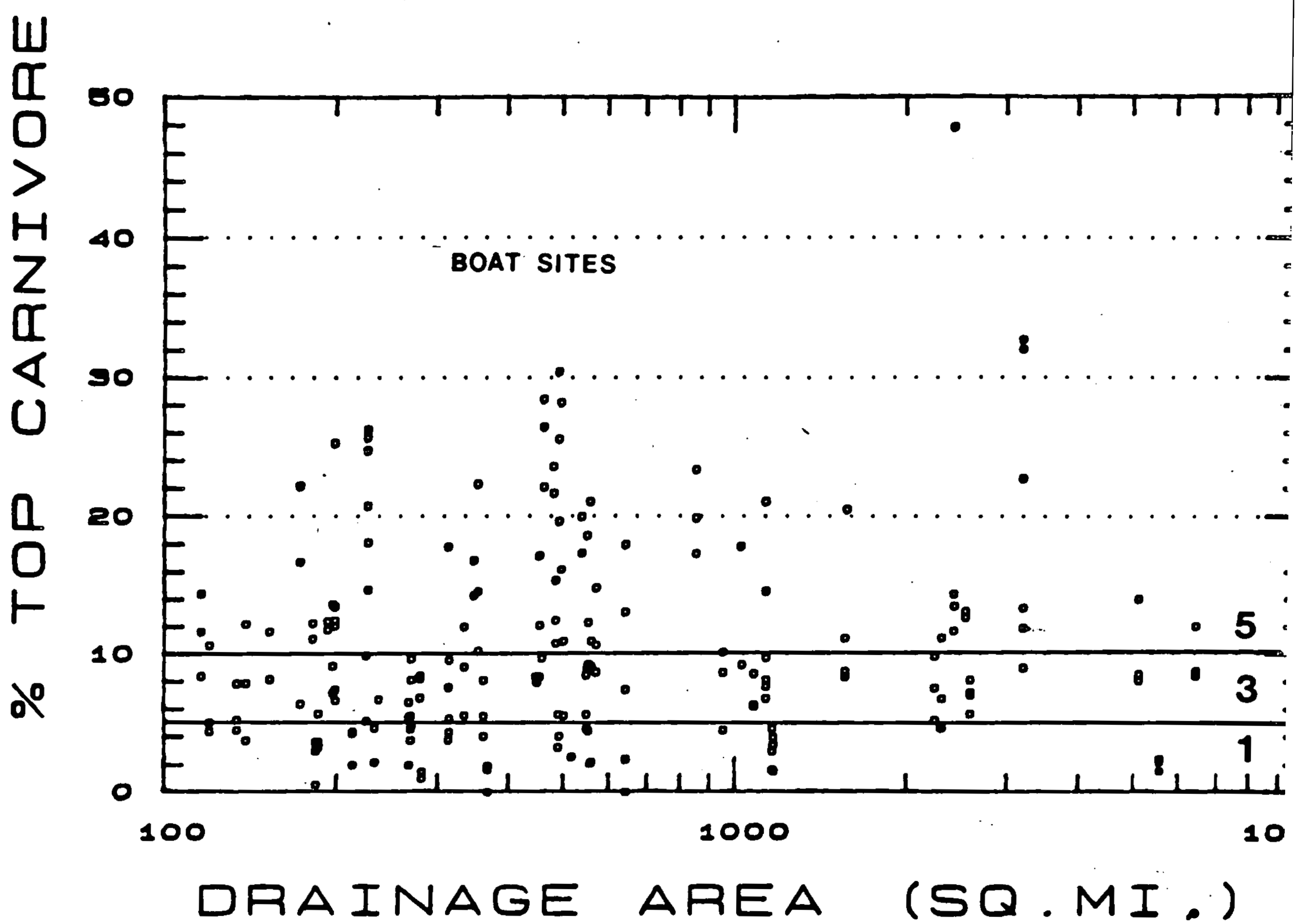

Figure 4-23. Percent top carnivores vs. drainage area at boat sites. The horizontal lines indicate the 5, 3, and 1 scoring boundaries and do not represent any trisection method.

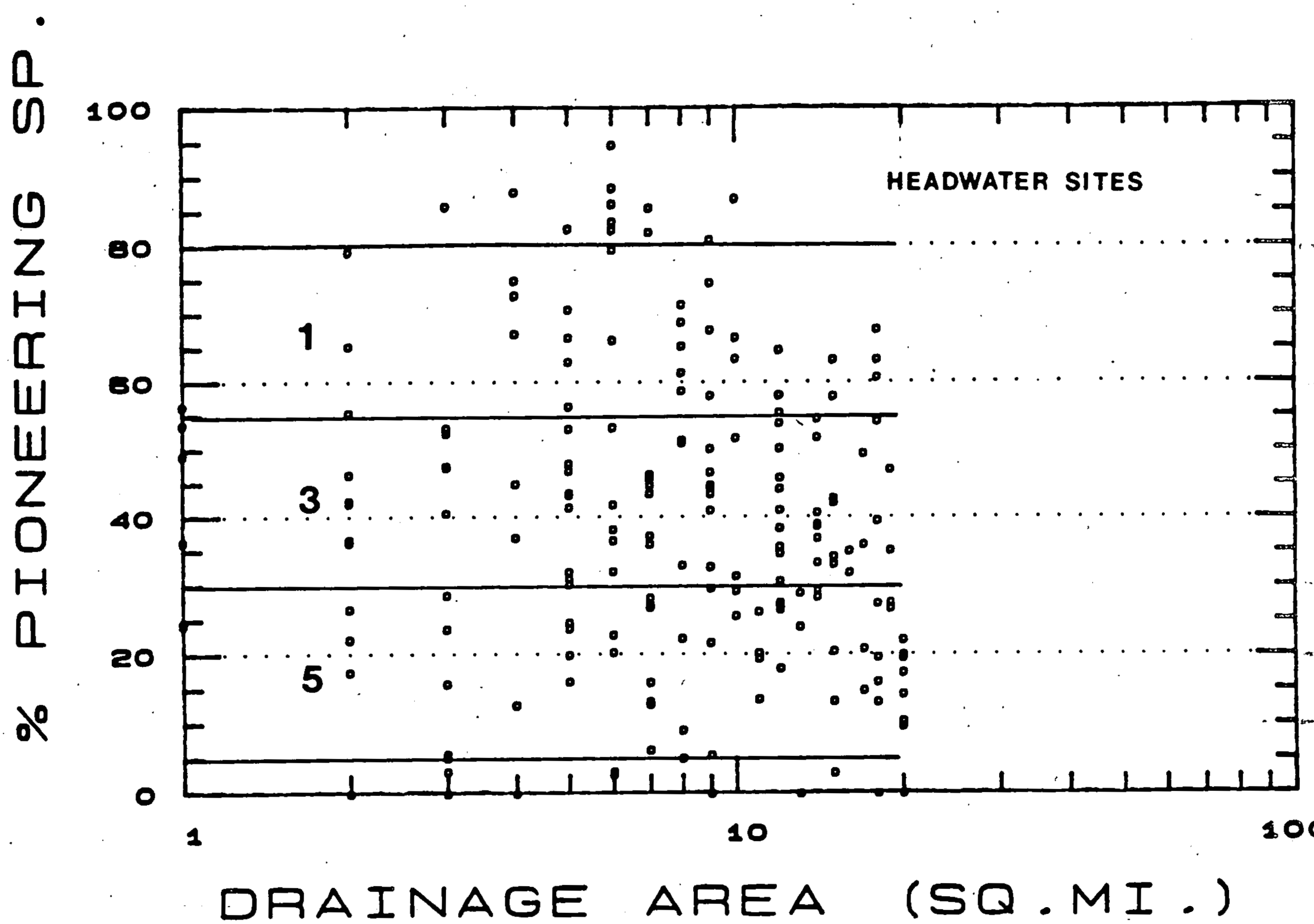

Figure 4-24. Percent pioneering species vs. drainage area (Headwaters sites) using the alternate trisection method (no relationship with drainage area) for determining 5, 3, and 1 IBI scoring.

Metric 10: Number of Individuals in a Sample (All)

General

This metric assesses population abundance as the number of individuals per unit of sampling effort. This metric is most sensitive at the low to middle end of biotic integrity when polluted sites yield fewer individuals (Karr et al. 1986). In such cases the normal trophic relationships are disturbed enough to have severe effects on fish production or directly reduce fish abundance through toxic effects. As integrity increases total abundance increases and becomes more variable (Figure 4-25) with natural factors such as ionic concentration, temperature, and amount of energy reaching the stream surface. However, certain perturbations, such as channelization with canopy removal, can lead to increases in the abundance of fishes, especially tolerant species (e.g. bluntnose minnow). Thus inclusion of these species may obscure negative environmental change. To decrease the variability in scoring of this metric and to avoid rewarding disturbed sites the relative number of individuals excludes species designated as tolerant (Table 4-3).

Wading and Headwaters Sites

Drainage area affects the number of individuals at headwaters and wading sites by increasing numbers with drainage area up to just under 8 sq. mi. (Figure 4-26). This relationship became horizontal above 8 sq. mi. Because the relationship between environmental quality and abundance of individuals is not linear a log transformation of the relative number of individuals (excluding tolerant species) was performed. Strong deviations from the expected in a least impacted stream (score of "1") were determined by examining fish numbers in a series of impacted streams and rivers. For both boat and wading sites this break point was 200 individuals (per km and 300 m, respectively). This number approximated the 5% lines in Figures 4-26 and 4-27. Remaining scoring criteria ("5" and "3") were calculated by bisecting the area in between the 5% and 95% lines. This was then used to determine the appropriate IBI metric score for the wading and boat sites (Tables 4-5 and 4-7).

Boat Sites

No relationship with drainage area was found for numbers at boat sites (Fig. 4-27). A bisection between the 5% and 95% lines was used to determine the scoring criteria given in Table 4-6.

007304

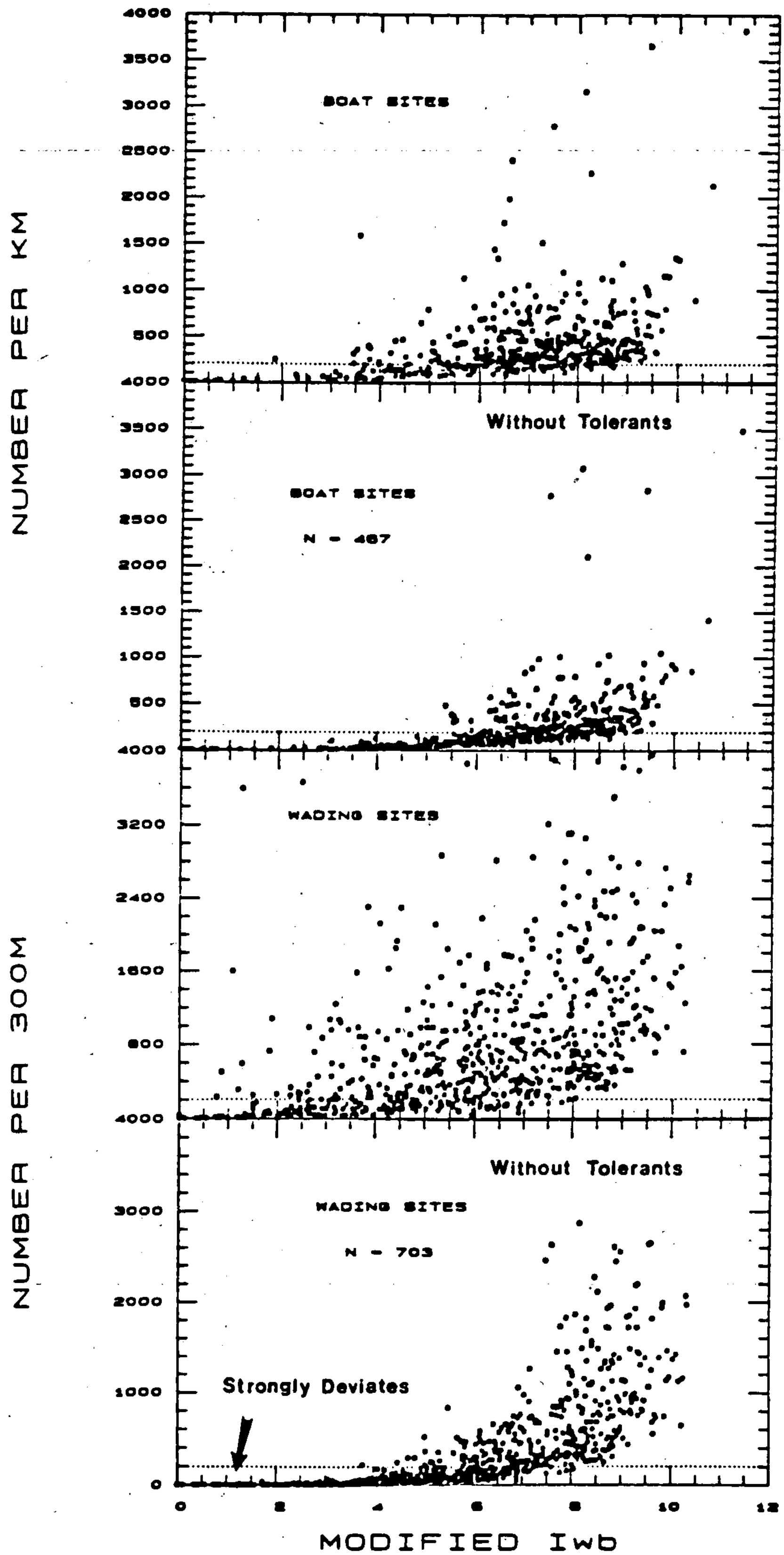

Figure 4-25. Plots of relative number of fish per 300 m (without tolerant species [labeled] and including tolerant species) versus modified I_{wb} for wading and boat sites sampled by pulsed-DC electrofishing methods during 1985 and 1986.

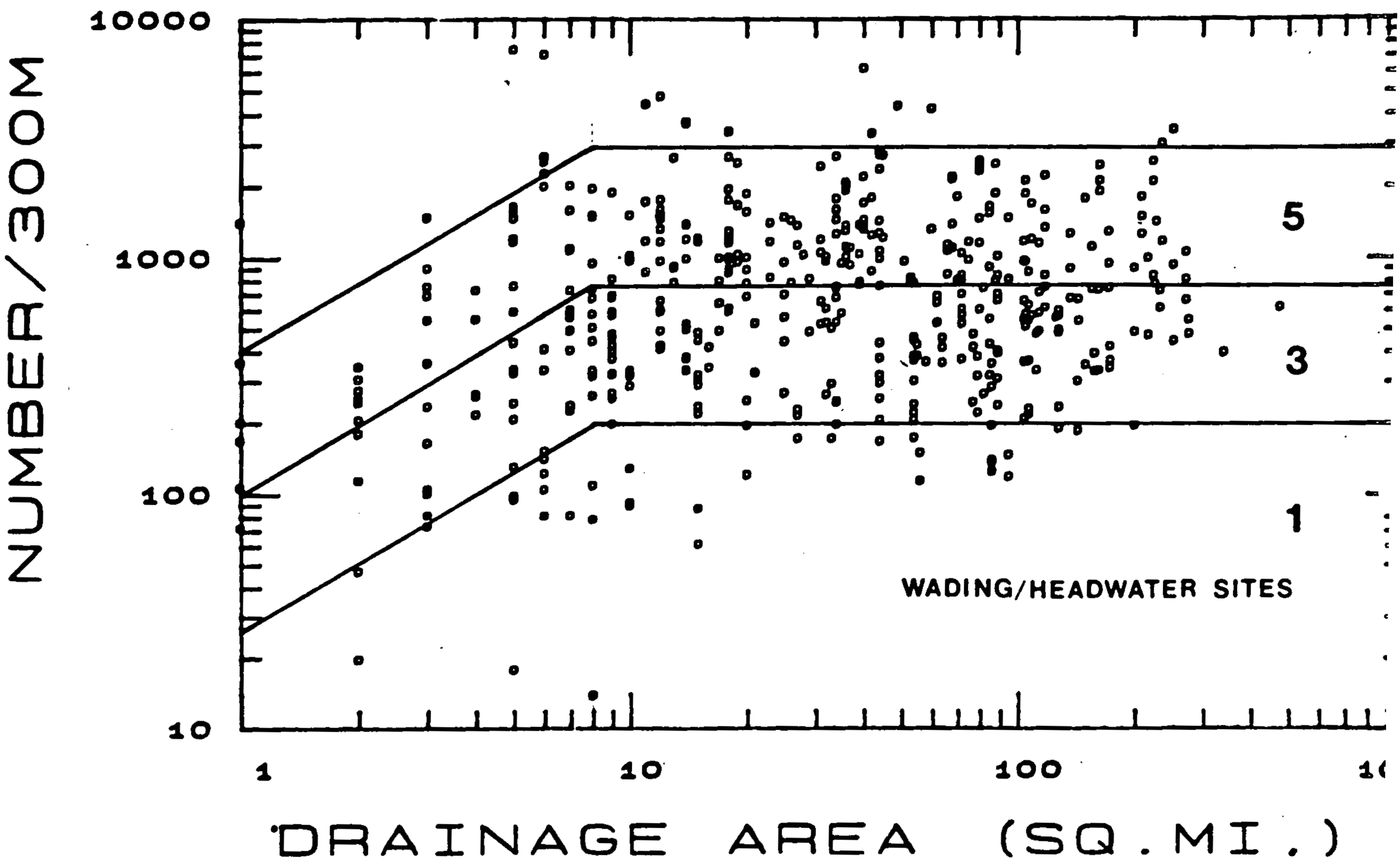

Figure 4-26. Number of individuals per 300 m (minus tolerants) versus drainage area (Headwaters and Wading sites) showing a bisection method for determining 5, 3, and 1 IBI scoring. For streams with extremely few fish (<200 individuals/0.3 km <u>including</u> tolerants) an alternate scoring procedure is used (see text).

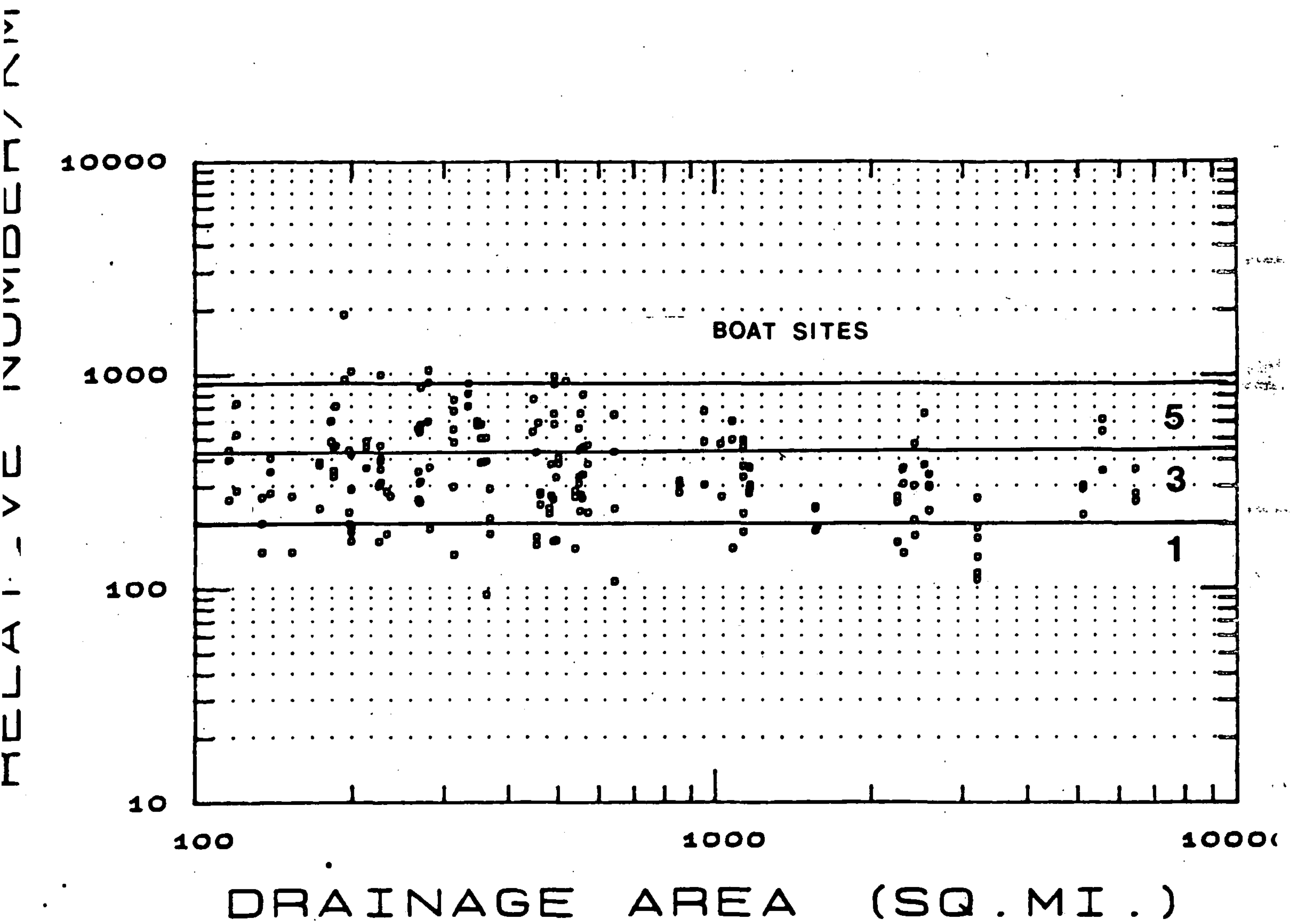

Figure 4-27. Number of individuals per km (minus tolerants) versus drainage area (Boat sites) showing a bisection method for determining 5, 3, and 1 IBI scoring. For streams with extremely few fish (<200 individuals/km <u>including</u> tolerants) an alternative scoring procedure is used (see text).

Metric 11: Proportion of Individuals as Simple Lithophilic Spawners

This metric was designed as a replacement metric for the proportion of individuals as hybrids. In Ohio streams the hybrid metric was not a consistent indication of water quality or habitat problems per its original intent. Hybrids have been observed to occur in high quality Ohio streams (e.g. minnow hybrids), can arise from sensitive parent species (e.g. longear sunfish), are often times absent from headwaters streams and severely impacted streams, and they can be difficult to identify. Although the frequency of hybridization has often been associated with habitat degradation this did not appear consistently enough in the Ohio EPA data base to distinguish this type of impact.

Spawning guilds have been shown to be affected by habitat quality (Berkman and Rabeni 1987) and have been suggested as an alternative IBI metric (Angermier and Karr 1986). Fish that exhibit simple spawning behavior and require clean gravel and/or cobble for successful reproduction (i.e. "lithophilous") appear to be the most environmentally sensitive of the spawning guilds. These simple lithophilic species broadcast their eggs which then come into contact with the bottom substrate. Eggs then develop in the interstitial spaces between sand, gravel, and cobble sized substrate particles. Berkman and Rabeni (1987) found a significant negative correlation between simple lithophilic spawners and the percentage of silt in riffles. Historically some simple lithophilic spawners have suffered population declines in Ohio, due in part to increased silt loads in streams (Trautman 1981). Some simple spawners do not require clean substrates and often have buoyant, adhesive, or fast developing eggs and photoactic larvae that have minimal contact with the substrate (Balon 1975). These are termed simple miscellaneous spawners. Fish species that exhibit a more complex spawning behavior can minimize the effects of silt and pollution by depositing their eggs away from silt on the undersurfaces of rocks (e.g. fantail darter, bluntnose and fathead minnows) or, by building nests and guarding and caring for the eggs (e.g. most sunfishes). These are termed complex with and without parental care. Designations of Ohio fish species appears in Appendix B, Table B-3.

Because of their unique sensitivity to environmental disturbances, particularly siltation, simple lithophilic species are used.

Wading and Boat Sites

No relationship with drainage area was observed at wading sites (Fig. 4-27). Thus scoring was accomplished using the alternate trisection method. Simple lithophils are a major component of the fish communities in these streams, reflecting the importance of clean gravel and cobble substrates. A partial relationship between the proportion of simple lithophilic species and drainage area was found at the boat sites (Fig. 4-28). This involved a decreasing trend at sites with drainage areas greater than 600 square miles. This is apparently related to the increased proprtion of groups such as buffaloes, carpsuckers, gars, gizzard shad, which are classified as simple miscellaneous spawners (Balon 1975).

Headwaters Sites

The number of simple lithophilic species is used instead of the proportion of individuals for headwaters. Because headwaters are more likely to be predominated by a few species, some of which may be simple lithophils, the number of simple lithophilic species is a more consistent environmental indicator. This metric is strongly related to drainage area at headwaters sites (Fig. 4-29).

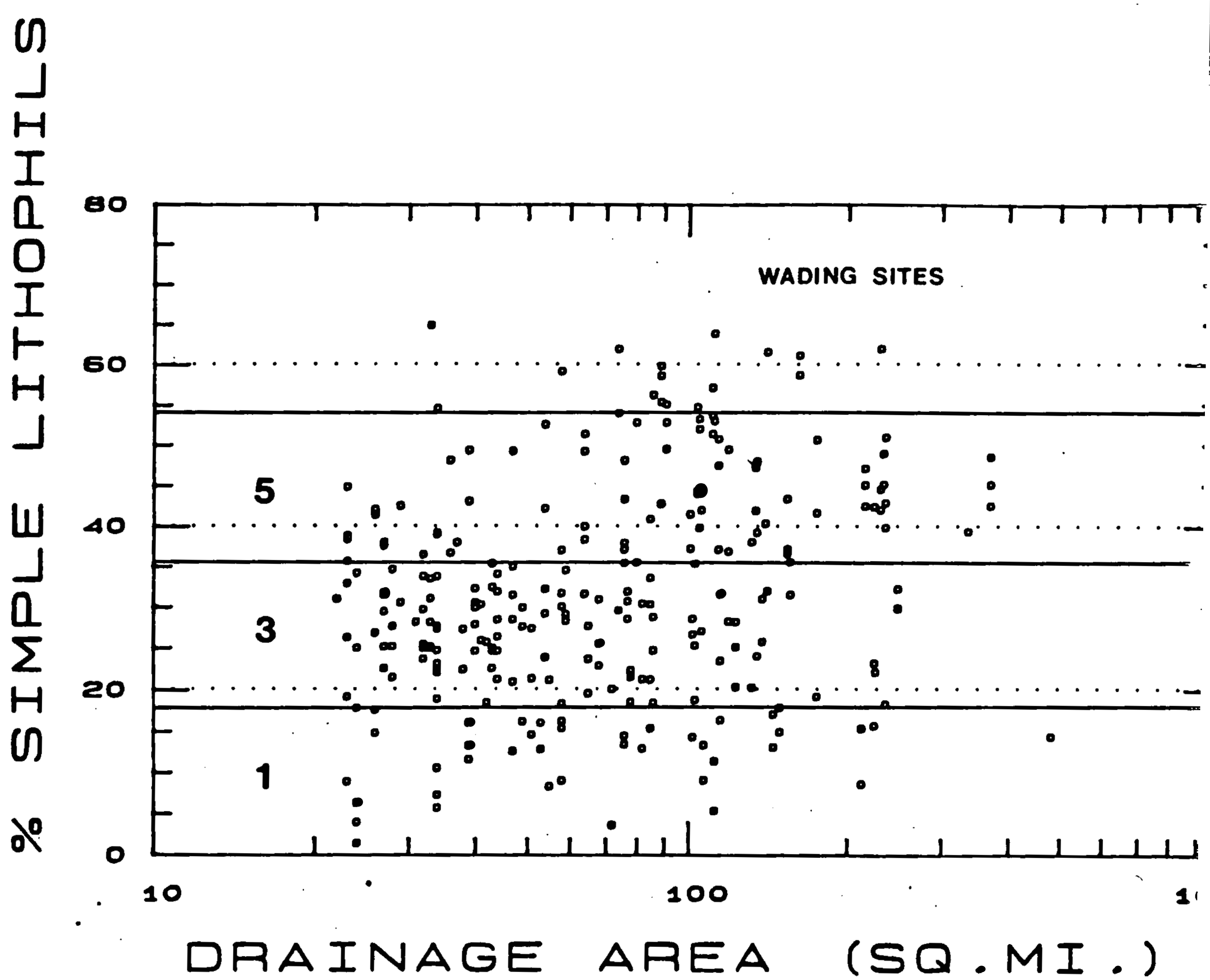

Figure 4-28. Percent of simple lithophilic species vs. drainage area (Wading sites) using the alternate trisection method (no relationship with drainage area) for determining 5, 3, and 1 IBI scoring. Values at sites draining less than 20 square miles are included for reference.

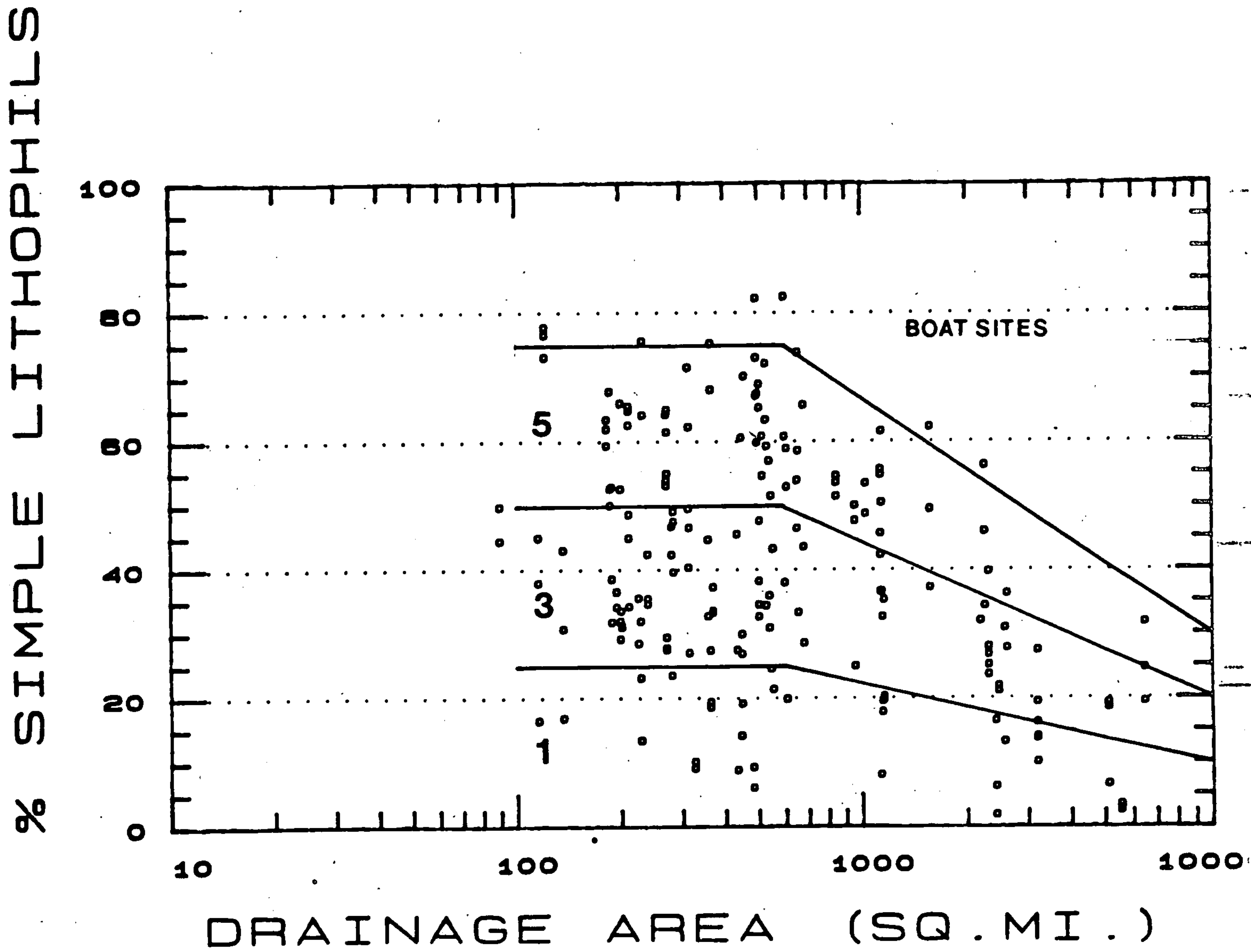

Figure 4-29. Percent of simple lithophilic species vs. drainage area (Boat sites) using the alternate trisection method (partial negative relationship with drainage area) for determining 5, 3, and 1 IBI scoring.

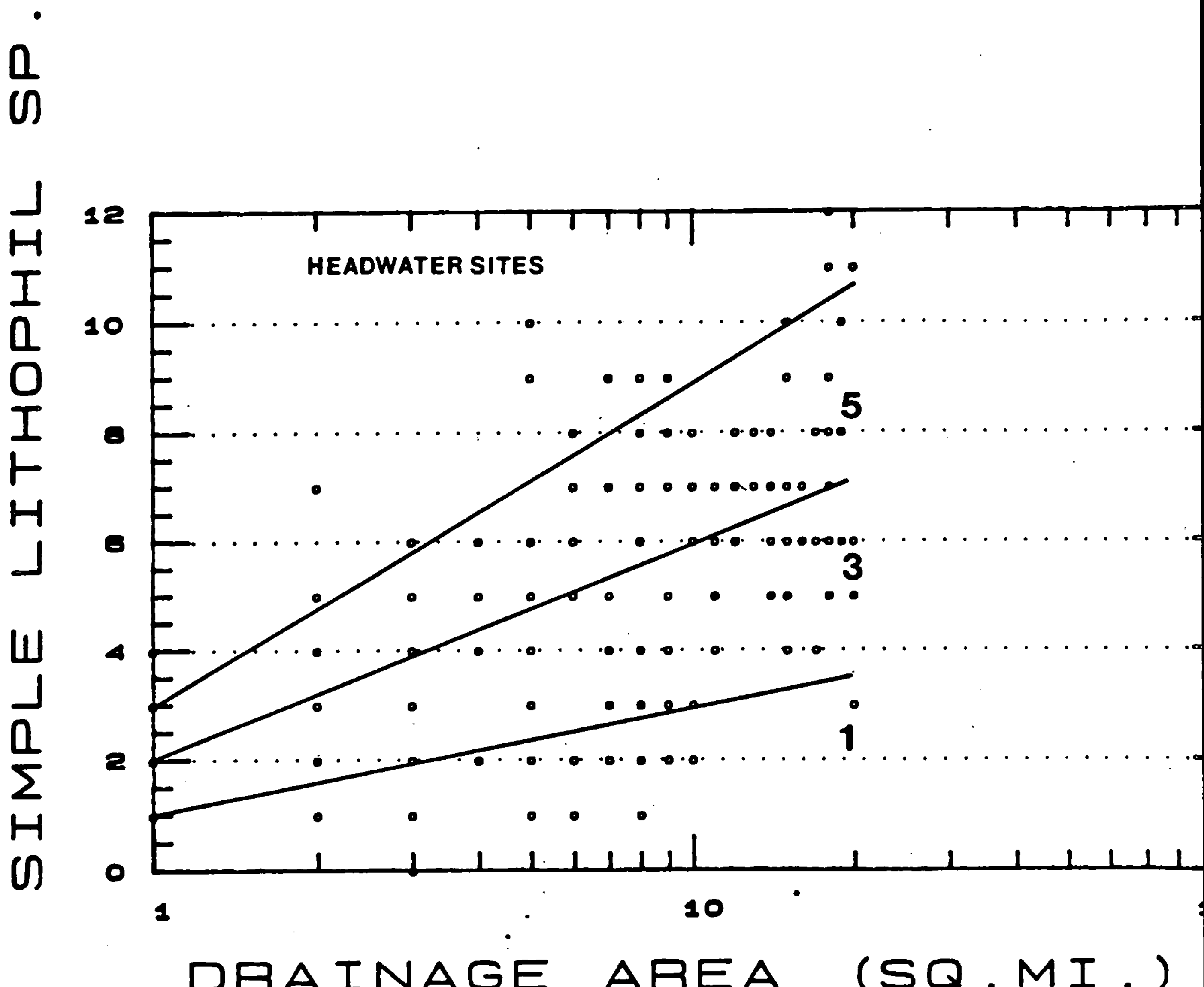

Figure 4-30. Percent of simple lithophilic species vs. drainage area (Headwaters sites) using the standard trisection method (positive relationship with drainage area) for determining 5, 3, and 1 IBI scoring.

Metric 12: Proportion of Individuals With Deformities, Eroded Fins, Lesions, and Tumors - DELT (All).

General

This metric keys in on the health of individual fish within a community using the percent occurrence of external anomalies and corresponds to the percentage of diseased fish in Karr's (1981) original IBI. Studies of wild fish populations have revealed that these and other anomalies are either absent or occur at very low rates at reference sites, but reach higher percentages at impacted sites (Mills et al. 1966; Berra and Au 1981; Baumann et al. 1987). Common causes of DELT (deformities, eroded fins, lesions, and tumors) anomalies are described in Allison et al. (1977), Post (1983) and Ohio EPA 1987a and include the effects of bacterial, viral, fungal, and parasitic infections, neoplastic diseases, and chemicals. An increase in the frequency of occurrence of these anomalies is generally an indication of stress and environmental degradation which may be caused by chemical pollutants, overcrowding, improper diet, excessive siltation, and other disturbances. Blackspot is not included because the presence and varying degrees of infestion may be natural and not related to environmental degradation (Allison et al. 1977; Berra and Au 1981). Also, analysis of Ohio data has shown no clear relationship between black spot and stream degradation (Whittier et al. 1987). Other parasites are also excluded due to the lack of a consistent relationship with environmental degradation although their effects can resemble and lead to tumors, deformities, and lesions. Prior to using this metric, Ohio EPA (1987a) should be referred to for consistent data recording procedures and as a reference for specific anomalies included in each category.

In Ohio, the highest incidence of DELT anomalies occurs in fish communities downstream from discharges of industrial and municipal wastewater, and areas subjected to the intermittent stresses from combined sewers and urban runoff. Leonard and Orth (1986) found that this metric showed consistent and marked responses between increasing incidence of anomalies and increasing stream degradation. Karr et al. (1986) report that the primary range of sensitivity for this metric is the low end of the IBI. We have also observed this metric to function well in situations where structural measures (i.e. species richness, numbers, biomass) indicate improving conditions. For example, modified I_{wb} scores indicative of near complete recovery in the Scioto River downstream from Columbus were accompanied by DELT values greater than 3%. This observation shows that subacute stresses are present and that recovery is not as complete as the structural measures alone indicate. Thus this metric can also represent the intermediate to high range of fish community sensitivity to environmental stress.

Wading and Boat Sites

Both the scoring method and criteria for this metric differs from Karr et al. (1986) and was developed by analyzing wading and boat method data from reference sites sampled in Ohio between 1983 and 1986. For wading sites, the median DELT anomalies was rounded to 0.1% for the highest expected score (between 5 and 3) and the 90th percentile value (1.3%) was used for determining the criteria between 3 and 1. For boat sites, the median DELT anomalies was 1.06% and the 90th percentile was 4.6%. A criteria of 0.5% was chosen for distinguishing between 5 and 3 and the 75th percentile (3.0%) was used for the criterion strongly deviating from the expected (between 3 and 1). We found that one fish would exceed the 0.5% criteria when the sample size contains less than 200 fish. One fish with a DELT anomaly would be accepted at a "5" site and two fish at a "3" site, so these criteria are used when a relative abundance of less than 200 fish is recorded.

Headwaters Sites

The same criteria used for the wading sites are also used for headwaters sites (Table 4-7).

Table 4-5. Index of Biotic Integrity metrics and scoring criteria based on fish community data from more than 300 reference sites throughout Ohio. These criteria apply to wading sites only (sampler types D, E, and F at sites >20 sq. mi.; Ohio EPA 1987a).

Category	Metric	Scoring Criteria 5	3	1
Species composition	Total species	Varies with drainage area (Fig. 4-2)		
	Darter species	Varies with drainage area (Fig. 4-4)		
	Sunfish species	>3	2-3	<2
	Sucker species	Varies with drainage area (Fig. 4-10)		
	Intolerant species <100 sq. mi.	>5	3-5	<3
	>100 sq. mi.	Varies with drainage area (Fig. 4-13)		
	% Tolerant (no.)	Varies with drainage area (Fig. 4-16)		
Trophic composition	% Omnivores	<18.6	18.6-34.3	>34.3
	% Insectivores ≤30 sq. mi.	Varies with drainage area (Fig. 4-20)		
	>30 sq. mi.	>54.6	26.3-54.6	<26.3
	% Top carnivores	>5	1-5	<1
Fish condition	% Simple Lithophils	>36	18-36	<18
	% DELT Anomalies	<0.1[a]	0.1-1.3[b]	>1.3
	Fish numbers[c]	>750	200-750	<200

[a] or >1 individual at sites with <200 total fish.
[b] or >2 individuals at sites with <200 total fish.
[c] excludes tolerant species; special scoring procedures are used when relative numbers are less than 200/0.3 km (see Appendix B).

Table 4-6. Index of Biotic Integrity metrics and scoring criteria based on fish community data from more than 300 reference sites throughout Ohio. These criteria apply to boat sites only (sampler types A and B; Ohio EPA 1987a).

		Scoring Criteria		
Category	Metric	5	3	1
Species composition	Total species	>20	10-20	<10
	% Round-bodied Suckers	>38	19-38	<19
	Sunfish species	>3	2-3	<2
	Sucker species	>5	3-5	<3
	Intolerant species	>3	2-3	<2
	% Tolerant (no.)	<15	15-27	>27
Trophic composition	% Omnivores	<16	16-28	>28
	% Insectivores	>54	27-54	<27
	% Top carnivores	>10	5-10	<5
Fish condition	% Simple Lithophils ≤600 sq. mi.	>50	25-50	<25
	>600 sq. mi.	Varies with drainage area (Fig. 4-29)		
	% DELT Anomalies	<0.5[a]	0.5-3.0[b]	>3.0
	Fish numbers[c]	<200	200-450	>450

a or >1 individual at sites with <200 total fish.
b or >2 individuals at sites with <200 total fish.
c excludes tolerant species; special scoring procedures are used when relative numbers are less than 200/km (see Appendix B).

Table 4-7. Index of Biotic Integrity metrics and scoring criteria based on fish community data from more than 300 reference sites throughout Ohio. These criteria apply to headwaters sites only (sampler types D, E, F, and G at sites <20 sq. mi.; Ohio EPA 1987a).

		Scoring Criteria		
Category	Metric	5	3	1
Species composition	Total species	Varies with drainage area (Fig. 4-2)		
	Darters + sculpin	Varies with drainage area (Fig. 4-5)		
	Headwater species	>3	2-3	<2
	Minnow species	Varies with drainage area (Fig. 4-12)		
	Sensitive sp.[a]	Varies with drainage area (Fig. 4-15)		
	% Tolerant (no.)			
	≤10 sq. mi.	<34	34-57	>57
	>10 sq. mi.	Varies with drainage area (Fig. 4-16)		
Trophic composition	% Pioneering sp.	<30	30-55	>55
	% Omnivores	Varies with drainage area (Fig. 4-18)		
	% Insectivores	Varies with drainage area (Fig. 4-20)		
Fish condition	Simple Lithophils	Varies with drainage area (Fig. 4-30)		
	% DELT Anomalies	<0.10[b]	0.10-1.30[c]	>1.30
	Fish numbers[d]			
	≤8 sq. mi.	Varies with drainage area (Fig. 4-26)		
	>8 sq. mi.	>750	200-750	<200

a includes intolerant and moderately intolerant species (Appendix B).
b or >1 individual at sites with <200 total fish.
c or >2 individuals at sites with <200 total fish.
d excludes tolerant species; special scoring procedures are used when relative numbers are less than 200/0.3 km (see Appendix B).

Calculation and Interpretation of IBI Scores

Karr et al. (1986) describes eight steps for the logical sequence of IBI calculation (Table 4-8). Step 1, developing expectation criteria for each metric, has been completed using reference site data from across Ohio. Step 3, assigning species to trophic guilds, and Step 4, identification of intolerant species, is also complete (see Appendix B, Table B-3). The following description of Step 2 and Steps 5-8 cover hand calculation of IBI scores. Computer generation of IBI scores, with appropriate cautions, is discussed later.

Step 2 consists of tabulating a list of species (in taxonomic order) captured in a survey and tallying in columns the relative number of each species at each site. Trophic guilds and intolerance status for Ohio fish species are listed in Appendix B, Table B-3.

In Step 5, the biological information needed for each metric is summarized in a worksheet similar that in Table 4-9 compiled for the Hocking River. Actual values (e.g., number of darter species) should be placed in the parentheses. It works best to use separate sheets for each different sampling method application (i.e. wading sites vs. headwaters sites, boat sites vs. wading sites, etc.) because each have different scoring criteria. The drainage area of each site should also be listed (see Appendix E).

Step 6 involves rating each metric for each site sampled. Criteria are found in Tables 4-5, 4-6, and 4-7 and in the individual figures for the five metrics that vary with drainage area. The scoring is arranged so that a "5" approximates what is expected at a reference site, a "3" deviates somewhat from, and a "1" strongly deviates from that expected at an applicable reference site. Care should be taken so that wading sites, boat sites, and headwaters sites samples are scored separately. In severely impacted streams with less than 200 individuals per 0.3 km (wading sites, headwaters sites) or per 1.0 km (boat sites), some of the conventions for scoring the proportional metrics (except for percent tolerant species) are altered following the guidance in Appendix B.

Step 7 is simply the summing of the twelve metric scores for each site. The maximum score possible is 60 (no perturbation); the minimum score, where all metrics deviate strongly from that expected at an applicable reference site, is 12 (extremely degraded).

Step 8 consists of assigning integrity classes to the scores that reflect a general qualitative summary of the community that non-professionals can understand and that are used to determine whether a stream is meeting its assigned use designation. This is discussed in Section 6, "Derivation of Biological Criteria". The procedure used to assign these categories in Ohio streams, which differs somewhat from the classes suggested by Karr et al. (1986), is discussed in this section.

Table 4-8. The eight steps in the calculation and interpretation of the Index of Biotic Integrity as described by Karr et al. (1986) and appropriately modified for use in Ohio.

Step - Description	Ohio EPA Application	Applicable Figs., Tables, Appendix
1. Develop expectation criteria for each IBI metric.	Stream Regionalization Project study design.	Figs. 2-1; 4-2 through 4-29; Tables 4-1 thru 4-7.
2. Tabulate number of fish by species.	Fish Information System (FINS).	
3. Assign species to trophic guilds.	Literature review Karr et al. (1986)	Appendix B, Table B-3.
4. Identify species tolerances.	Appendix B - based on statewide data base and Trautman (1981).	Appendix B, Table B-3.
5. Summarize information for each IBI metric.	Depends on application (wading, boat, head-waters).	Table 4-1;
6. Rate each IBI metric according to criteria developed.	Follow guidelines for each application (wading, boat, head-waters).	Tables 4-5 through 4-7; Figs. 4-2 thru 4-29.
7. Calculate total IBI score.	Do by hand or use computer assistance.	
8. Convert total IBI score to one of five integrity classes.	Ohio biological criteria for WQS use attainment/non-attainment.	See Table 7-1 and consult Section 8.

Table 4-9. Evaluation of the fish community at two sites in the upper Hocking River during August-September, 1982 using the Index of Biotic Integrity modified for application to Ohio waters (boat sites). Scores are assigned based on whether the individual metric values (in parentheses) approximate (5), partially deviate (3), or strongly deviate (1) from what is expected in a least impacted stream or river.

	Sampling Station (River Mile)					
IBI Metrics	82.4	82.4	82.4	78.3	78.3	78.3
NUMBERS OF						
Total Species	1(6)	1(5)	1(4)	3(16)	3(14)	3(14)
Total Individuals	1(8)	1(12)	1(4)	1(87)	1(106)	1(130)
Sunfish Species	3(2)	1(1)	3(2)	5(4)	3(3)	5(4)
Sucker Species	1(2)	1(1)	1(2)	3(3)	3(5)	3(3)
Intolerant Species	1(0)	1(0)	1(0)	1(0)	1(0)	1(0)
PROPORTION OF INDIVIDUALS (%)						
Round-bodied Suckers	1(4)	1(0)	1(4)	3(19)	3(32)	3(34)
Omnivores	1(70)	1(67)	1(76)	1(53)	1(41)	1(38)
Insectivores	1(22)	1(19)	1(20)	3(36)	3(54)	3(50)
Tolerant Species	1(85)	1(86)	1(92)	1(60)	1(44)	1(42)
Top Carnivores	3(7)	3(7)	1(4)	3(5)	1(4)	3(10)
Simple Lithophils	1(22)*	1(7)*	1(8)*	5(60)	5(72)	5(57)
Anomalies	1(0)*	1(0)*	1(0)*	5(0)	5(0)	5(0)
Index Value	16	14	14	34	30	34
Drainage Area	334	334	334	437	437	437

* these metrics are adjusted because of low overall numbers according to the guidelines for "low-end" scoring.

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Extremely Few Numbers ("Low-end Scoring")

Samples with extremely low numbers in the catch can present a scoring problem in some of the proportional metrics unless certain adjustments are made. Aquatic habitats that are severely impacted by strong perturbations (e.g. toxic substances, acid mine drainage) usually have a severe disruption of the food base and very low numbers of individuals. At such low population sizes the normal structure of the community is unpredictably altered. The proportion of omnivores, insectivorous fishes, and percent affected by anomalies do not always match expected trends in such situations. Although these metrics would be expected to deviate strongly from the expected in such areas (i.e. score a 1) this is not always the case. In fact the absence or low proportion of these metrics results in metric scores that reflect the opposite of the overall situation.

Scoring very degraded sites without modifying scoring criteria for the proportional metrics can overrate the total IBI score for these sites. To remedy this situation we examined data from known impacted sites to determine a relative numbers criterion below which an alternative scoring mechanism (i.e. "low end scoring") is used for the proportional metrics. These problems are encountered when relative numbers are fewer than 200 individuals per 0.3 km (wading) or 1.0 km (boat). When 200 and fewer individuals are recorded the guidance in Table 4-10 is used making IBI scoring modifications. This was developed by examining the reaction of the IBI metrics for moderately and severely impacted sites (Appendix A).

During the process of tallying catch results, summarizing biological information for each metric, and scoring each metric, the biologist should be assessing the community and examining whether the scoring approximates the conceptual model of an applicable reference site or whether the site they are examining is anomalous for one reason or another. The inherent redundancy of the IBI should greatly reduce the possibility of such anomalies. The possibility does exist, however remote, for the IBI to "incorrectly" characterize a site; thus the biologist should have a thorough knowledge of the local fauna and the data. This is one reason why the Ohio EPA relies on multiple measures (IBI and I_{wb}) and multiple organism groups (fish and invertebrates) to make decisions on complex water quality issues. Guidelines for the use of the IBI as a water quality criterion is discussed further in Section 7, "Biological Criteria for Ohio Surface Waters".

The above caveats are purposely mentioned prior to the description of computer generated IBI scores. Karr et al. (1986) give strong cautions about the possible misuses of the IBI including computer generated score calculations. Total IBI scores themselves, calculated without an in-depth analysis of the fish communities, can be an inappropriate measure of environmental quality. However, when the components of the IBI and the fish community are examined by a trained biologist, computer generation of IBI scores can serve to enhance the overall evaluation by reducing time spent on calculations and increasing the time available for IBI score interpretation.

Table 4-10. Guidelines for scoring the proportional metrics of the IBI in severely impacted streams in Ohio with less than 200 individuals per 0.3 km (wading methods) or per 1.0 km (boat methods). "Total individuals" in this table refers to relative number.

Metric	Guidelines for IBI Scoring Modifications
Proportion as Omnivores	For wading sites results we recommend assigning a score of "1" for this metric with less than 50 total individuals. With 50-200 total individuals a score of "1" is assigned when species considered as generalist feeders are numerically dominant. In Ohio creek chub and blacknose dace are the generalist feeders that usually predominate in these situations. The same procedure is used for boat sites results. For headwaters sites less than 8 sq. mi. drainage area, the numbers cutoff changes from 200 to 25, reflecting the fewer expected individuals at these sites.
Proportion as Insectivores	At sites with a high proportion of insectivorous species and less than 50 total individuals (25 individuals at headwaters sites <8 sq. mi.) a score of "1" is automatically assigned. At sites with 50-200 total individuals this metric can be scored "1" if this metric is predominated by either striped shiner, common shiner, or spotfin shiner, species that can act as omnivores under certain conditions (Angermeier 1985).
Proportion as Top Carnivores	At boat sites the levels of top carnivores that would normally attain a score of "5" at sites with less than 200 total individuals should be scored a "1", dependent on the judgement of the biologist involved in scoring. A simialr procedure should be used at sites sampled with wading methods if the high proportion of top carnivores is due to a predominance of grass pickerel in impacted areas.
Proportion as Simple Lithophils	This metric always scores a "1" at sites with less than 50 total individuals; however, this is rarely different from its score without the adjustment. This applies at both wading and boat sites. No adjustment is necessary at headwaters sites.

Table 4-10. (continued).

Metric	Guidelines for IBI Scoring Modifications
Proportion with DELT Anomalies	Sites with less than 50 total individuals are scored a "1" for this metric (25 individuals at headwaters sites). Sites with 50-200 total individuals are also scored a "1" if circumstances suggest that DELT anomalies may be underestimated. A predominance of young fish that have not "accrued" anomalies may also be sufficient reason to score a "1".
Proportion as Pioneering Species	At headwaters sites this metric is scored a "1" if there are less than 50 total individuals at >8 sq. mi., and 25 at <8 sq. mi.
Proportion as Tolerants	No adjustments are necessary for this metric.
Proportion as Round-bodied Suckers	No adjustments are necessary for this metric.

Index of Well-Being

The results of river studies in which the Index of Well-Being (Iwb) was used have shown a positive relationship between this index and the quality of the water and habitat. This approach relies on the assertion that least impacted stream segments support a larger variety and abundance of fish than stressed segments in the same system. This hypothesis has been tested and verified in several different situations (Gammon 1976; WAPORA 1978; Gammon et al. 1981; Yoder et al. 1981; Ohio EPA 1982) and confirms the value that this method has for monitoring environmental quality, measuring the effectiveness of water pollution control programs, and determining attainment of Clean Water Act goals (i.e. fishable waters, biological integrity). The Ohio EPA has used a set of guidelines employing ranges of the Iwb and narrative descriptions of community structure and function to assist in establishing attainable use criteria and to determine attainment of Clean Water Act goals since 1980 (see Section 8).

The Iwb incorporates four measures of fish communities that have traditionally been used separately; numbers of individuals, biomass, and the Shannon diversity index (H) based on numbers and weight (two separate calculations). The computational formulas for the Iwb and Shannon index are given in Table 4-11. Relative abundance (numbers and weight) data are derived from pulsed D.C. electrofishing catches where sampling effort is based on distance rather than time (Gammon 1976). Ohio EPA bases relative abundance on a per kilometer basis for boat methods and on a 0.3 kilometer basis for wading methods (Ohio EPA 1987a).

The Iwb presents some advantages over the IBI particularly in the calculation of site scores. Unlike the IBI the Iwb is the result of a mathematical calculation based on the results of standardized sampling. While this may appear to be an undesirable attribute based on the cautions given by Karr et al. (1986), we view this as an advantage in having a result that is comparable from site to site, as long as field sampling is performed according to specifications (Ohio EPA 1987a). In addition we have found that the additional collection of biomass data (required to calculate the Iwb) is not a significant expenditure of time as long as subsampling techniques are used (Appendix C).

A modification of the original Iwb was recently developed (Appendix C) which makes the index more sensitive to a wider array of environmental disturbances, particularly those that result in shifts in community composition without large reductions in species richness, numbers, and/or biomass. The modified Iwb retains the same computational formula as the conventional Iwb developed by Gammon (1976). The difference is that any of 13 highly tolerant species, hybrids, or exotic species are eliminated from the numbers and biomass components of the Iwb. However, they are included in the two Shannon index calculations. This modification eliminates the "undesired" effect caused by a high abundance of tolerant species, but retains their

Table 4-11. Computational formulae for the modified index of well-being (I_{wb}) and the Shannon diversity index.

Modified Index of Well-Being (Iwb)

$$I_{wb} = 0.5 \ln N + 0.5 \ln B + \bar{H}\,(no.) + \bar{H}\,(wt.)$$

where:

N = relative numbers of all species excluding species designated "highly tolerant" (Appendix B, Table B-3).

B = relative weights of all species excluding species designated "highly tolerant" (Appendix B, Table B-3).

$\bar{H}$ (no.) = Shannon diversity index based on numbers.

$\bar{H}$ (wt.) = Shannon diversity index based on numbers.

Shannon Diversity Index

$$\bar{H} = - \sum \frac{(n_i)}{N} \log_e \frac{(n_i)}{N}$$

where;
n_i = relative numbers or weight of the ith species
N = total number or weight of the sample

"desired" influence on the Shannon indices. We have also found that examining the difference between the original I_{wb} and modified I_{wb} can be of value. An increasing difference between the modified and original I_{wb} is a direct indication of the influence of tolerant species which in turn is correlated with a loss of integrity in the fish community.

Calculation of modified I_{wb} scores for electrofishing samples is best performed with the aid of a computer. The data requirements are somewhat more rigorous than the IBI since standardized relative numbers and biomass data is required and the Shannon index and I_{wb} calculations themselves involve log functions. Other requirements include sampling effort based on distance following the procedures outlined in Ohio EPA (1987a). Data collected in any different manner will simply not be comparable to the Ohio EPA reference site data base.

SECTION 5: BIOLOGICAL DATA EVALUATION: MACROINVERTEBRATES

Macroinvertebrates have been widely used nationwide for many years in pollution studies involving flowing waters. At the Ohio EPA, macroinvertebrate communities have been collected and analyzed since the Agency's inception in 1973 in an effort to provide biological data to be used in the water quality monitoring process. To date, data has been collected at least one time from over 1500 locations displaying a wide variety of water quality conditions within the state.

Aquatic macroinvertebrates are animals without backbones that are large enough to be seen by the unaided eye, can be retained by a U.S. Standard #30 mesh seive (0.595 mm openings), and live at least part of their life cycles within or upon available substrates in a waterbody. Stream macroinvertebrates include organisms such as crayfish, snails, clams, aquatic worms, and, by far the most predominant, larval forms and some adults of several insect orders. As a group, they have a number of characteristics that make them useful as indicators of environmental quality:

1) they form permanent, relatively immobile stream communities;

2) they can be easily collected in large numbers in even the smallest of streams;

3) they can be easily sampled at relatively low cost per sample;

4) they are quick to react to environmental change;

5) they occupy all stream habitats and, even within family and generic groupings, display a wide range of functional feeding preferences (i.e. predators, collectors, shredders, scrapers);

6) they inhabit the middle of the aquatic food web and are a major source of food for fish and other aquatic and terrestrial animals; and

7) taxonomy has developed in recent years to the point where species level identifications of many larval forms are available along with much environmental and pollution tolerance information.

Species composition and community structure of stream macroinvertebrates are determined by environmental factors that have existed throughout the life spans of the organisms. Consequently, most types of environmental disturbance, whether long or short term, can alter the existing community structure. The duration and magnitude of community alterations depend upon the duration and severity of the environmental change.

Evaluations using macroinvertebrates are based on the fact that characteristic assemblages of these organisms occur in waters of varying physical and chemical properties. In streams of high water quality and suitable habitat, assemblages of these organisms occur in waters of varying physical and chemical properties. In streams of high water quality and suitable habitat, a stable, well-balanced macroinvertebrate community usually exists. The organisms in these areas are usually larval forms of predominantly pollution sensitive insect groups such as stoneflies, mayflies, and caddisflies. The most pollution tolerant groups such as sludgeworms, pulmonate snails, and many types of larval dipteran insects (i.e. bloodworms) are often represented by a few species in low numbers. When environmental quality is adversely impacted, the sensitive groups decline or are eliminated and the few tolerant organisms present greatly increase in number. All types of organisms may be absent under extreme toxic conditions.

Invertebrate Community Index (ICI)

The principle measure of overall macroinvertebrate community condition used by the Ohio EPA is the Invertebrate Community Index (ICI), a measurement derived inhouse from the wealth of information collected over the years. The ICI is a modification of the Index of Biotic Integrity (IBI) for fish developed by Karr (1981) and explained in detail in Section 4 of this document. The ICI consists of ten structural and functional community metrics, each with four scoring categories of 6,4,2, and 0 points (Table 5-1). The point system generally evaluates a sample against the database of relatively undisturbed reference sites (Figure 2-3, Appendix A-3). Six points will be scored if a given metric has a value comparable to those of exceptional stream communities, 4 points for those metric values characteristic of more typical good communities, 2 points for metric values slightly deviating from the expected range of good values, and 0 points for metric values strongly deviating from the expected range of good values. The summation of the individual metric scores (determined by the relevant attributes of an invertebrate sample with some consideration given to stream drainage area) results in the ICI value. Four scoring categories were chosen because of the historical use by the Ohio EPA of four levels of biological community condition (i.e. exceptional, good, fair, poor) a situation which (as defined above) is reflected by the metric score of a sample. The scoring categories were calibrated using data from the 232 reference sites. To determine the 6,4,2, and 0 values for each ICI metric, the reference site database was plotted against drainage area. Each metric was visually examined to determine if any relationship existed with drainage area. When it was decided if a direct, inverse, or no relationship existed, the appropriate 95% line was estimated and the area beneath quadrisected as determined by the distribution of the reference points. Some percent abundance and taxa richness categories were not quadrisected since the data points showed a tendency to clump at or near zero. In these situations, a quadripartite method was used where one of the four scoring categories included zero values only, and, in two cases, the remaining scoring categories were delineated by an equal division of the reference data points.

The decision to use the ten metrics listed was determined by analyzing the process by which Ohio EPA staff biologists judge the quality of a macroinvertebrate sample. In effect, the index quantified a more subjective,

Table 5-1. Macroinvertebrate community metrics and criteria for calculating the Invertebrate Community Index (ICI) and ICI scores for evaluating biological condition.

Metric	Score 0	Score 2	Score 4	Score 6
1. Total Number of Taxa	Varies with drainage area (Fig. 5-1)			
2. Total Number of Mayfly Taxa	Varies with drainage area (Fig. 5-2)			
3. Total Number of Caddisfly Taxa	Varies with drainage area (Fig. 5-3)			
4. Total Number of Dipteran Taxa	Varies with drainage area (Fig. 5-4)			
5. Percent Mayfly Composition	0	>0,≤10	>10,≤25	>25
6. Percent Caddisfly Composition	Varies with drainage area (Fig. 5-6)			
7. Percent Tribe Tanytarsini Midge Composition	0	>0,≤10	>10,≤25	>25
8. Percent Other Dipteran and Non-Insect Composition	Varies with drainage area (Fig. 5-8)			
9. Percent Tolerant Organisms (from Table 5-2)	Varies with drainage area (Fig. 5-9)			
10. Total Number of Qualitative EPT Taxa	Varies with drainage area (Fig. 5-10)			

narrative approach that was used previously (described in DeShon et al. 1980). The end product was a single number to evaluate biological condition that has incorporated into it ten measurements that, with various degrees of effectiveness, can and have often been used to accomplish this task individually. It was thought that, used as a set, these metrics would minimize the weaknesses and drawbacks each has separately. Mostly structural rather than functional components were used because of their accepted historical use, simpler derivation, and ease of interpretation. Metrics 1-9 are all generated from the artificial substrate sample data while Metric 10 is based on the qualitative sample data only.

Metric 1. Total Number of Taxa

The plot of the total taxa metric vs. drainage area is depicted in Figure 5-1. Taxa richness has historically been a key component in most all evaluations of macroinvertebrate integrity. The underlying reason is the basic ecological principle that healthy, stable biological communities have high species richness and diversity. As can be seen by the scatterplot the total number of taxa tends to decrease in the larger rivers. This can be explained by the stream continuum concept (Cummins 1975) which predicts fewer species in larger rivers due to changes in organic inputs and plant growth. Another possibility is that even the best, larger Ohio rivers with reference sites have some cultural degradation.

Metric 2. Number of Mayfly Taxa

Mayflies are an important component of an undisturbed stream macroinvertebrate fauna. As a group, they are decidedly pollution sensitive and are often first to disappear with the onset of perturbation. Thus, they are a good indicator of ambient conditions. The plot of reference site mayfly taxa vs. drainage area is depicted in Figure 5-2. The general trend in mayfly diversity reflects highest variety of types in intermediate size streams with slight decreased diversity in the smaller and larger drainages. This is probably a result of the transitional nature of the intermediate streams and the corresponding increased variety of macrohabitat, microhabitat, and food sources. In effect, environmental conditions are highly diverse and support a mayfly fauna transitional between the smaller Ohio streams (predominated by shredders and collectors) and the larger Ohio rivers (predominated by collectors and grazers).

Metric 3. Number of Caddisfly Taxa

Caddisflies are often a predominant component of the macroinvertebrate fauna in larger, relatively unimpacted Ohio streams and rivers. Though tending to be a little more pollution tolerant as a group than mayflies, they display a wide range of tolerance among types. Not withstanding, however, few can tolerate heavy pollutional stress and, as such, can be good indicators of environmental conditions. The distribution of reference site caddisfly taxa vs. drainage area shows a clear, increasing trend with stream size (Figure 5-3). This can be explained by the predominance in Ohio of net spinning, filter feeding caddisflies of the families Hydropsychidae, Polycentropodidae, and Philopotamidae and micro-caddisflies of the family Hydroptilidae. Habitat preferences of the filter feeders are streams with abundant suspended organic matter while the micro-caddisflies feed mainly on periphytic diatoms and filamentous algae. These environmental conditions are best met in the larger streams and rivers where import of fine particulate organic matter is maximized and plant growth optimal due to availability of finer sediments and more open canopies. As can be seen in the figure, for drainages less than 600 square miles, zero scores occur only when no caddisfly taxa are present. For

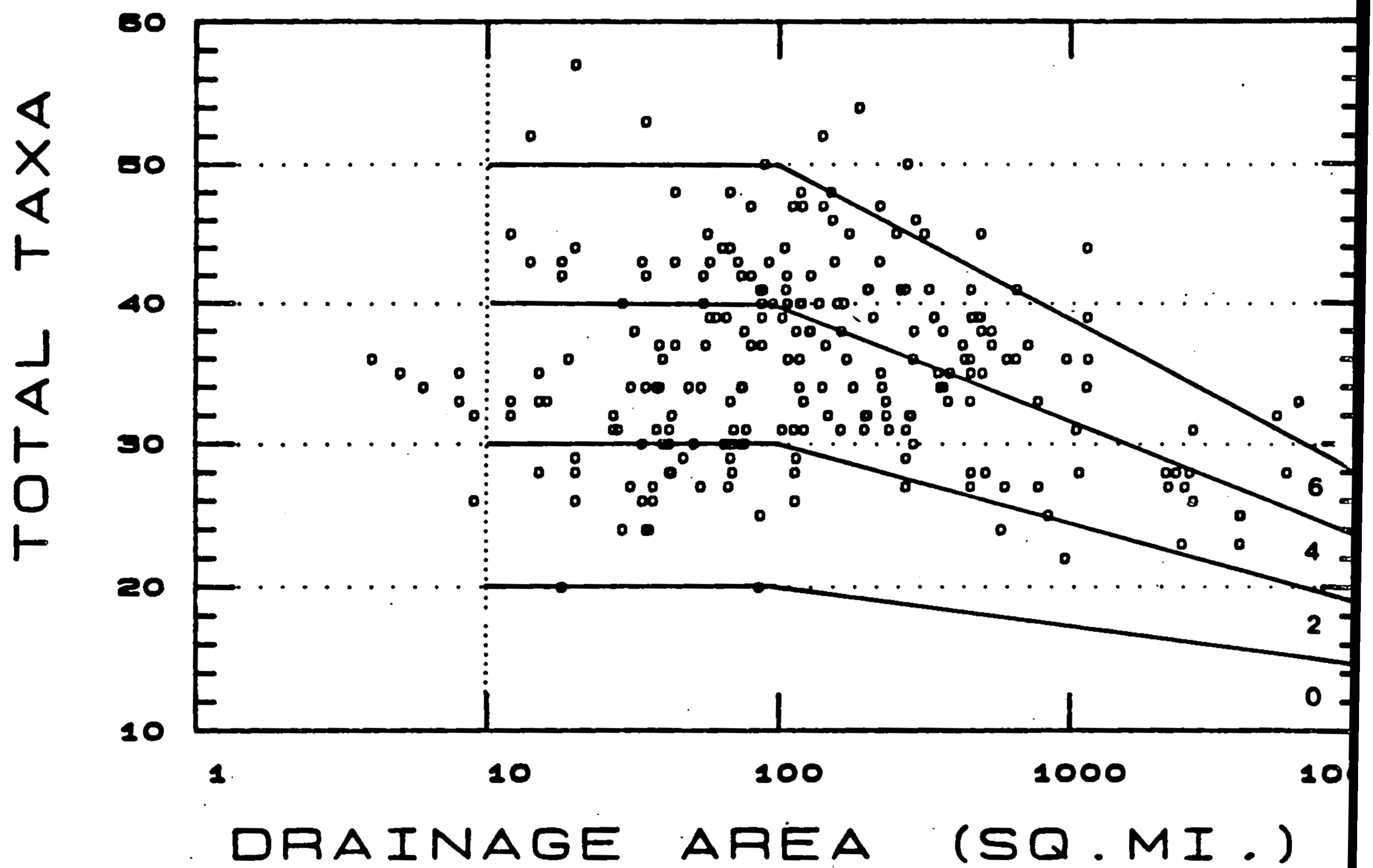

Figure 5-1. Total macroinvertebrate taxa vs. drainage area using the quadrisect method for determining 6,4,2, and 0 ICI scoring (Inverse relationship with drainage areas >100 sq.miles.).

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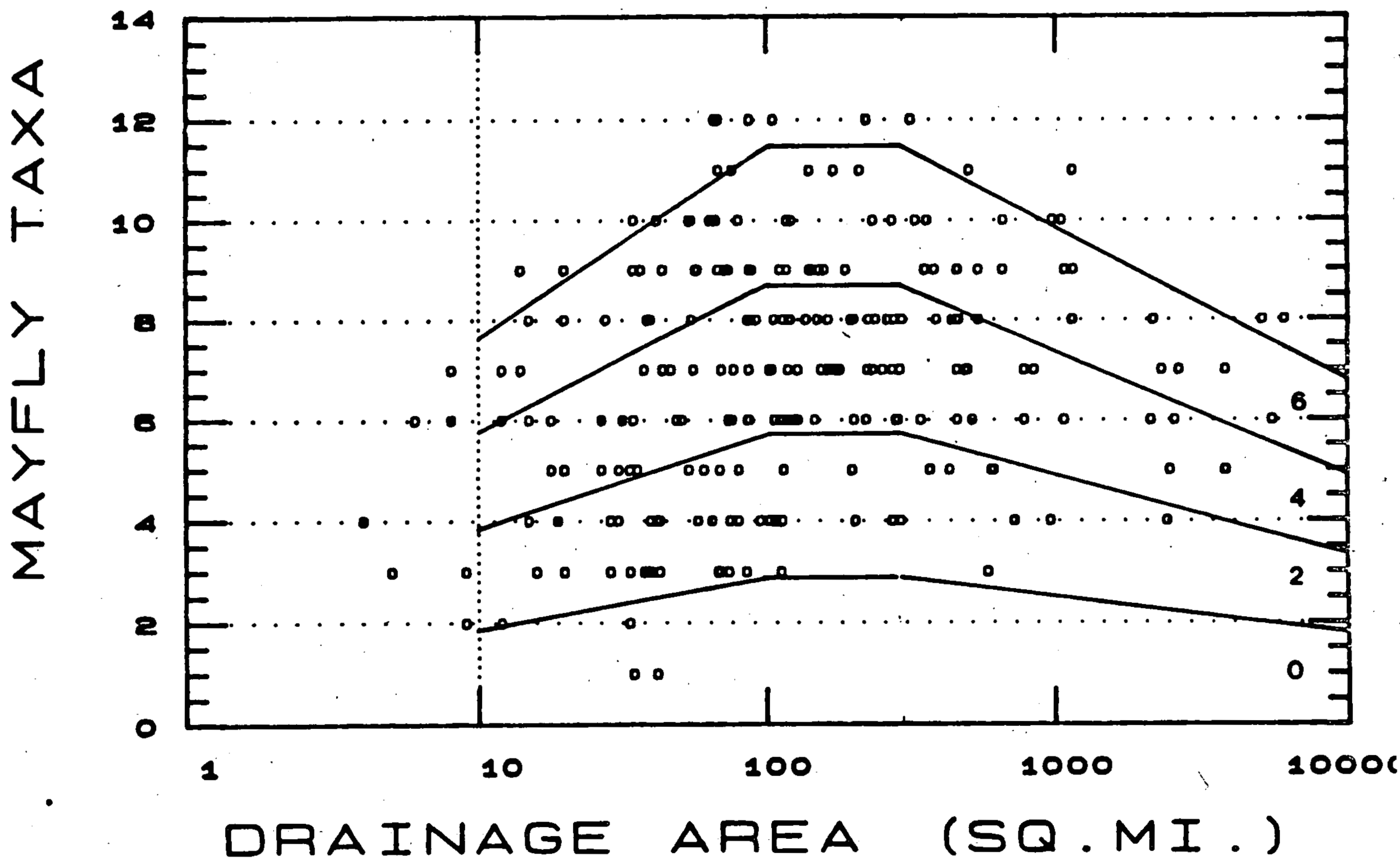

Figure 5-2. Total mayfly taxa vs. drainage area using the quadrisect method for determining the 6,4,2, and 0 ICI scoring (Direct relationship with drainage areas <100 sq. miles; inverse relationship with drainage areas >300 sq. miles.).

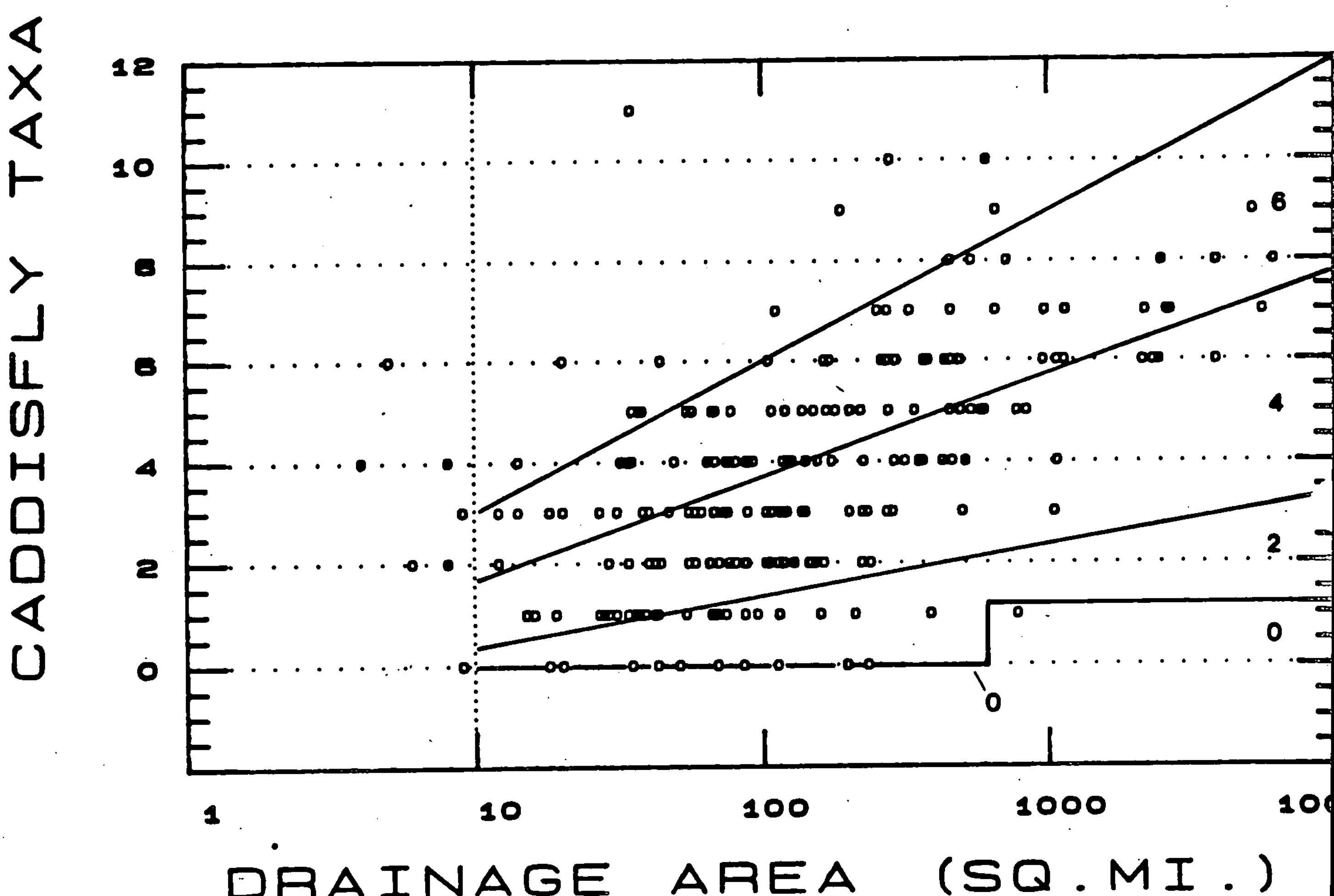

Figure 5-3. Total caddisfly taxa vs. drainage area using a quadripartite method for determining 6,4,2, and 0 ICI scoring (Direct relationship with drainage area; zero scoring for zero taxa for drainage areas <600 sq. miles; zero scoring for ≤1 taxa for drainage areas >600 sq. miles.).

drainages greater than 600 square miles, at least two taxa must be present to score other than zero.

Metric 4. Number of Dipteran Taxa

Of all major aquatic invertebrate groups, dipterans, especially midges of the family Chironomidae, have the greatest faunal diversity and display the greatest range of pollutional tolerances. They are usually the major component of an invertebrate collection using Ohio EPA methodology and, under heavy pollutional stress, can often be the only insect collected and, at the same time, be the predominant macroinvertebrate group. Larval taxonomy has improved greatly for the group and clear patterns of organism assemblages have become distinct under water quality conditions ranging from the pristine to the heavily organic and toxic. The fact that they do not usually disappear under severe pollutional stress makes them especially valuable in evaluating water quality. The distribution of dipteran taxa vs. drainage area is shown in Figure 5-4. A clear, inverse relationship with larger drainages (>100 sq miles) is apparent. In the larger rivers, there is a tendency towards increased populations of fewer dipteran taxa. This is probably the result of abundant food supplies but fewer functional feeding groups as habitat conditions become more monotonous.

Metric 5. Percent Mayflies

As with number of mayfly taxa, the percent abundance of mayflies in a sample can react stongly and rapidly to often minor environmental disturbances. Though much more reference site variability exists in this metric compared with the taxa metric, there is a strong relationship with water quality. As can be seen by Figure 5-5, the range of abundances in the relatively unimpacted reference site database varies from near zero to greater than 80 percent. However, data from slightly degraded (fair) and severely degraded (poor) stream communities in Ohio indicate that mayfly abundance is reduced considerably under slight impact and is essentially nonexistant under severe impact. Thus, it was felt that even a few mayflies in low abundance should score at least minimally. Therefore, only those samples with no mayflies will score zero for the metric. Scoring categories also reflect the observation that no relationship exists with drainage area.

Metric 6. Percent Caddisflies

As with number of caddisfly taxa, percent abundance of caddisflies is strongly related to stream size (Figure 5-6). Again, optimal habitat and availability of appropriate food type seem to be the main considerations for large populations of caddisflies. As can be seen in the figure, the caddisflies can make up a significant portion of the macroinvertebrate community, often exceeding 25 percent of the organisms collected. However, they are just as likely to be found in quite low numbers, at times less than 1 percent. Because of their general position as an intermediately pollution tolerant group between the mayflies and dipterans and because they disappear rapidly under environmental stress, zero scores are restricted to those sites less

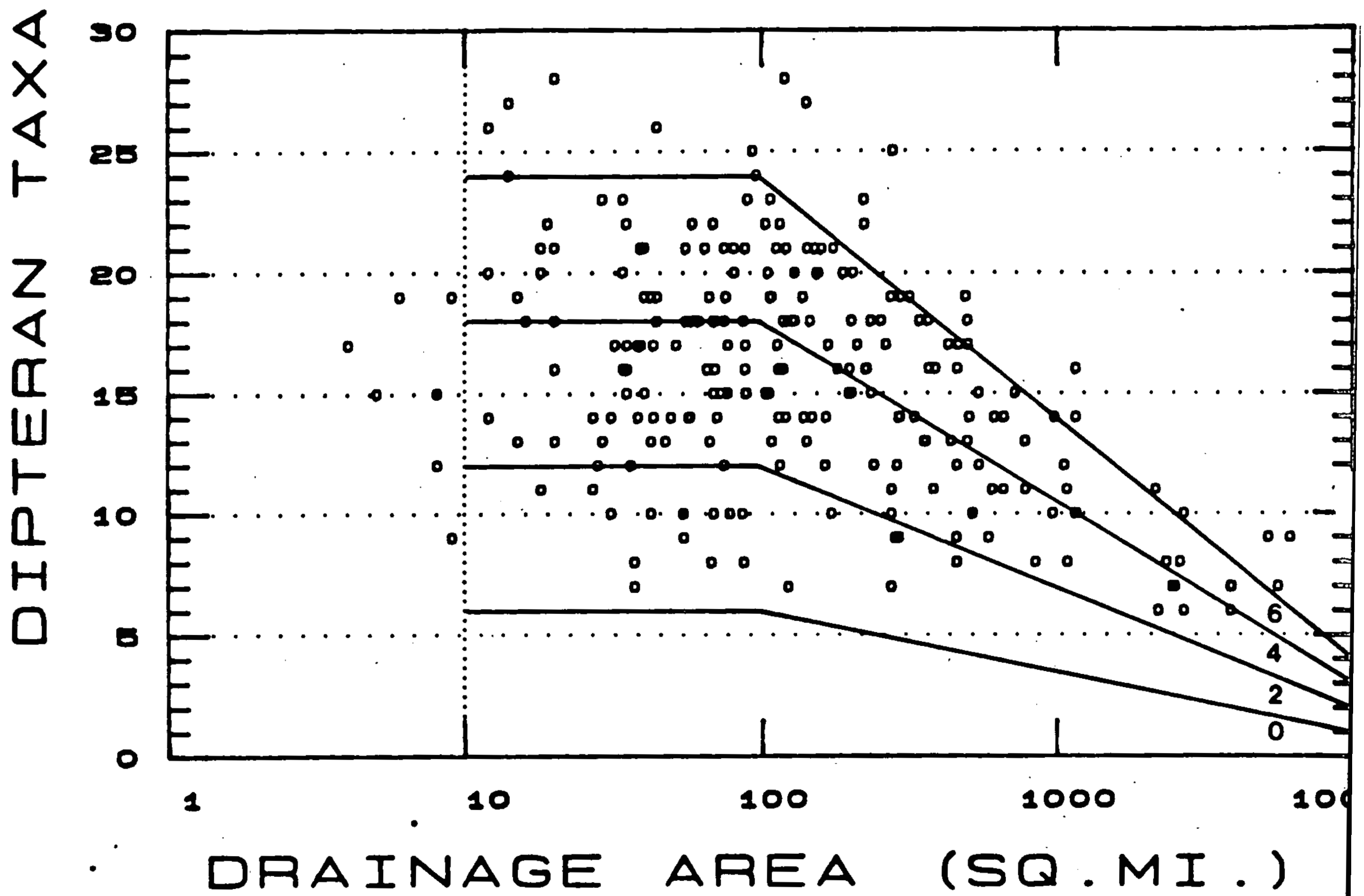

Figure 5-4. Total dipteran taxa vs. drainage area using the quadrisect method for determining 6,4,2, and 0 ICI scoring (Inverse relationship with drainage areas >100 sq. miles.).

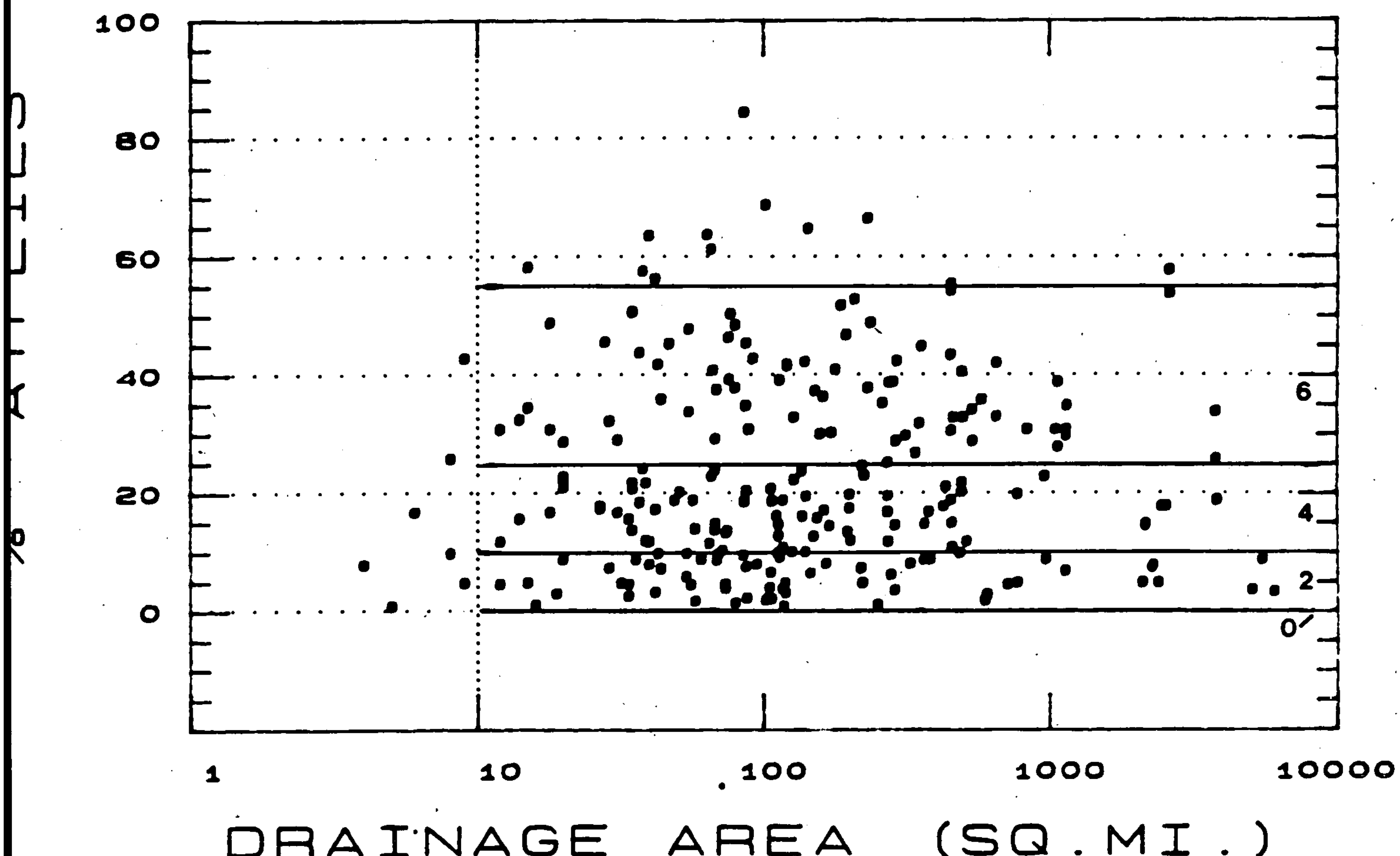

Figure 5-5. Percent abundance of mayflies vs. drainage area using a quadripartite method for determining 6,4,2, and 0 ICI scoring (No relationship with drainage area; zero scoring for zero mayflies.).

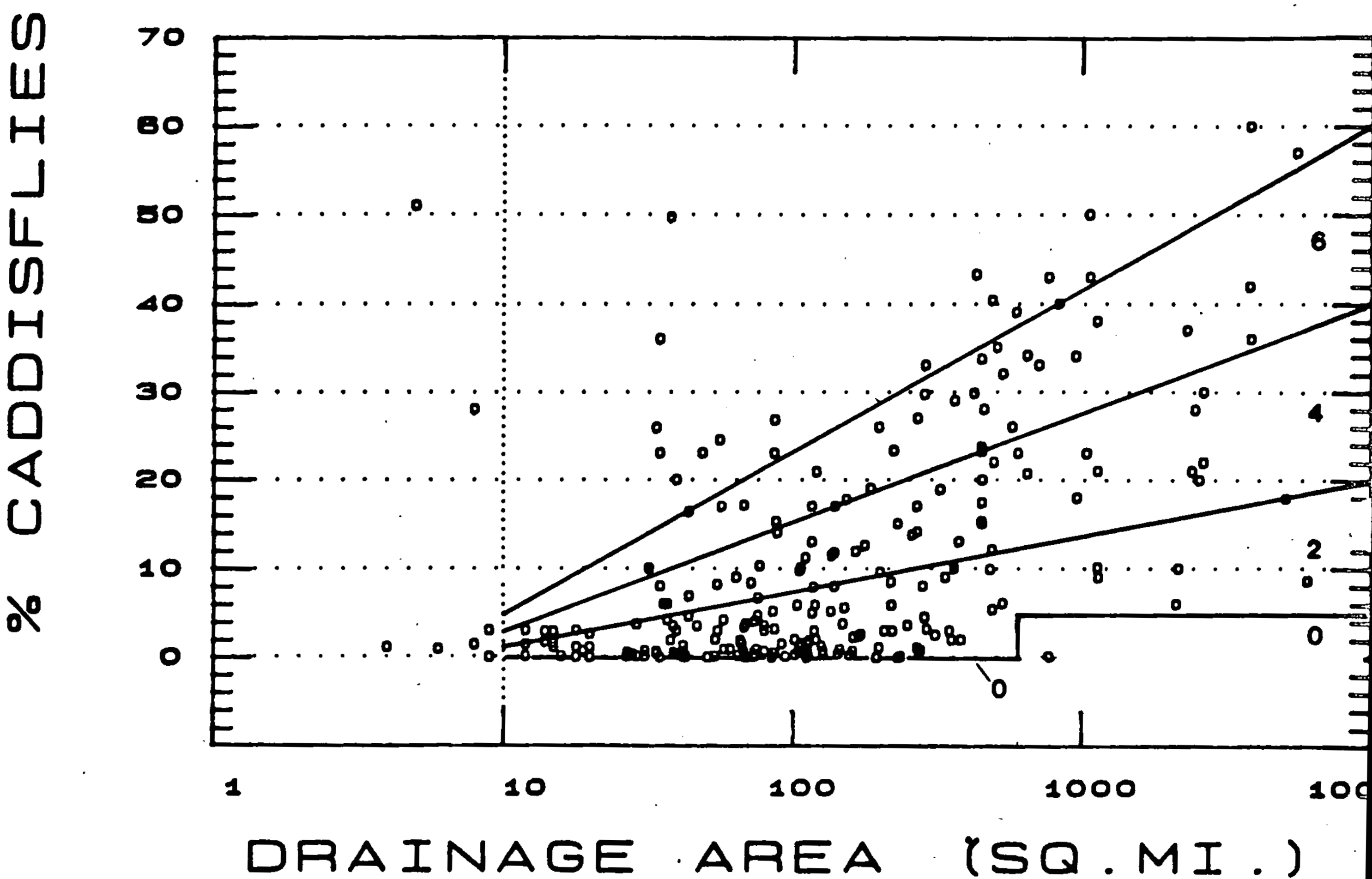

Figure 5-6. Percent abundance of caddisflies vs. drainage area using a quadripartite method for determining 6,4,2, and 0 ICI scoring (Direct relationship with drainage area; zero scoring for zero caddisflies for drainage areas <600 sq. miles; zero scoring for minimal percent abundance for drainage areas >600 sq. miles.).

than 600 square miles where no caddisflies are collected. At sites greater than 600 square miles, it is felt that appropriate habitat conditions are much more likely to exist and, therefore, caddisflies should be present in at least minimal numbers to score greater than zero.

Metric 7. Percent Tanytarsini Midges

The tanytarsini midges are a tribe of the chironomid subfamily Chironominae. The larvae are generally burrowers or clingers, and many species build cases out of sand, silt, and/or detritus. Many species feed on microorganisms and detritus through filtering and gathering though a few are scrapers. Eleven genera and up to 140 species occur in North America, although only 8 genera and 21 distinct taxa have been collected in Ohio. In the relatively unimpacted Ohio reference sites, they are most often the predominant midge group, often exceeding 50 percent of the total number of organisms collected. They also appear to be relatively pollution sensitive and often disappear or decline under even minor pollutional stress. As can be seen in Figure 5-7, there is apparently no drainage area effect on their abundance. Because of their relative intolerance to environmental disturbance, zero scores only occur when no tanytarsini midges are present.

Metric 8. Percent Other Diptera and Non-Insects

This metric includes the community percentage of all dipterans (excluding the midge tribe Tanytarsini) and other non-insect invertebrates such as aquatic worms, flatworms, scuds, aquatic sow bugs, freshwater hydras, and snails. This metric is one of two negative metrics of the ICI. Taxa in these groups of macroinvertebrates, though often present as part of a healthy stream community, are those that generally tend to become predominant under adverse water quality conditions. In many cases, even under minor influences, these organisms will comprise over 90 percent of the individuals collected in an invertebrate sample. Figure 5-8 depicts the distribution of reference site data for the metric. As indicted, reference site percentages are inversely related to stream size. However, this relationship does not seem to hold for impacted situations; under these circumstances, other dipterans and non-insects usually predominate as a high percentage regardless of stream size. In cases where conditions are so severe that no organisms are collected (in effect, 0 percent other dipterans and non-insects), the metric should score a zero.

Metric 9. Percent Tolerant Organisms

Values for this metric are generated using the list of organisms provided in Table 5-2. The list includes those organisms in Ohio that appear to be extremely pollution tolerant <u>and</u> tend to predominate in cases of severe perturbation. The list includes organisms tolerant to organic degradation as well as some Ohio taxa found to resist toxic impact, so the metric should be a reasonable measurement of community tolerance under both types of degradation. This is a desirable difference over other established measurements of community tolerance (i.e. Hilsenhoff's BI) that were developed

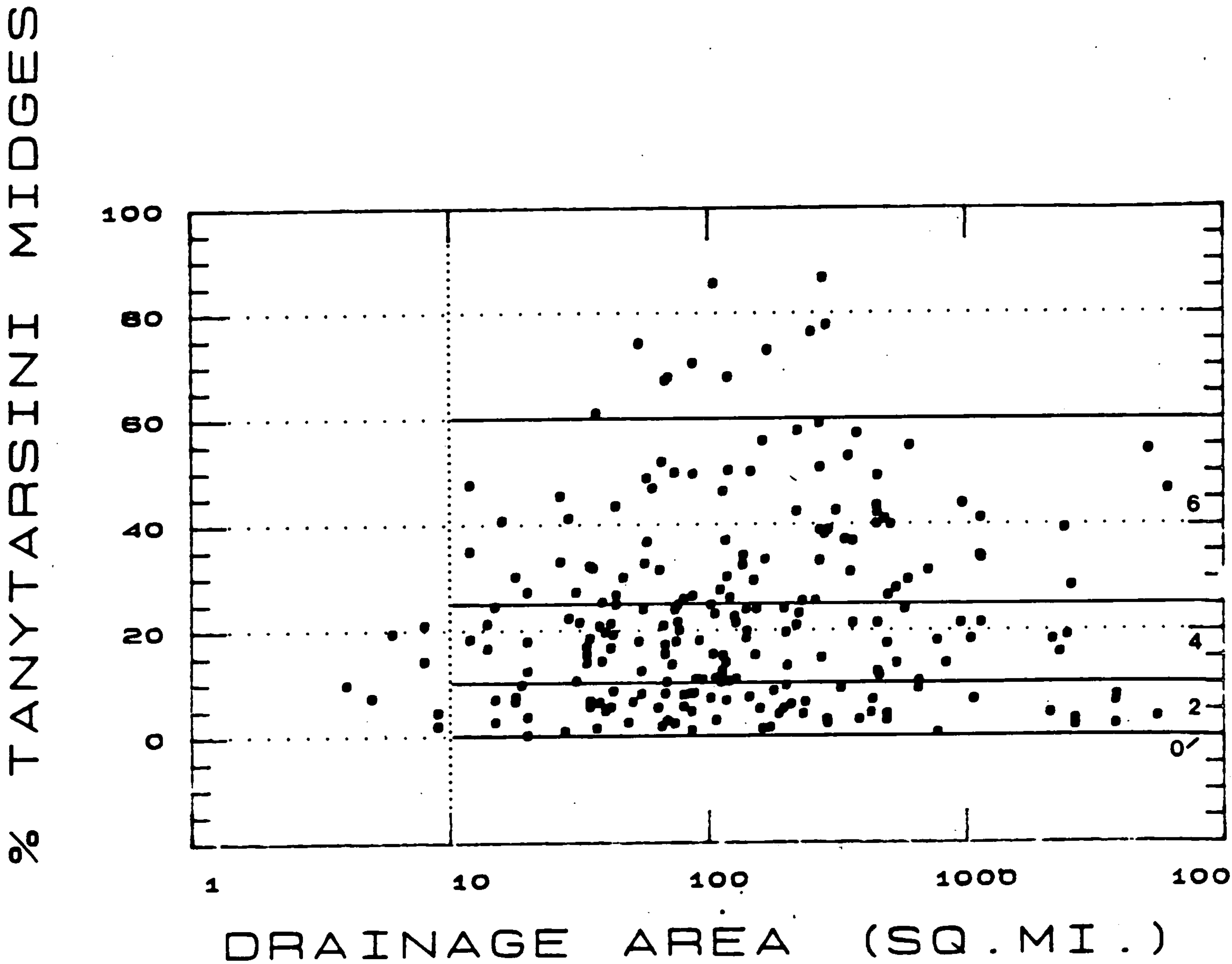

Figure 5-7. Percent abundance of tanytarsini midges vs. drainage area using a quadripartite method for determining 6,4,2, and 0 ICI scoring (No relationship with drainage area; zero scoring for zero tanytarsini midges.).

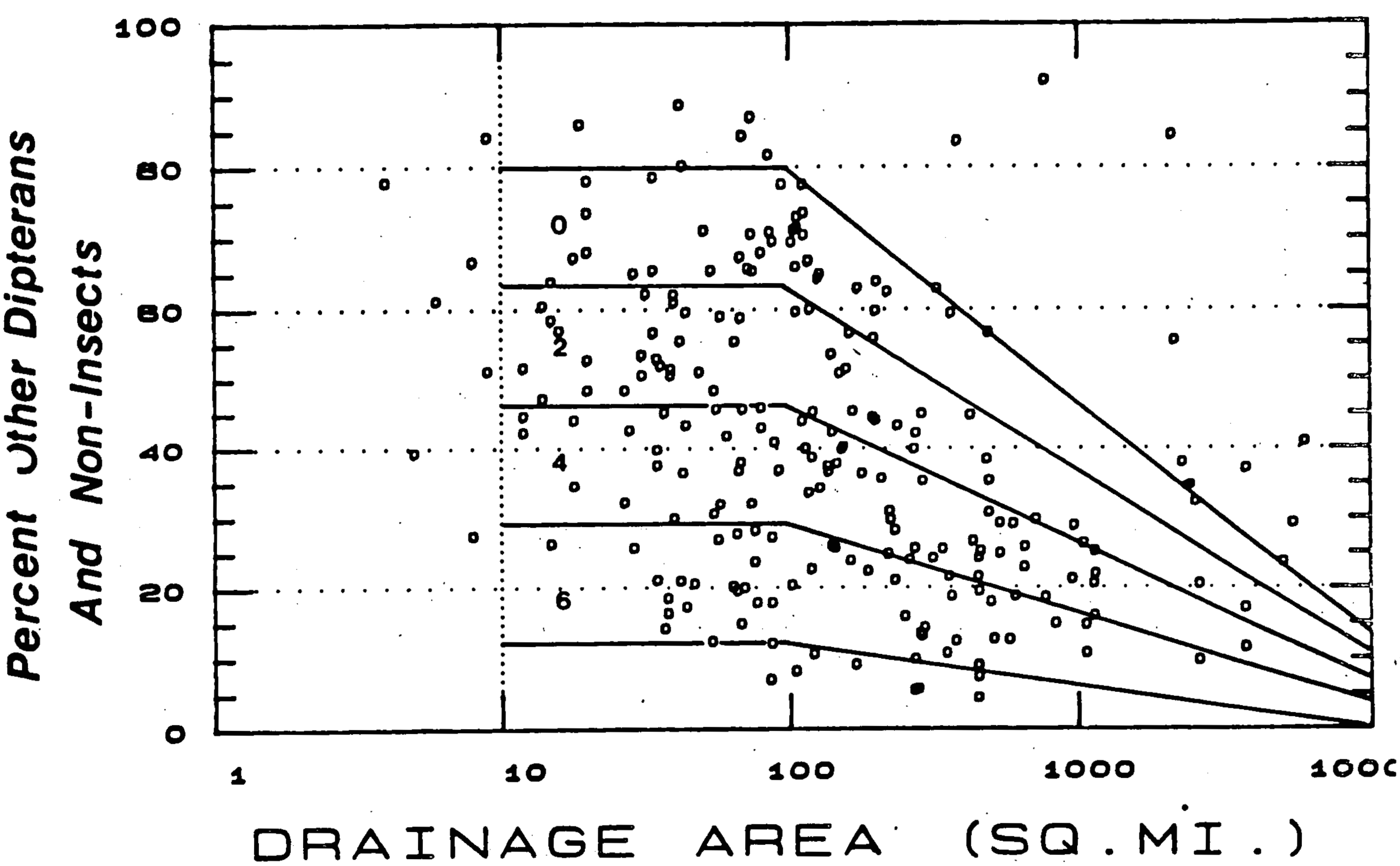

Figure 5-8. Percent abundance of dipterans (excluding tanytarsini midges) and non-insects vs. drainage area using the quadrisect method for determining 6,4,2, and 0 ICI scoring (Inverse relationship with drainage areas >100 sq. miles.).

Table 5-2. List of pollution tolerant organisms used to determine Metric 9 of the Invertebrate Community Index.

Common Name	Scientific Name
Aquatic segmented worms	Annelida: Oligochaeta
Midges	Diptera: Psectrotanypus dyari
	Cricotopus (C.) bicinctus
	Cricotopus (Isocladius) sylvestris group
	Nanocladius (N.) distinctus
	Chironomus (C.) spp.
	Dicrotendipes simpsoni
	Glyptotendipes prob. barbipes
	Parachironomus hirtalatus
	Polypedilum (P.) fallax group
	Polypedilum (P.) illinoense
Limpets	Mollusca: Ferrissia spp.
Pond snails	Physella spp.

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to reflect one type of pollution or the other. Like Metric 8, this is a negative metric and, as such, complete absence of organisms in a sample should score a zero for the metric. Figure 5-9 depicts the reference site tolerant organism percentages vs. drainage area. A strong inverse relationship with drainage area exists. For drainages greater than 1000 square miles, the percent of tolerant organisms found at reference sites becomes so low that the scoring categories are quite restrictive. In fact, at a number of the reference sites, none or less than 1 percent of these organisms were present. However, as with Metric 8, drainage area tends to have little effect when pollutional disturbances are prevalent. Sites with minor or severe degradation can have large populations of these organisms regardless of stream size.

Metric 10. Qualitative EPT Taxa

This metric is the one ICI metric that is generated by the qualitative sample taken in conjunction with the artificial substrate sampling. Since the qualitative sampling utilizes a substrate dependent method, that is, a method affected by the kinds of natural substrates available in the sampling area, the metric is a measurement of habitat quality as well as of habitat types other than the run habitat where artificial substrate sampling occurs. The metric consists of the taxa richness of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). Since stoneflies are relatively uncommon in summer collections in Ohio, the metric is mostly dependent on the kinds of mayflies and caddisflies found. The depiction of qualitative EPT taxa vs. drainage area (Figure 5-10) reflects a trend similar to Metric 2, the number of mayfly taxa. Again, it is thought that this trend is a result of greater habitat and food type variety in the intermediate sized streams transitional between small streams and large rivers.

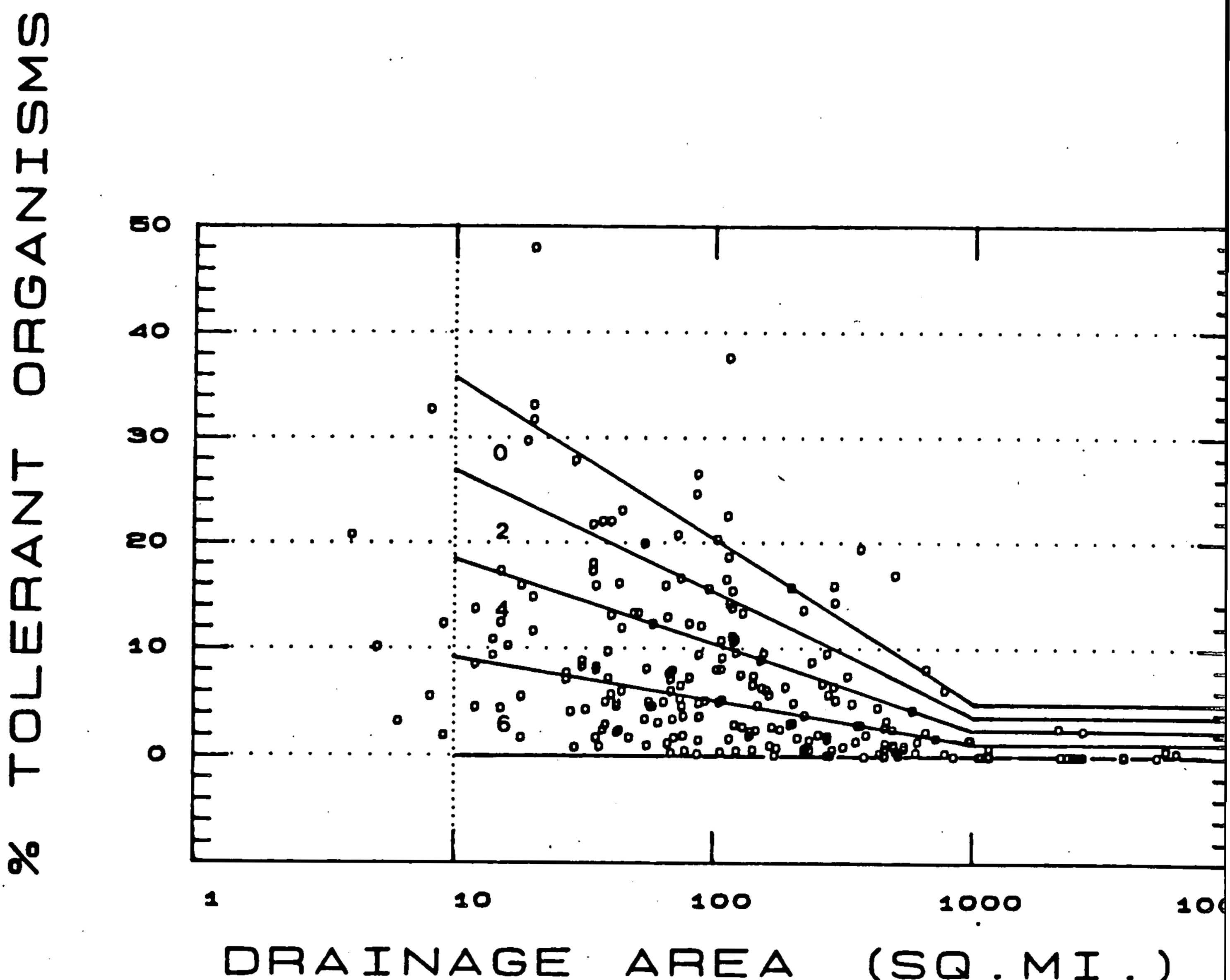

Figure 5-9. Percent abundance of pollution tolerant organisms vs. drainage area using the quadrisect method for determining 6,4,2, and 0 ICI scoring (Inverse relationship with drainage areas <1000 sq. miles.).

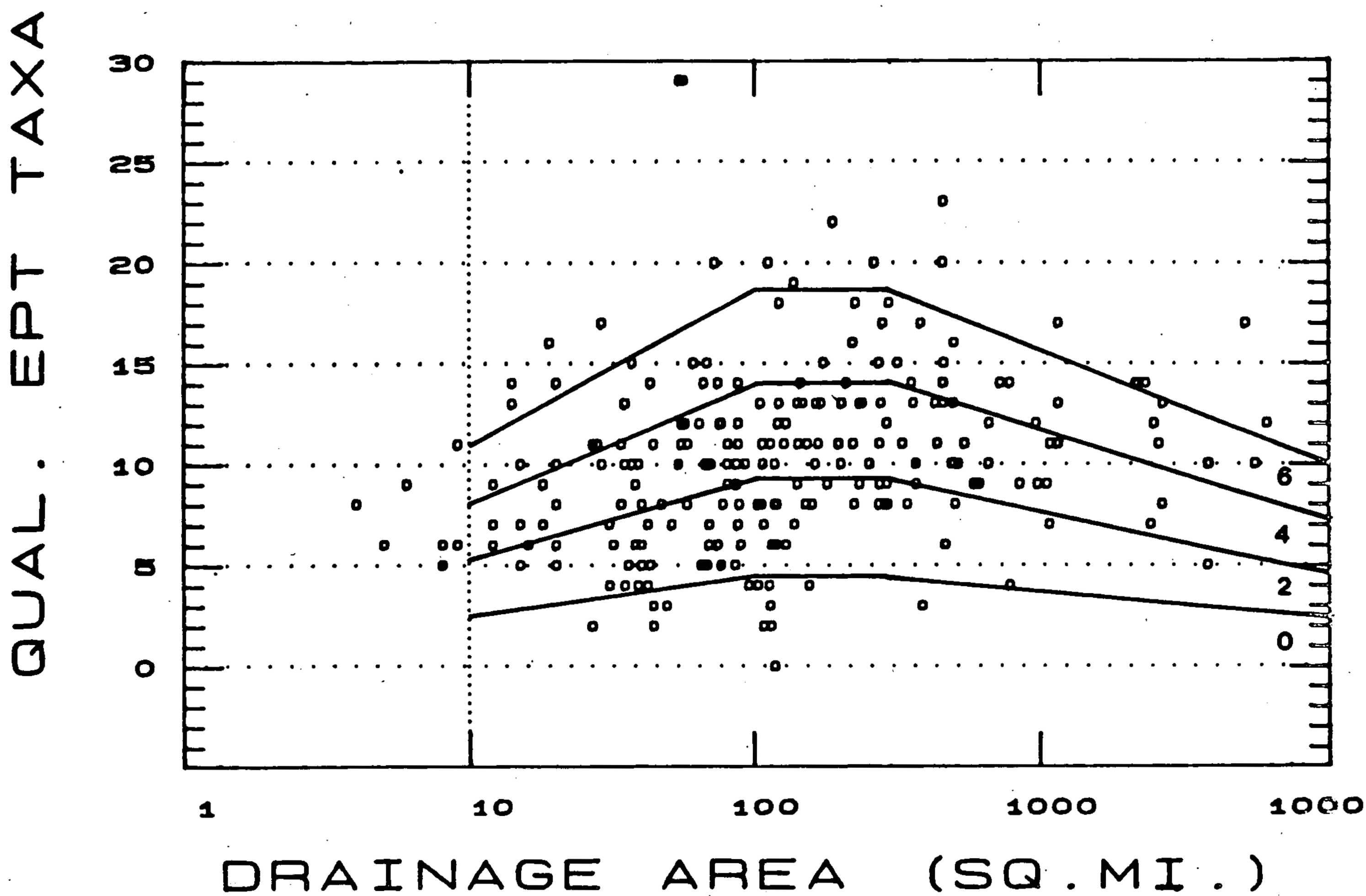

Figure 5-10. Total number of qualitative EPT taxa vs. drainage area using the quadrisect method for determining 6,4,2, and 0 ICI scoring (Direct relationship with drainage areas <100 sq. miles; inverse relationship with drainage areas >300 sq. miles.).

SECTION 6: DERIVATION OF BIOLOGICAL CRITERIA

General

The derivation of biological criteria for Ohio surface waters is essentially based on a knowledge of what biological community performance can be attained at reference sites selected according to the Stream Regionalization Project (SRP) study design (Whittier et al. 1987). This is consistent with the definition of biotic integrity as discussed by Karr and Dudley (1981), Hughes et al. (1982), Karr et al. (1986), and Ohio EPA (1987b). The biological criteria represent the ecological structure and function that can reasonably be attained given present-day background conditions (Whittier et al. 1987). Thus, these criteria are not an attempt to define "pristine", pre-Columbian conditions. This does not preclude the possibility that future changes to the criteria could take place with changes in population, urbanization, and/or land use practices that are observed to result in improved biological community performance.

Biological data from the reference sites were used to establish regional criteria (where appropriate) for the IBI, modified I_{wb}, and ICI. A notched box-and-whisker plot method was used to portray the results for each biological index by ecoregion. These plots contain sample size, medians, ranges with outliers, and 25th and 75th percentiles. Box plots have one important advantage over the use of means and standard deviations (or standard errors) because they do not assume a particular distribution of the data. Furthermore, outliers (i.e. points that are two interquartile ranges beyond the 25th or 75th percentiles) do not exert an undue influence as they can in the derivation of means and standard errors.

Ecoregional criteria for the Warmwater Habitat (WWH) use designation are established as the 25th percentile value of the reference sites for each ecoregion. The Exceptional Warmwater Habitat (EWH) criteria are based on a combination of the entire statewide reference site data set (by method) and are set at the 75th percentile value. Both WWH and EWH are defined in the Ohio Water Quality Standards (WQS; Ohio Administrative Code Chapter 3745-1) and reflect attainment of the "fishable/swimmable" goals of the Water Quality Act of 1987. For example, when all sites sampled for fish during 1979-1986 are considered the WWH criteria (using a modified I_{wb} benchmark of 8.5 for WWH) represents the upper 13-17% of the modified I_{wb} values recorded during that period (Fig. 6-1). The EWH criteria (using a modified I_{wb} benchmark of 9.5 for EWH) represent the upper 3-6%. Choosing the 25th percentile excludes those reference sites that were initially selected based on general watershed characteristics, but which did not perform up to our expectations due to influences that only the resident biota could discern given the scope of the investigation. It also excludes sites which were initially thought to be marginal (i.e. HELP ecoregion), but which were retained to provide a sufficient sample size to examine for ecoregional differences. In this sense choosing the 25th percentile as the minimum WQS WWH criterion is environmentally conservative and virtually eliminates any bias induced by including marginal sites. This relatively low percentile value was chosen because the reference sites used to construct the reference site database were carefully selected as "least impacted" sites. This clearly is not a random sample of sites within each ecoregion, but is biased towards the watersheds

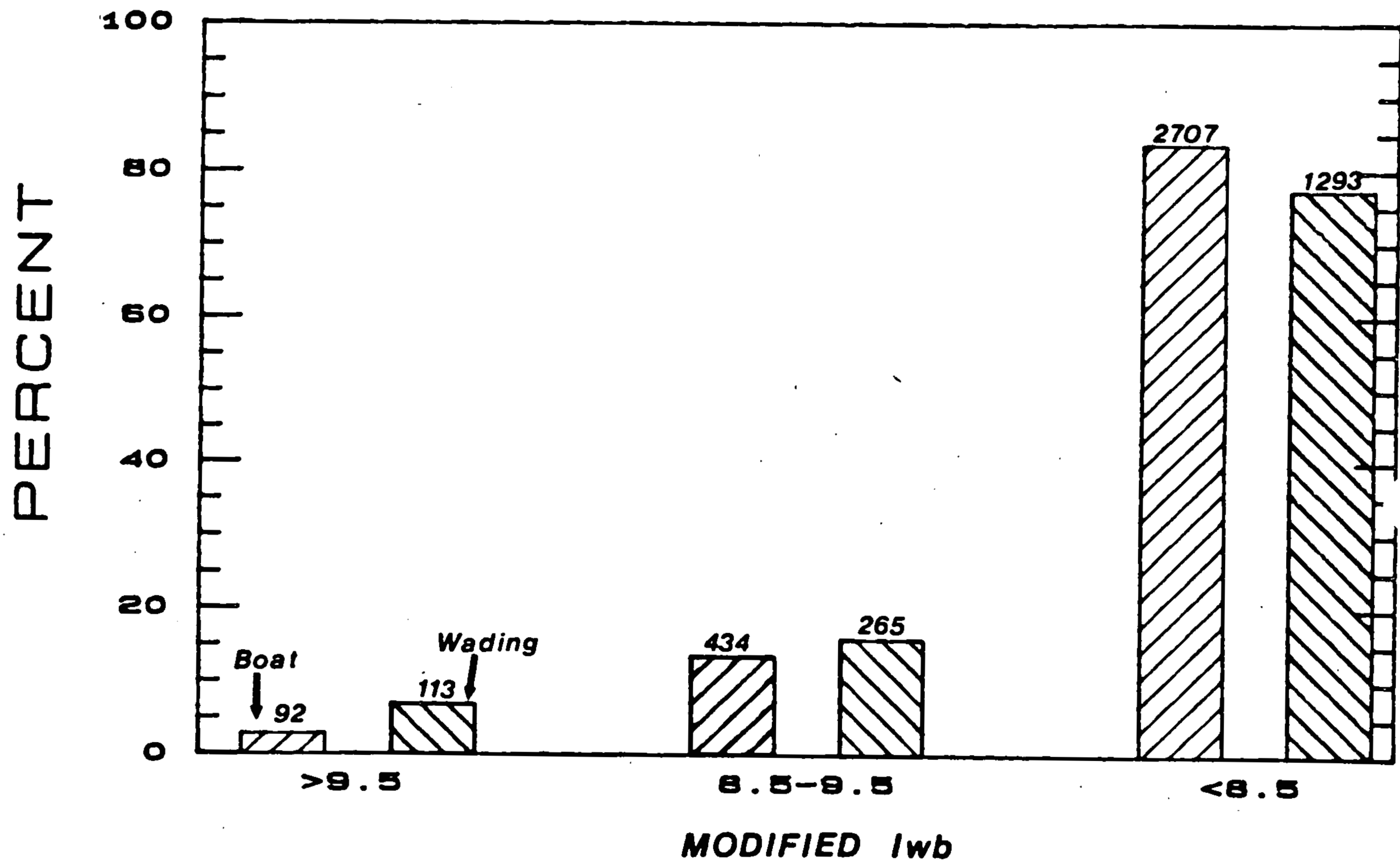

Figure 6-1. Percentage of electrofishing samples (boat and wading results) that occur in three ranges of the modified I_{wb} based on collections during 1979-1986. Modified I_{wb} values of $\geq$9.5 approximates EWH attainment, 8.5-9.5 approximates WWH attainment, and <8.5 reflects non-attainment of WQS (sample size appears above each bar).

Table 6-1. Fish community characteristics of sites that attain Exceptional Warmwater Habitat (EWH) and Warmwater Habitat (WWH) in the Ohio reference site database compared to sites that do not attain WWH based on a set of impacted sites used to establish low-end scoring criteria.

Classification (no. samples)	Mean Iwb (IQR)	Mean IBI (IQR)	Intol. Species	%Omni-vores	%Tol. Spec.	%Round Suckers	%Top Carn.	Darter Species	Total Species
Wading Methods:									
EWH (40)[1]	10.0 (9.7-10.3)	53 (50-58)	6	12	15	13	4.8	6	30
WWH (66)[2]	9.0 (8.7-9.2)	44 (42-48)	3	18	27	7	4.4	5	24
Impacted(45)	3.7 (3.0-4.5)	20 (16-24)	0	33	85	0.5	2.1	0	9
Boat Methods:									
EWH (15)[1]	9.9 (9.6-10.2)	52 (50-54)	4	16	10	37	10.4	3	27
WWH (55)[2]	9.0 (8.8-9.3)	44 (42-46)	2	21	12	29	12.1	1	21
Impacted(82)	3.5 (1.9-4.8)	18 (16-20)	0	60	57	4	3.1	0	5

IQR - Interquartile Range.

1 for purposes of illustration, EWH criteria: IBI $\geq$50 and Iwb $\geq$9.5.
2 for purposes of illustration, WWH criteria: IBI $\geq$40, <50 and Iwb $\geq$8.5, <9.5.

with the least influence from human activities. The EWH criteria (upper 25% of all reference sites) appropriately reflects the EWH definition in the Ohio WQS and is applied evenly across the state. Streams and rivers designated EWH are characterized by an above average abundance of sensitive macroinvertebrate taxa and fish species (intolerant plus moderately intolerant species), and in larger streams, top carnivores (e.g. smallmouth bass). EWH waters are also generally characterized by more intolerant and fewer tolerant species than other streams (Tables 6-1 and 6-4) and generally provide habitat for unique species assemblages (i.e. species listed as rare, endangered, and threatened).

At least two factors used in setting the WWH and EWH criteria offer additional protection against the potential influence of a less than optimum initial selection of reference sites. IBI and ICI are based on a trisection and quadrisection procedure, respectively (see Section 4), which focuses on a line of maximum value (i.e. 95% line). Thus the influence of sites with metric values that are low for one reason or another is negligible because this method is weighted in favor of the sites with higher values. Secondly, choosing the 25th percentile of the reference site results for each index eliminates values that were low because of factors which the resident biota could discern, but to which the initial reference site selection procedure was not sufficiently sensitive. Together these ensure that the criteria are consistent with the goals of the Water Quality Act and protective of their designated uses.

Variations in the ecological criteria between ecoregions are related to general habitat and biogeographical differences that are linked to the particular features (soils, vegetation, land form, land use) that characterize each ecoregion. Thus the influence of these factors are eventually accounted for in the derivation of the biological criteria on an ecoregional basis.

Fish Community Data

Wading Sites

The notched box-and-whisker plot for the IBI and the modified I_{wb} using data from 113 wading sites (generally sites with drainage areas less than 300 sq. mi., but > 20 sq. mi.) is presented in Figs. 6-2 and 6-3. The notch in the box-and-whisker plot corresponds to the width of a confidence interval for the median. The confidence level on the notches is set to allow pairwise comparisons to be performed at the 95% level by examining whether two notches overlap. Strong ecoregional differences are evident in the IBI between the Huron/Erie Lake Plain (HELP), Western Allegheny Plateau (WAP), and the remaining 3 ecoregions. The modified I_{wb} was lowest in the HELP ecoregion, followed by the EOLP, and highest in the remaining three ecoregions. The mean (±SE), median, minimum and maximum range, and quartile values for the IBI and I_{wb} for each of the five ecoregions and statewide combined are given in Table 6-2. The IBI values reported here differ somewhat from those reported by Whittier et al. (1987). This is due to later refinements in the IBI by Ohio EPA and the use of a larger data base to establish the ecoregional criteria.

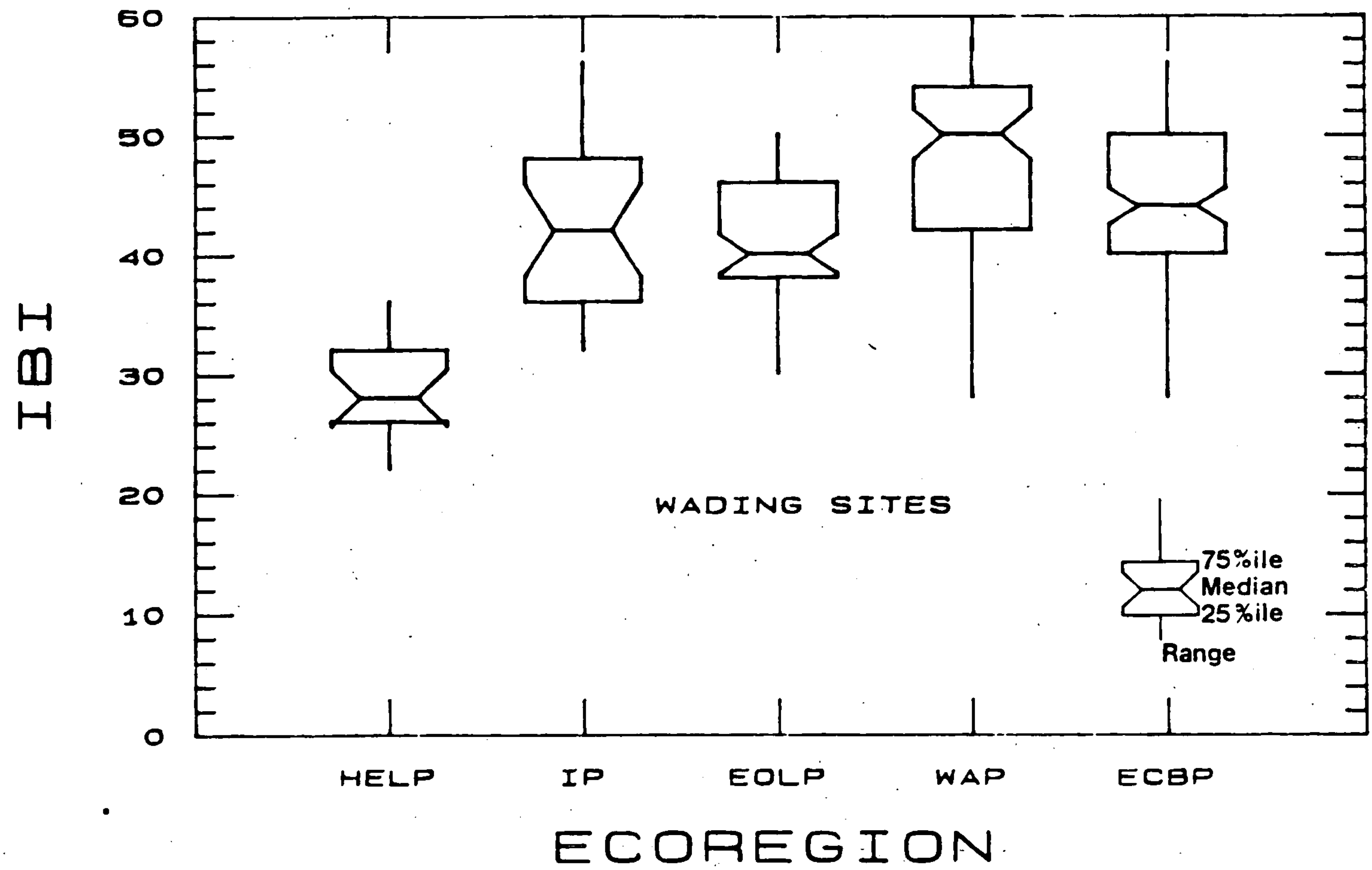

Figure 6-2. Notched box-and-whisker plot of Ohio reference site results for the Index of Biotic Integrity (Wading sites) showing maximum, minimum, median, and upper (75%) and lower (25%) quartile ranges. Notch overlap between regions indicates that the median values are not significantly different (P<0.05).

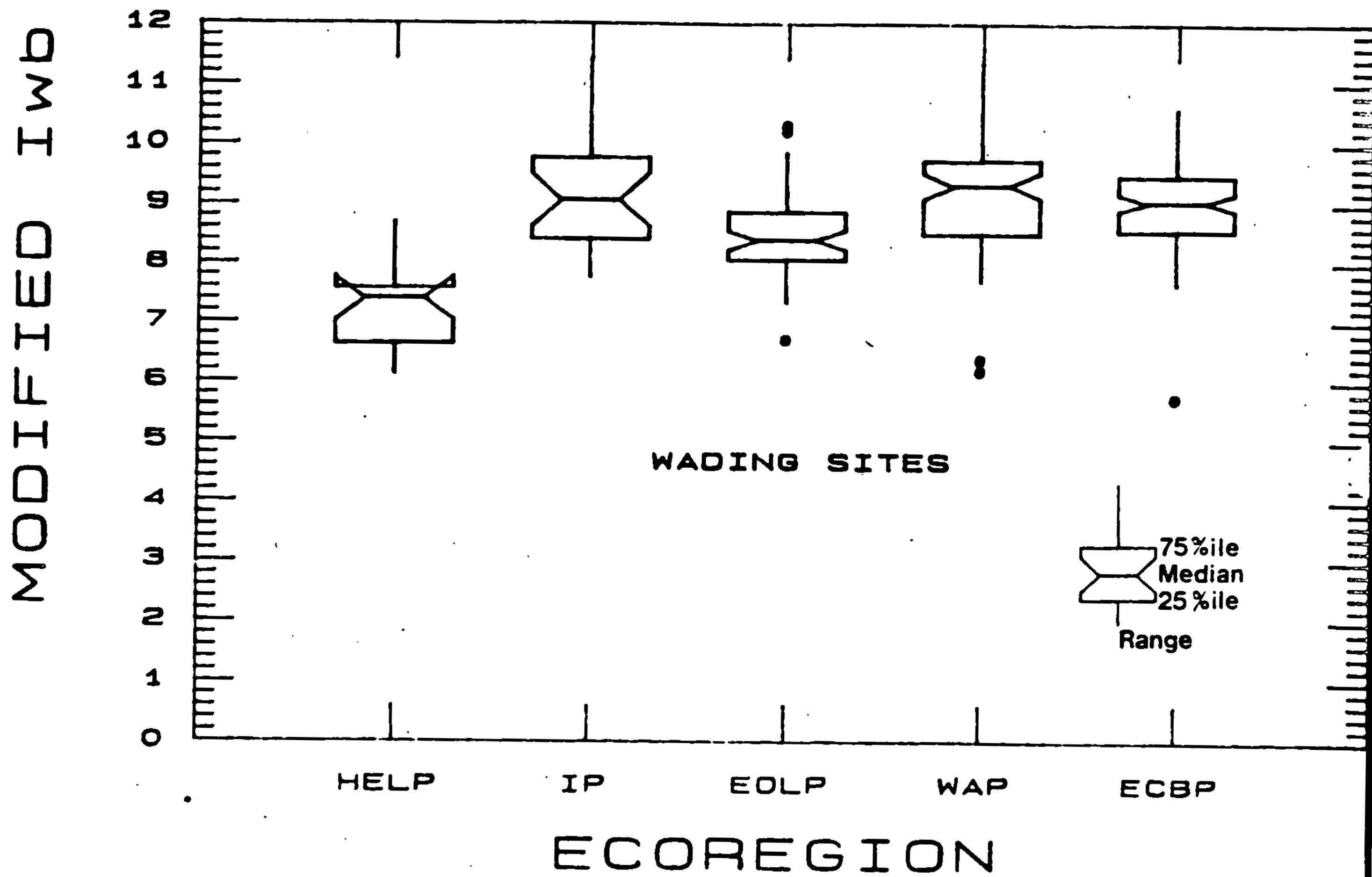

Figure 6-3. Notched box-and-whisker plot of Ohio reference site results for the Modified Index of Well-Being (Wading sites) showing maximum, minimum, outliers, median, and upper (75%) and lower (25%) quartile ranges. Notch overlap between regions indicates that the median values are not significantly different (P<0.05).

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Boat Sites

Examination of the boat sites data base (75 sites) showed less pronounced differences between the ecoregions than that shown for the wading sites for both the IBI and the modified I_{wb} (Figs. 6-4 and 6-5). For IBI the highest interquartile values occured in the Eastern Corn Belt Plains (ECBP) with the lowest values in the Huron/Erie Lake Plain (HELP) ecoregion. The modified I_{wb} showed a different pattern with the Erie/Ontario Lake Plain (EOLP) ecoregion having the lowest interquartile values. The overall results were comparatively similar. The differences between ecoregions for both the IBI and modified I_{wb} were less pronounced in comparison to that shown with the wading sites. This seems reasonable in that larger stream and river systems extend between and through adjacent ecoregions and tend to "dampen out" some of the sub-watershed specific characteristics apparent with the streams that are entirely located within one ecoregion. The ecoregional and statewide summary is given in Table 6-2.

Headwaters Sites

The Headwaters version of the IBI was used to evaluate fish community data for 70 headwaters sites (drainage areas <20 square miles). The notched box-and-whisker plot for the IBI (modified for headwaters sites) using data from the 70 reference sites is presented in Fig. 6-6. Ecoregional differences are evident for the IBI between the Huron/Erie Lake Plain (HELP) and the remaining 4 ecoregions. The range between the 25th and 75th percentile values was relatively large in the Interior Plateau (IP) and Western Allegheny Plateau (WAP) compared to the other ecoregions. The ecoregional and statewide summary data are given in Table 6-2.

It is not appropriate to use the modified I_{wb} to evaluate Headwaters Sites. This is because of the very strong influence of drainage area on the I_{wb} and the marked change in scale of the I_{wb} at these sites. This is due in large part to the character of the fish fauna at headwaters sites. Large fish that contribute to the biomass component of the I_{wb} in the larger streams and rivers are either reduced in abundance or generally absent from these areas. Also, species richness is very much affected by drainage area which accounts for part of the effect of this factor on the I_{wb} itself.

<u>Habitat Considerations</u>

Macro-habitat for fish was evaluated using the Qualitative Habitat Evaluation Index (QHEI) which was developed by Ohio EPA (Ohio EPA 1987a). This index is based on the following macro-habitat characteristics: substrate type, amount and type of instream cover, channel morphology development and stability, riparian zone width and composition, pool and riffle-run quality, gradient, and drainage area. The QHEI scores for each site type by ecoregion are presented along with the biological index results in Table 6-2. Ecoregion quartiles, means, and medians are remarkably similar among all except the HELP ecoregion where scores are markedly lower. The 75th percentile QHEI for the HELP is lower than the 25th percentile QHEI in the other four ecoregions at wading sites. Only a slight overlap exists for the headwaters sites and no

Table 6-2. Summary ecological and drainage area characteristics of the reference sites used to establish attainable ecological criteria for Ohio's rivers and streams based on the IBI and modified Iwb.

	Ecoregion					
	Huron/Erie Lake Plains (HELP)	Interior Plateau (IP)	Erie/Ont. Lake Plains (EOLP)	W. Allegheny Plateau (WAP)	E. Corn Belt Plains (ECBP)	Statewide (all sites combined)
I. FISH COMMUNITIES						
1. WADING SITES (Sampler Types D, E, F)						
Number of Sites	7	10	21	34	41	113
No. of Samples	16	23	57	79	102	277
Drainage Area (mi.^{2})						
Mean	58.1	150.7	45.9	98	91.4	86.8
(±SE)	7.2	16.5	3.2	7.4	7.1	4.2
Median	57	115	43	89	73	65
Range	24-107	28-371	20-114	22-337	23-483	20-483
Quartile						
lower (25%)	34	34	27	43	39	36
upper (75%)	86	216	54	134	119	111
Number of Species						
Mean	16.6	26.2	20.9	26.8	23.8	24.0
(±SE)	1.1	0.8	0.6	0.6	0.5	0.3
Median	17	27	23	27	23	24
Range	9-25	18-35	11-28	14-37	13-37	9-37
Quartile						
lower (25%)	14	24	20	24	20	20
upper (75%)	19	27	24	31	27	27
Modified Index of Well-Being (Iwb)						
Mean	7.2	9.1	8.5	9.1	9.0	8.8
(±SE)	0.19	0.19	0.09	0.11	0.07	0.06
Median	7.4	9.0	8.4	9.3	9.0	8.9
Range	6.1-8.7	7.8-11.4	6.7-10.3	6.2-11.3	5.7-10.6	5.7-11.4
Quartile						
lower (25%)	6.6	8.4	8.0	8.5	8.5	8.3
upper (75%)	7.6	9.7	8.8	9.7	9.5	9.4

Table 6-2. (continued).

	Ecoregion					
	Huron/Erie Lake Plains (HELP)	Interior Plateau (IP)	Erie/Ont. Lake Plains (EOLP)	W. Allegheny Plateau (WAP)	E. Corn Belt Plains (ECBP)	Statewide (all sites combined)
1. WADING SITES (Sampler Types D, E, F) - continued						
Index of Biotic Integrity (IBI)						
Mean	28	43	42	48	44	44
(±SE)	1.1	1.6	0.7	0.8	0.6	0.5
Median	28	42	40	50	44	45
Range	22-36	32-56	30-50	28-58	28-56	22-58
Quartile						
lower (25%)	26	36	38	42	40	38
upper (75%)	32	48	46	54	50	50
Qualitative Habitat Evaluation Index (QHEI)						
Mean	56	75	73	74	74	73
(±SE)	4.6	2.0	1.8	1.4	1.3	0.0
Median	55	74	74	75	75	74
Range	41-74	64-84	53-90	55-91	59-90	41-91
Quartile						
lower (25%)	49	72	70	68	69	68
upper (75%)	62	82	78	78	80	78
2. BOAT SITES (Sampler Type A)						
Number of Sites	7	7	10	12	39	75
No. of Samples	20	20	20	28	103	191
Drain. Area (mi.^{2})						
Mean	1443	532	252	2213	707	941
(±SE)	431	88	33	401	74	94
Median	371	359	229	1884	503	483
Range	202-5559	116-1145	117-630	90-6471	122-3197	90-6471
Quartile						
lower (25%)	346	195	137	382	272	240
upper (75%)	2428	959	367	2577	655	1030

Table 6-2. (continued).

	Ecoregion					
	Huron/Erie Lake Plains (HELP)	Interior Plateau (IP)	Erie/Ont. Lake Plains (EOLP)	W. Allegheny Plateau (WAP)	E. Corn Belt Plains (ECBP)	Statewide (all sites combined)
2. BOAT SITES (Sampler Type A) - continued.						
Number of Species						
Mean	24.4	23.9	19.2	22.4	22.0	22.2
(±SE)	1.1	1.1	1.0	1.1	0.4	0.3
Median	25	23	19	21	22	22
Range	17-34	15-38	11-27	15-37	8-31	8-38
Quartile						
lower (25%)	20	21	15	19	19	19
upper (75%)	27	27	23	25	25	24
Modified Index of Well-Being (Iwb)						
Mean	9.2	9.2	8.9	9.0	9.0	9.0
(±SE)	0.2	0.1	0.1	0.1	0.1	0.05
Median	9.4	9.1	8.9	9.0	9.0	9.0
Range	7.3-11.3	8.5-10.2	7.8-10.0	8.1-10.4	7.5-10.4	7.3-11.3
Quartile						
lower (25%)	8.6	8.8	8.3	8.4	8.7	8.6
upper (75%)	10.0	9.4	9.4	9.5	9.4	9.45
Index of Biotic Integrity (IBI)						
Mean	37	43	40	42	46	44
(±SE)	1.6	1.1	1.1	1.2	0.6	0.5
Median	36	45	40	42	46	44
Range	26-48	32-52	28-52	28-54	26-56	26-56
Quartile						
lower (25%)	33	37	37	38	42	38
upper (75%)	43	49	43	48	52	50

Table 6-2. (continued).

	Ecoregion					
	Huron/Erie Lake Plains (HELP)	Interior Plateau (IP)	Erie/Ont. Lake Plains (EOLP)	W. Allegheny Plateau (WAP)	E. Corn Belt Plains (ECBP)	Statewide (all sites combined)
2. BOAT SITES (Sampler Type A) - continued.						
Qualitative Habitat Evaluation Index (QHEI)						
Mean	78	81	75	75	76	76
(±SE)	3.7	1.2	2.7	2.9	1.0	0.9
Median	80	82	75	77	76	77
Range	67-90	74-84	58-90	60-88	60-88	58-90
Quartile						
lower (25%)	67	80	71	65	73	72
upper (75%)	86	83	80	85	79	91
3. HEADWATERS SITES (Sampler Types D, E, and F at sites <20 mi.^{2})						
Number of Sites	2	10	23	16	19	70
No. of Samples	5	18	48	27	38	136
Drain. Area (mi.^{2})						
Mean	4.6	9.1	10.5	7.3	9.8	9.3
(±SE)	0.3	1.5	0.8	0.9	0.8	0.5
Median	5	7	10	6	9	9
Range	4-5	2-18	1-20	1-15	1-19	1-20
Quartile						
lower (25%)	4	4	6	3	5	5
upper (75%)	5	18	14	12	13	14
Number of Species						
Mean	8.4	16.5	16.0	13.6	17.0	15.4
(±SE)	1.5	1.1	0.7	1.4	0.8	0.5
Median	6	16	16	14	18	16
Range	6-12	10-26	6-27	3-31	5-27	3-31
Quartile						
lower (25%)	6	14	13	7	14	12
upper (75%)	12	19	20	18	20	19

Table 6-2. (continued).

	Ecoregion					
	Huron/Erie Lake Plains (HELP)	Interior Plateau (IP)	Erie/Ont. Lake Plains (EOLP)	W. Allegheny Plateau (WAP)	E. Corn Belt Plains (ECBP)	Statewide (all sites combined)
3. HEADWATERS SITES (Sampler Types D, E, and F at sites <20 mi.^{2}) - continued.						
Index of Biotic Integrity (IBI)						
Mean	27	46	43	47	45	44
(±SE)	1.0	2.2	0.8	1.6	1.1	0.7
Median	26	44	42	48	46	45
Range	24-30	28-58	28-56	30-60	34-60	24-60
Quartile						
lower (25%)	26	40	40	40	40	40
upper (75%)	28	54	48	54	50	50
Qualitative Habitat Evaluation Index (QHEI)						
Mean	61	65	67	67	66	66
(±SE)	6.5	1.1	1.2	1.3	1.5	0.7
Median	61	65	66	66	65	66
Range	54-67	60-70	54-77	56-76	58-76	54-77
Quartile						
lower (25%)	54	63	62	64	61	62
upper (75%)	67	68	71	70	72	71

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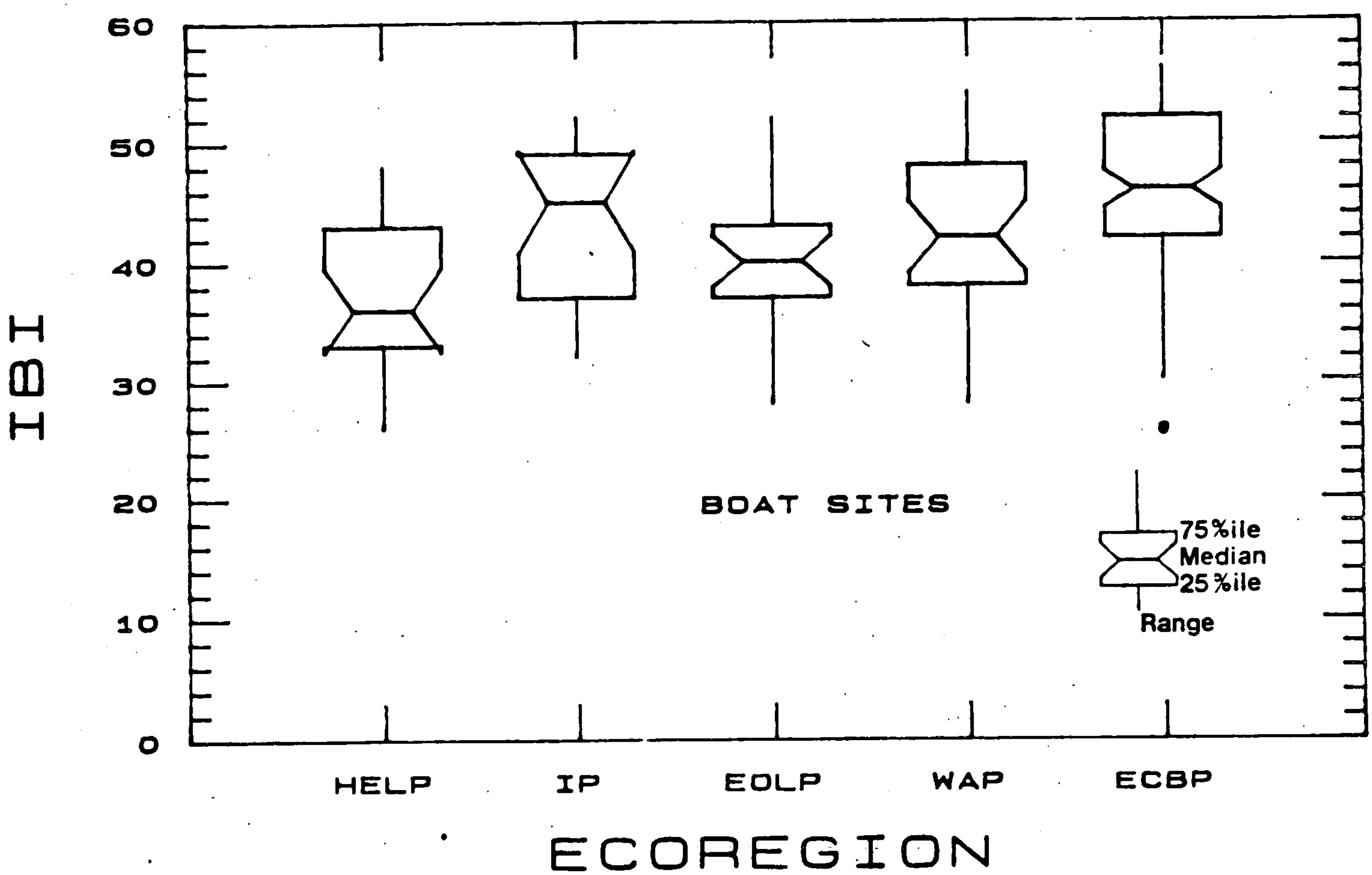

Figure 6-4. Notched box-and-whisker plot of Ohio reference site results for the Index of Biotic Integrity (Boat sites) showing maximum, minimum, outliers, median, and upper (75%) and lower (25%) quartile ranges. Notch overlap between regions indicates that the median values are not significantly different (P<0.05).

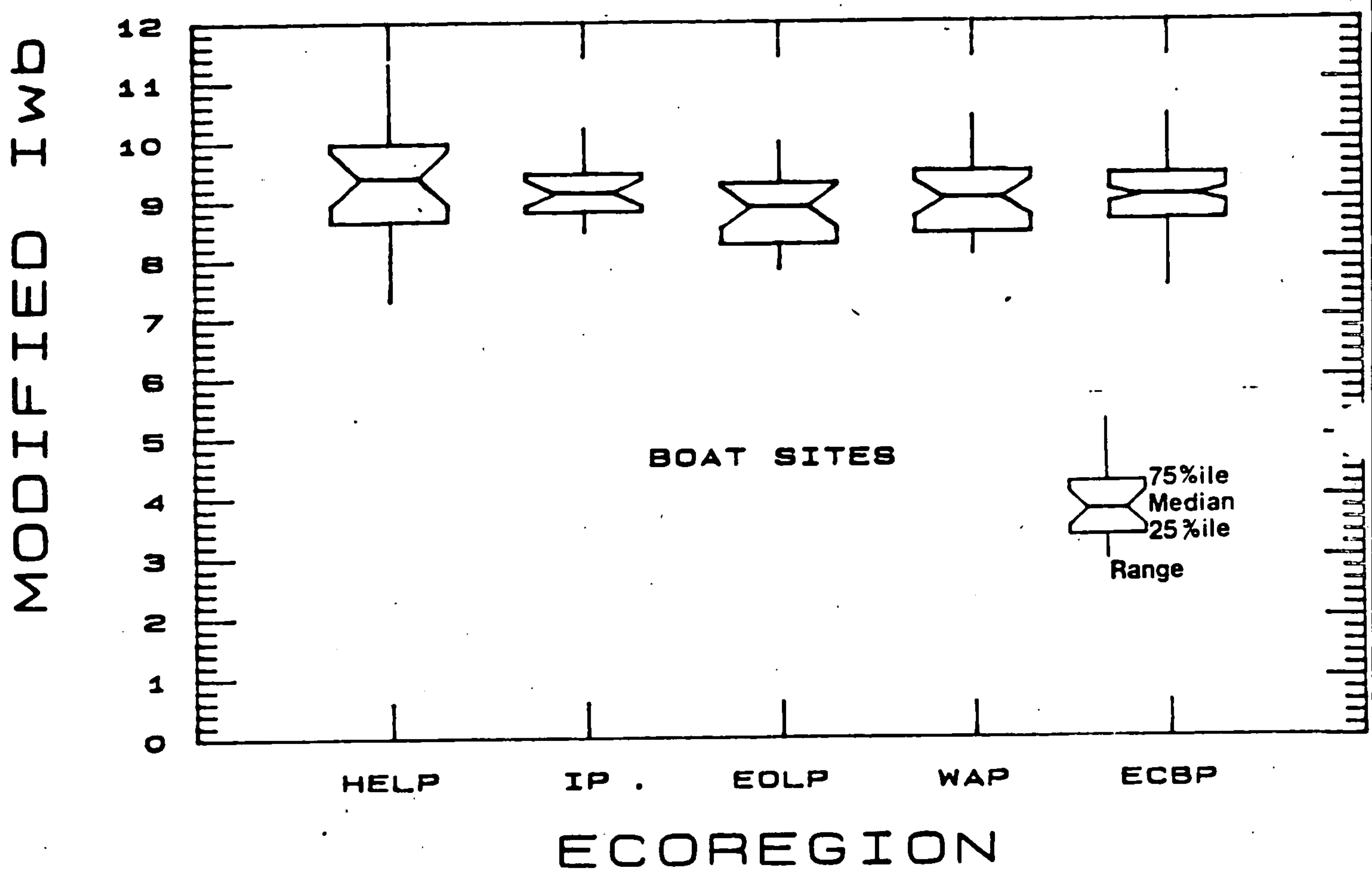

Figure 6-5. Notched box-and-whisker plot of Ohio reference site results for the Modified Index of Well-Being (Boat sites) showing maximum, minimum, outliers, median, and upper (75%) and lower (25%) quartile ranges. Notch overlap between regions indicates that the median values are not significantly different (P<0.05).

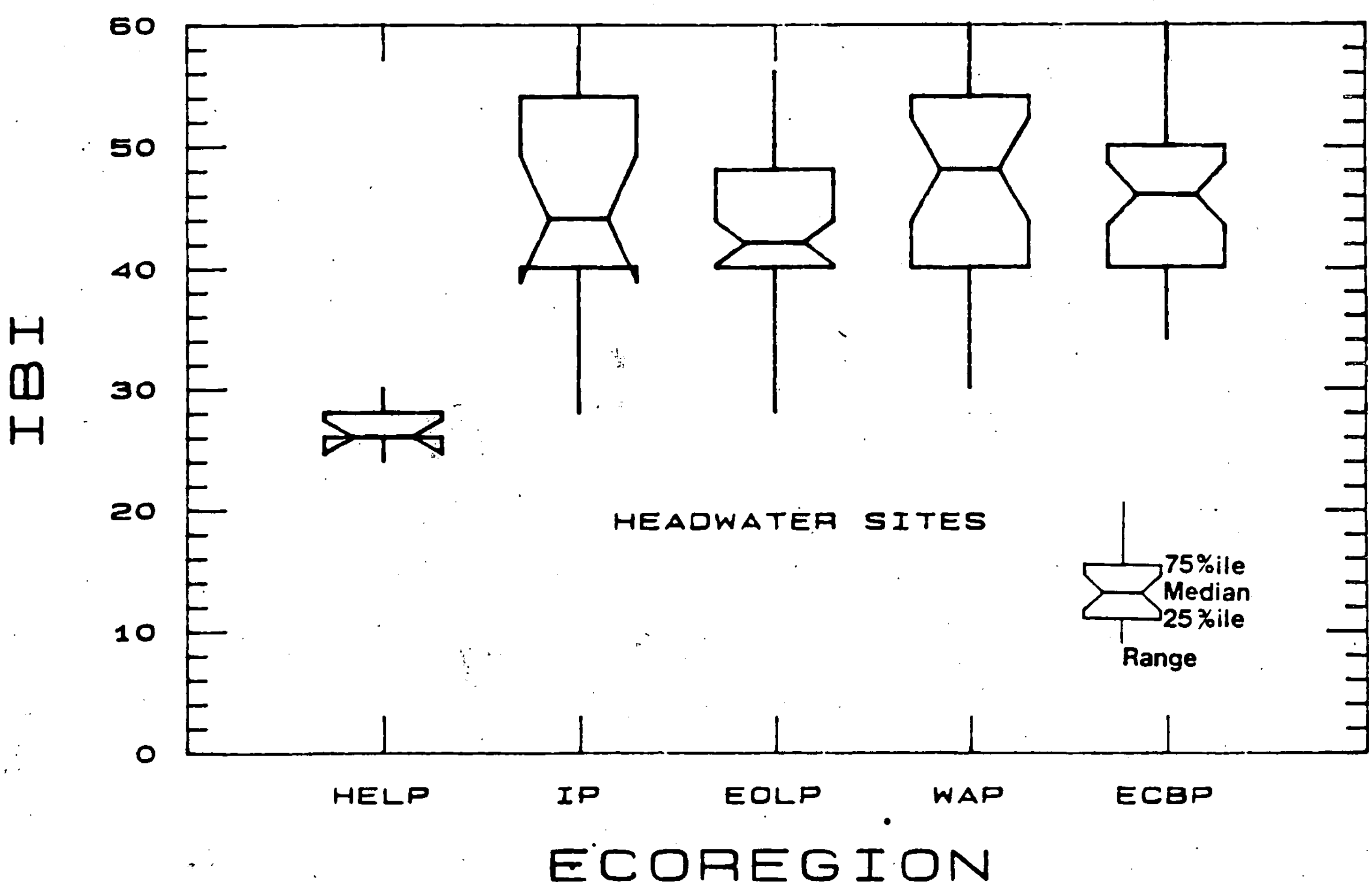

Figure 6-6. Notched box-and-whisker plot of Ohio reference site results for the Index of Biotic Integrity (Headwaters Sites) showing maximum, minimum, outliers, median, and upper (75%) and lower (25%) quartile ranges. Notch overlap between regions indicates that the median values are not significantly different (P<0.05).

appreciable difference was evident for the boat sites. Much of the difference observed at the wading and headwaters sites is because of the extensive degree to which small streams have been modified in the HELP ecoregion.

Macroinvertebrate Community Data

The notched box-and-whisker plot for the ICI using data from the 232 reference sites sampled with modified Hester-Dendy multiple-plate artificial substrate samplers is presented in Figure 6-7. Summary information of the database including the 25th percentile value for each of the five ecoregions and the statewide 75th percentile value is given in Table 6-3.

Examination of the data indicates that median values are statistically different only between the Huron/Erie Lake Plain (HELP) sites and the Western Allegheny Plateau (WAP) and Eastern Corn Belt Plains (ECBP) sites. Even here, however, the significance is marginal. The same trend holds for the 25th percentile values which range from 34 in the HELP to 38 in the WAP and ECBP. Similar variation exists in the 75th percentile values where all regions score from 44 to 48. It is apparent from the reference site data that ecoregion has less effect on the ICI using Ohio EPA sampling methodology than it does on headwaters and stream fish communities.

To determine the performance of the ICI, macroinvertebrate data from 431 sampling locations collected from 1981 to 1984 and previously evaluated using more traditional approaches (i.e. diversity index, taxa richness, BPJ) were compiled and index values determined. Results are summarized in Table 6-4 and frequency histograms depicted in Figure 6-8. The database consists of 279 locations that were evaluated as good or exceptional (no or slight biological impairment), 76 locations evaluated as fair (moderate biological impairment), and 76 locations evaluated as poor (severe biological impairment). Fair and poor evaluations indicated nonattainment of the goals of the Water Quality Act (WQA). Some of the least impacted good and exceptional sites were subsequently included in the reference site database. In contrast to the reference sites, sampling locations represented a wide range of water quality and habitat conditions even among the good and exceptional set where minor water quality and habitat problems may have been exerting influences. The frequency histograms in Figure 6-8 reveal a clear segregation of sites considered to have met WQA goals (good and exceptional) from those sites considered not to have met the goals (fair and poor). Table 6-4 supports this by indicating wide separation, both statewide and within ecoregions, in all summary measurements. These results indicate that the ICI can provide an objective, quantifiable, and standardized means of evaluating biological integrity. In essence, it compares stream sampling locations with proven reference streams of similar size and ecoregional characteristics. This presents a substantial advantage over evaluation on a site-by-site basis using one or a few community characteristics and/or a heavy reliance on best professional judgement.

Table 6-3. Summary ecological and drainage area characteristics of the reference sites used to establish attainable ecological criteria for Ohio's rivers and streams based on the ICI.

	Ecoregion					
	Huron/Erie Lake Plains (HELP)	Interior Plateau (IP)	Erie/Ont. Lake Plains (EOLP)	W. Allegheny Plateau (WAP)	E. Corn Belt Plains (ECBP)	Statewide (all sites combined)
I. MACROINVERTEBRATES						
1. Composite Sample of Five Artificial Substrates						
Number of Sites	31	19	45	48	89	232
Drainage Area (mi.^{2})						
Mean	671	274	65	563	406	397
(+SE)	200	69	11	176	83	57
Median	327	195	40	146	128	114
Range	15-5544	14-1145	4-367	15-6082	6-3849	4-6082
Quartile						
lower (25%)	68	80	20	87	55	46
upper (75%)	776	358	86	292	453	321
Invertebrate Community Index (ICI)						
Mean	38	41	40	42	42	41
(+SE)	1.5	2.1	1.3	1.0	0.9	0.5
Median	38	42	42	44	44	42
Range	18-50	22-56	18-54	24-56	12-54	12-56
Quartile						
lower (25%)	34	34	36	38	38	36
upper (75%)	44	48	48	46	48	48

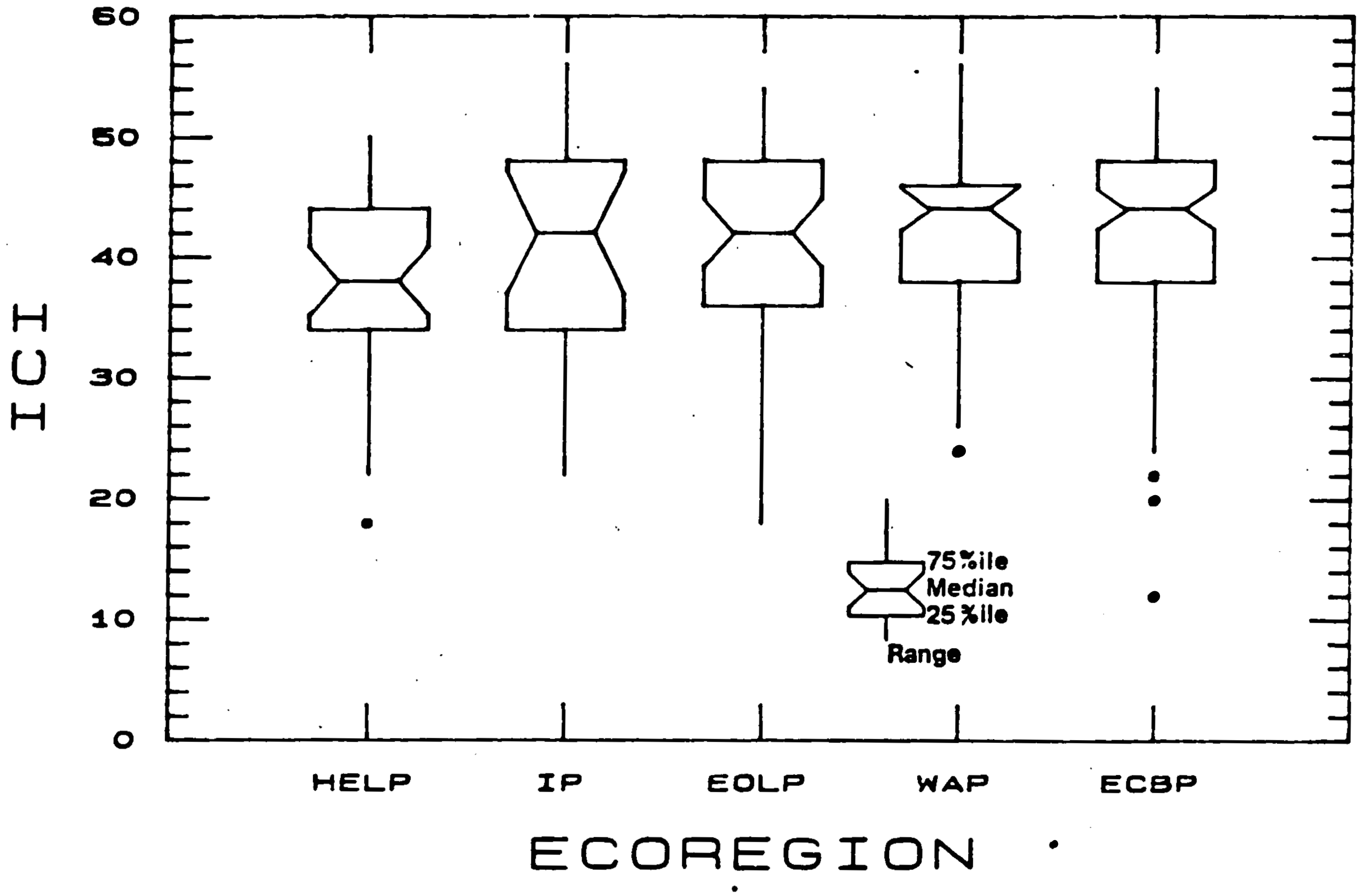

Figure 6-7. Notched box-and-whisker plot of Ohio reference site results for the Invertebrate Community Index (ICI) showing maximum, minimum, outliers, median, and upper (75%) and lower (25%) quartile ranges. Notch overlap between regions indicates that the median values are not significantly different ($p<0.05$).

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Table 6-4. Summary ecological characteristics of macroinvertebrate sites collected from 1981-84 used to judge the performance of the Invertebrate Community Index (ICI). Exceptional, good, fair, and poor classifications were based on best professional judgement techniques used prior to development of the ICI.

	Ecoregion					
	HELP	IP	EOLP	WAP	ECBP	Statewide
1. Good/Exceptional Sites (n=279)						
Mean	37	45	37	37	40	39
(±SE)	2.1	1.4	1.2	1.6	0.7	0.5
Median	38	46	38	36	42	40
Range	20-50	30-56	20-54	20-54	18-54	18-56
Quartile						
lower(25%)	30	38	30	32	36	34
upper(75%)	46	50	46	44	46	46
2. Fair Sites (n=76)						
Mean	18	13	17	16	17	17
(±SE)	2.4	5.0	0.9	1.1	0.6	0.6
Median	16	13	17	16	16	16
Range	8-28	8-18	6-32	12-20	14-22	6-32
Quartile						
lower(25%)	15	8	14	14	16	14
upper(75%)	22	18	22	18	18	20
3. Poor Sites (n=76)						
Mean	4	0	6	4	7	5
(±SE)	1.2	0.0	0.7	1.1	1.5	0.5
Median	4	0	5	4	7	4
Range	0-8	0-0	0-16	0-12	0-14	0-16
Quartile						
lower(25%)	0	0	2	0	5	1
upper(75%)	8	0	10	6	10	10

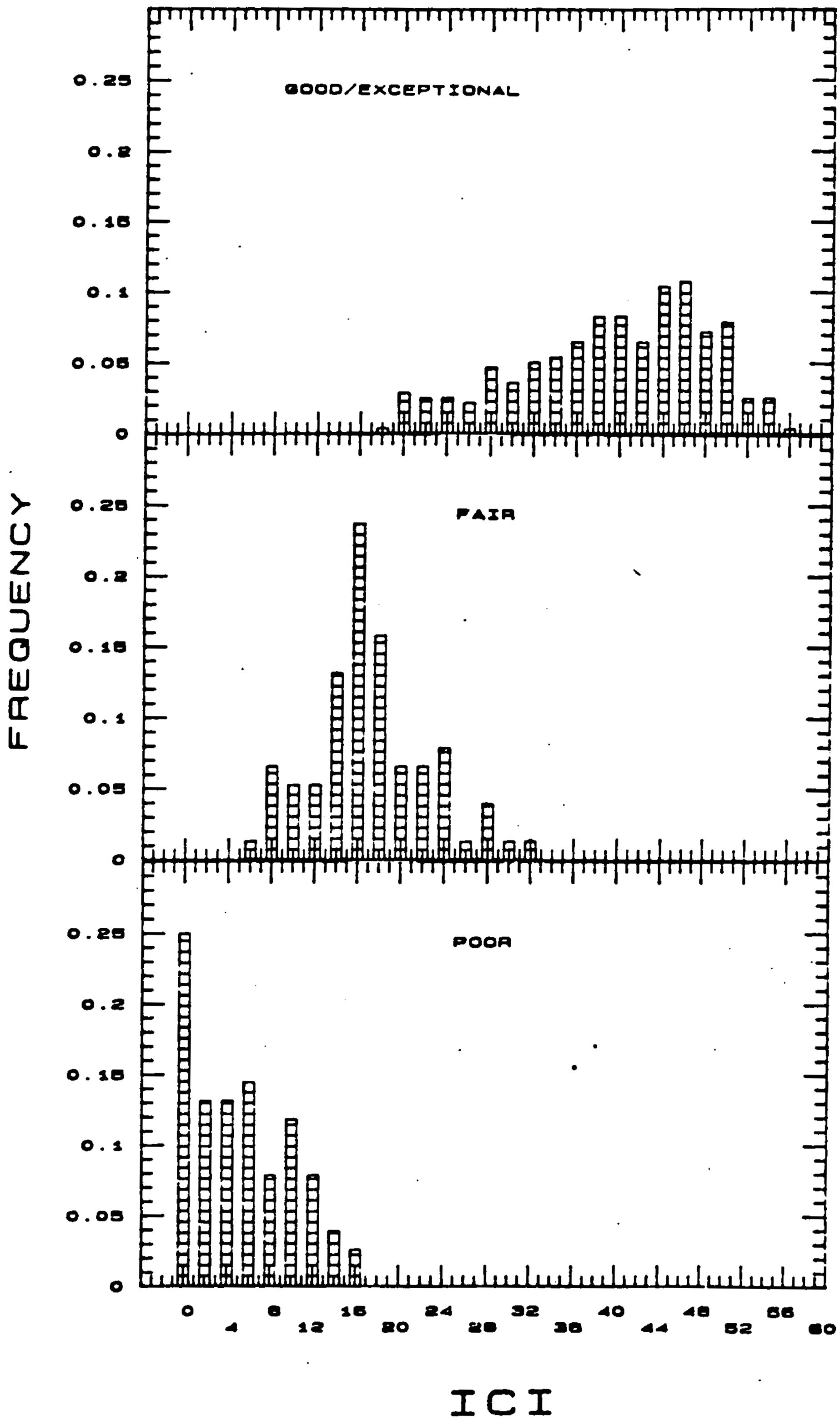

Figure 6-8. Relative frequency histograms of ICI values determined for macroinvertebrate samples collected in Ohio from 1981-84 with prior evaluations of good or exceptional (n=279), fair (n=76), and poor (n=76).

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Problems Unique to the HELP Ecoregion

Defining the WWH criteria for the IBI and I_{wb} in the Huron/Erie Lake Plain (HELP) ecoregion involved detailed considerations of past and present physical habitat modifications. Based on the site evaluation descriptions (including Qualitative Habitat Evaluation Index scores; Table 6-2), the field observations of Ohio EPA biologists, and the descriptions of land use patterns in this ecoregion (Whittier et al. 1987) none of the wading and headwaters reference sites in the HELP ecoregion reflected "least impacted" conditions relative to the reference sites in the other four ecoregions. The distinction is with the widespread degree to which macro-habitats have been altered among the headwaters and small streams in the HELP ecoregion. Intensive rowcrop agriculture and attendant drainage practices (i.e. channel modification to improve subsurface drainage) have left few streams that fit the true definition of "least impacted" in this ecoregion. As a result IBI and I_{wb} values from the wading and headwaters reference sites of this ecoregion reflect these influences. Deriving the WWH wading and headwaters sites criteria for the HELP ecoregion involved an examination of IBI and I_{wb} results from all sites sampled during 1979-1986 (Figs. 6-9 and 6-10). We chose the IBI and I_{wb} values that marked the upper 10% (90th percentile) of all sites sampled (Table 6-5) as an alternative to choosing the 25th percentile of the reference sites (which yielded lower values; Table 6-2). An accompanying review of some historical descriptions of streams in this ecoregion (Meek 1889, c.f. Trautman 1981; Kirsch 1895; Trautman 1939, 1981; Smith 1968; Trautman and Gartman 1974) assisted in making some of the necessary judgements about attainable WWH conditions in this ecoregion.

Modified Warmwater Habitat (MWH)

The pervasive nature of the modified habitat conditions among the wading and headwaters sites throughout the HELP ecoregion prompted the development of a use designation different than WWH. This was done to better use the existing concept of use designations and chemical-numerical and narrative criteria with the biological criteria approach. The Modified Warmwater Habitat (MWH) designation applies to highly modified habitats that support the semblance of a warmwater biological community, but where that community falls short of attaining the WWH biological criteria because of functional and structural alterations due to alterations of the macro-habitat. Examples of this include most of the small stream systems in the HELP ecoregion that have been extensively channelized and straightened (e.g. Little Auglaize R. subbasin). This concept is also extended to streams in the other ecoregions although not to the widespread extent as within the HELP ecoregion. A common attribute of all MWH stream segments is that they have been altered by the physical modification of the stream channel and/or substrate to the extent that full attainment of the WWH use is not expected in the near future. Such impacts are not necessarily limited to a direct manipulation of the stream channel, but can include heavy sedimentation and extensive impoundment. Recovery of such areas to WWH is not possible without a recovery of the stream channel to a pre-modified condition or extensive basin-wide land use changes (e.g. elimination of sediment runoff from abandoned surface mines). Areas impacted by these activities contain functionally and structurally altered fish communities resulting from the degradation of the macro-habitat. Such altered communities are characterized by a predominance of tolerant species, a

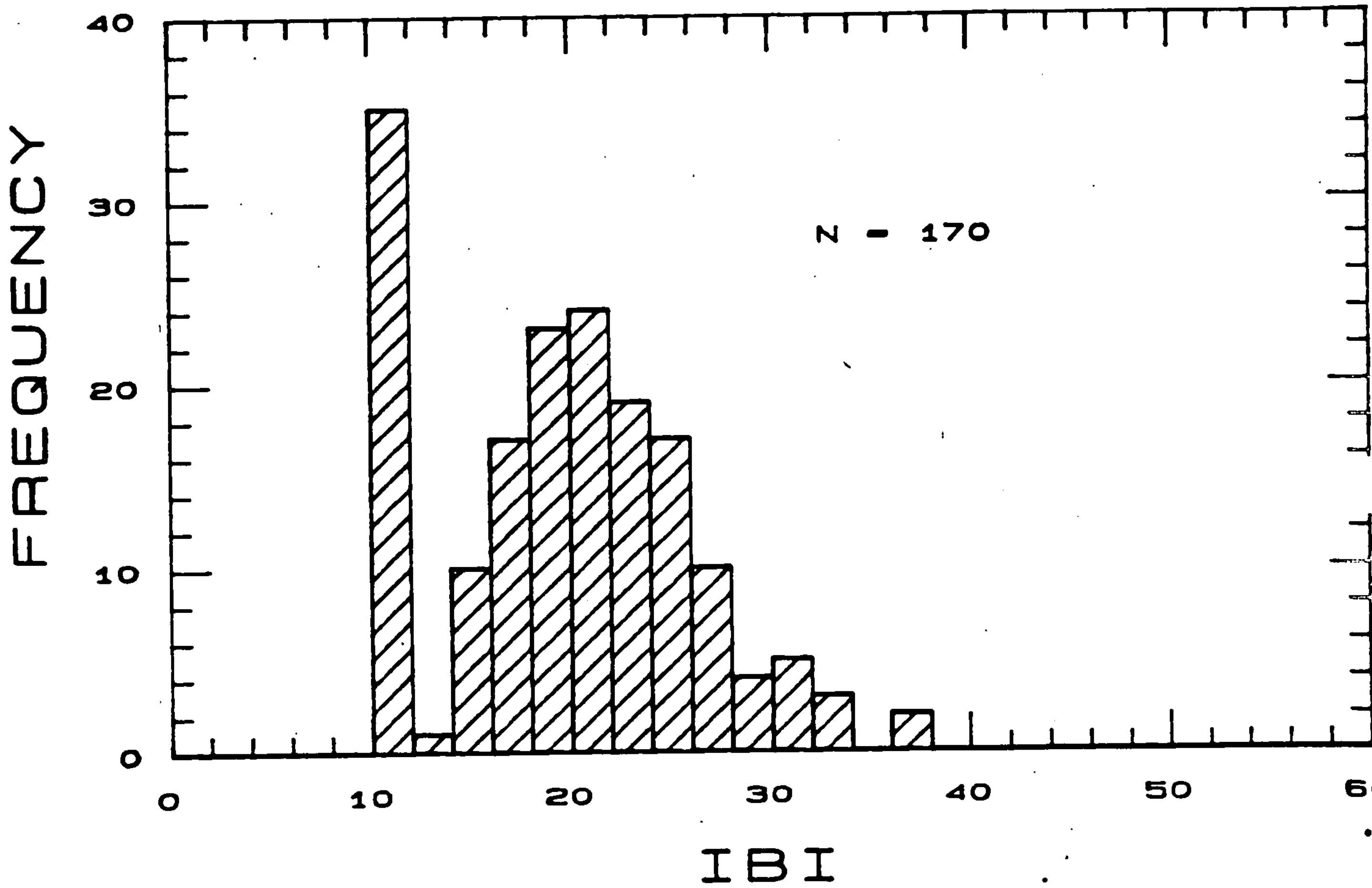

Figure 6-9. Frequency histogram of Index of Biotic Integrity (IBI) values at all wading and headwaters sites in the HELP ecoregion during 1979-1986.

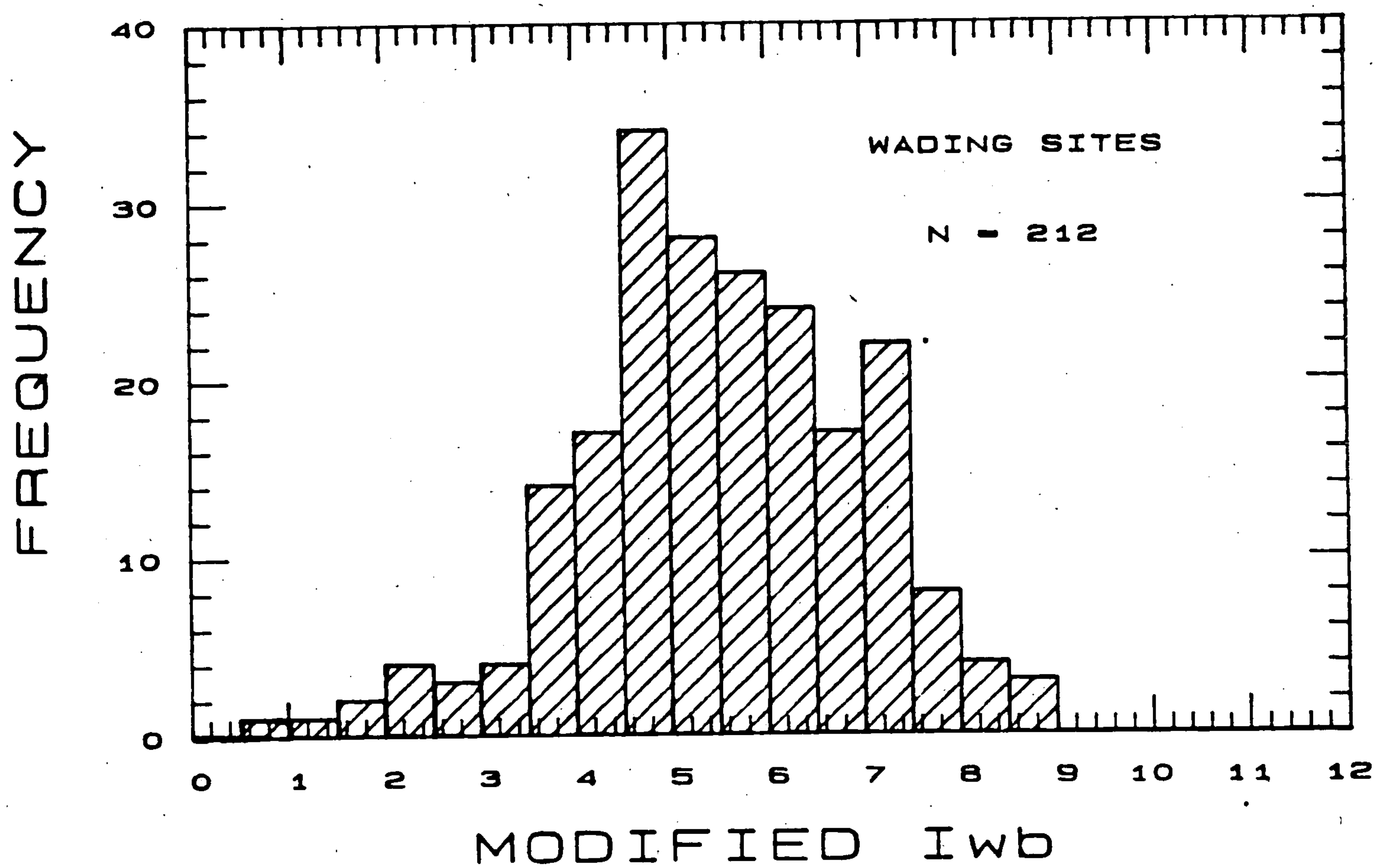

Figure 6-10. Frequency histogram of Modified Index of Well-Being (Iwb) values at all wading sites in the HELP ecoregion during 1979-1986.

predominance of functional guilds such as omnivores and generalists, and only moderately reduced diversity. Ironically, abundance as reflected by fish numbers can be very high as the result of the increased productivity of tolerant species, omnivores, and generalists. Such communities are tolerant of low D.O., elevated ammonia, and/or nutrient enrichment.

The MWH use is needed to administratively handle those situations where it is known (through demonstrated field studies) that water quality based effluent limits based on WWH chemical criteria (particularly D.O. and ammonia) are not necessary to protect these altered aquatic communities, but where application of the Limited Resource Waters (formerly Nuisance Prevention) designation is inadvisable because the aquatic community requires some greater level of chemical protection, particularly for some toxic substances. However, MWH is not being proposed as a way to achieve large scale modification of streams that currently meet the WWH biological criteria.

Initially the MWH use will be designated and evaluated based on the fish community. Macroinvertebrate results reflected by the ICI do not apply, primarily because the current sampling method (artificial substrates) diminishes the influence of habitat. These results will be used, however, to evaluate the significance of any water quality impacts in MWH designated waters. An effort will be made to develop macroinvertebrate evaluation techniques that respond to the macro-habitat modifications included in the MWH designation. IBI and modified I_{wb} criteria for the MWH use were established by using data from a set of habitat modified reference sites. These sites were selected based on their extensively modified nature and grouped into three disturbance type categories; 1) channelized, 2) mine drainage affected (does not include sites with chronic low pH), and 3) impounded sites (primarily larger streams and rivers excluding publically owned lakes and reservoirs). Sites located downstream from point sources and with chemical water quality problems were not included. Because of the number and geographical distribution of the modified reference sites we combined data from the four non-HELP ecoregions; the HELP ecoregion was analyzed separately. The mine affected disturbance type was unique to the WAP ecoregion. Summary statistics by ecoregion grouping (HELP and Other) and disturbance type are given in Table 6-5.

The Qualitative Habitat Evaluation Index (QHEI; Ohio EPA 1987a) is also included since it plays a key role in determining the applicability of the MWH use designation. A comparison of the MWH and WWH reference sites shows that QHEI values are clearly lower for the MWH sites. The lower quartile (25th percentile) QHEI values at the WWH reference sites were consistently higher than the upper quartile (75th percentile) MWH reference sites. Some slight overlap between the minimum WWH QHEI scores and the maximum MWH QHEI scores was evident. The relationship between the QHEI and IBI was demonstrated by using the WWH and MWH reference sites data base (Fig. 6-11). The correlation was positive and significant for each site category, but some scattering of points away from the regression line was evident. Although QHEI is an adequate evaluation tool for use designation purposes it is not a precise predictor of IBI. Guidance for designating aquatic life uses is discussed in Section 8.

Table 6-5. Summary ecological and habitat characteristics for the Modified Warmwater Habitat reference sites used to derive the Modified Warmwater Habitat (MWH) biological criteria.

	Channelized		Mine Affected	Impounded	
	HELP	Other	WAP Only	HELP	Other
1. WADING SITES (Sampler Types D, E, F)					
Number of Sites	10	12	7	-	-
Number of Samples	24	25	17	-	-
Index of Biotic Integrity (IBI)					
Mean	24	32	30	-	-
(±SE)	0.7	1.3	1.4	-	-
Range	18-30	24-48	22-40	-	-
Quartile:					
lower	22	28	26	-	-
upper	28	36	32	-	-
Modified Index of Well-Being (Iwb)					
Mean	6.6	6.7	6.5	-	-
(±SE)	0.25	0.25	0.26	-	-
Range	4.8-8.7	4.0-8.6	4.7-8.2	-	-
Quartile:					
lower	5.6	6.2	5.9	-	-
upper	7.3	7.6	7.2	-	-
Number of Species					
Mean	13.9	15.3	17.5	-	-
(±SE)	0.9	1.0	1.1	-	-
Range	7-25	8-26	10-27	-	-
Quartile:					
lower	10.5	11.0	15.0	-	-
upper	15.5	18.0	20.0	-	-
Qualitative Habitat Evaluation Index (QHEI)					
Mean	53	49	67	-	-
(±SE)	3.2	2.9	3.4	-	-
Range	41-74	36-67	47-73	-	-
Quartile:					
lower	40	40	68	-	-
upper	45	55	72	-	-

Table 6-5. continued.

	Channelized		Mine Affected	Impounded	
	HELP	Other	WAP Only	HELP	Other
2. BOAT SITES (Sampler type A)					
Number of Sites	7	6	6	7	16
No. of Samples	20	17	14	21	48
Index of Biotic Integrity (IBI)					
Mean	26	24	27	28	33
(±SE)	1.2	1.2	1.3	1.3	0.8
Range	18-38	20-38	20-36	20-40	16-42
Quartile:					
lower	21	26	24	24	30
upper	29	32	30	30	36
Modified Index of Well-Being (Iwb)					
Mean	6.1	6.5	6.1	7.2	7.4
(±SE)	0.18	0.25	0.20	0.28	0.14
Range	4.6-7.7	4.9-8.9	4.9-7.7	4.6-9.3	4.6-9.1
Quartile:					
lower	5.5	5.8	5.3	6.7	6.9
upper	6.6	7.1	6.6	8.0	8.0
Number of Species					
Mean	13.3	13.2	10.9	14.5	13.3
(±SE)	0.6	1.0	0.71	0.9	0.4
Range	9-19	9-23	7-15	7-21	7-20
Quartile:					
lower	11	11	9	11	11
upper	16	14	13	17	15
Qualitative Habitat Evaluation Index (QHEI)					
Mean	56	48	55	58	62
(±SE)	2.5	3.9	2.0	0.6	1.2
Range	47-66	36-62	48-63	56-60	56-71
Quartile:					
lower	50	41	51	56	58
upper	61	54	57	59	64

Table 6-5. continued.

	Channelized		Mine Affected	Impounded	
	HELP	Other	WAP Only	HELP	Other
3. <u>HEADWATERS SITES</u> (Sampler Types D, E, and F at sites <20 mi.[2])					
Number of Sites	4	12	-[a]	-	-
No. of Samples	10	25	-[a]	-	-
Index of Biotic Integrity (IBI)					
Mean	25	29	-[a]	-	-
(±SE)	1.5	0.7	-	-	-
Range	18-32	24-36	-	-	-
Quartile:					
lower	22	26	-	-	-
upper	28	32	-	-	-
Number of Species					
Mean	10.0	13.6	-[a]	-	-
(±SE)	0.7	0.9	-	-	-
Range	7-14	5-22	-	-	-
Quartile:					
lower	9	11	-	-	-
upper	12	16	-	-	-
Qualitative Habitat Evaluation Index (QHEI)					
Mean	45	46	-	-	-
(±SE)	3.1	1.5	-	-	-
Range	40-53	38-56	-	-	-
Quartile:					
lower	40	43	-	-	-
upper	50	48	-	-	-

a combined with wading sites due to small sample size.

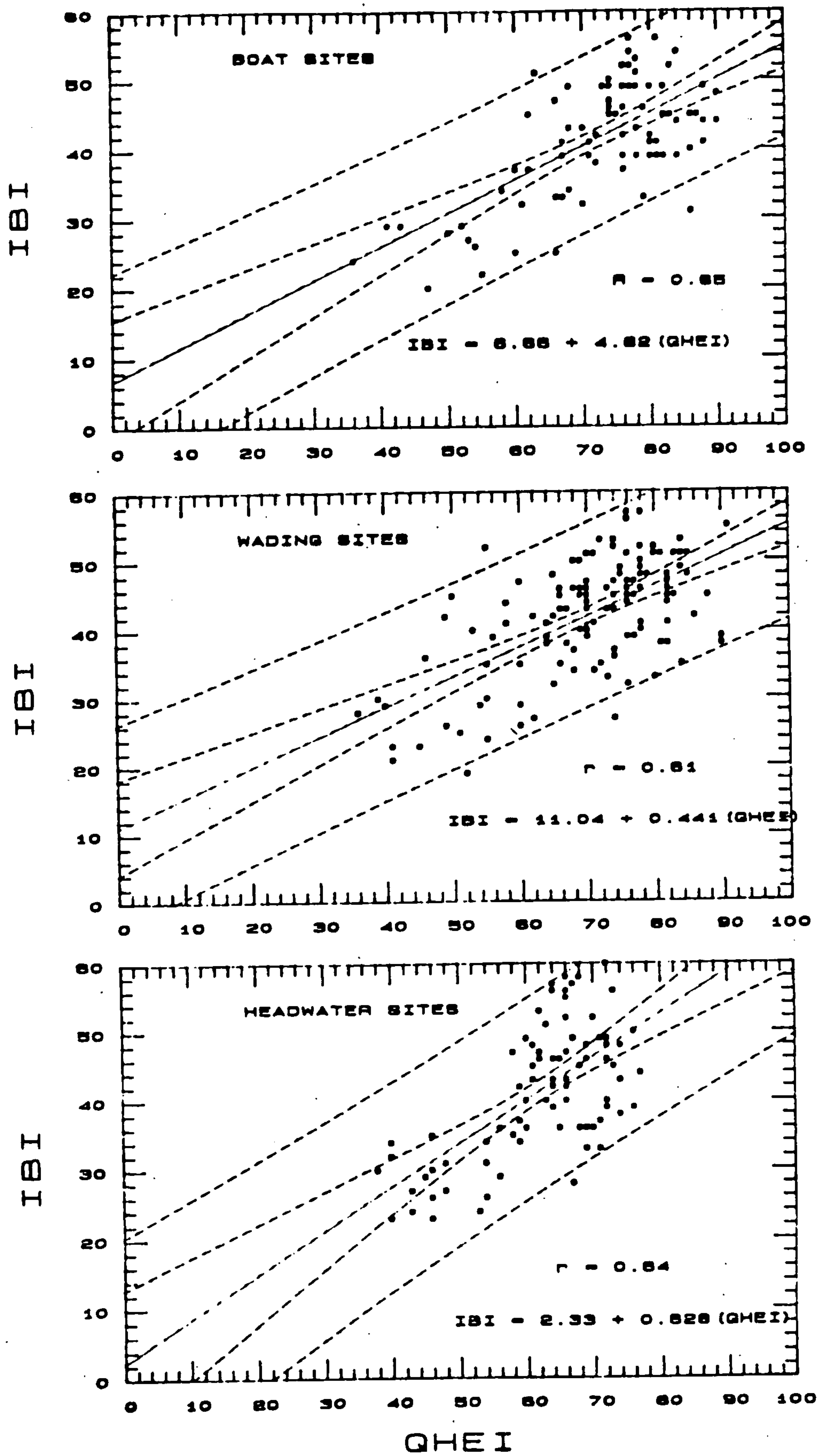

Figure 6-11. Linear regression analysis of the relationship of QHEI to IBI at wading (top), boat (middle), and headwaters (bottom) reference sites for MWH and WWH. Correlation coefficients (r) are signifi at the $P < 0.001$ level. Dashed lines represent the regression line (middle), 95% confidence interval (closest to regression line), and the prediction limits (outside).

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SECTION 7: BIOLOGICAL CRITERIA FOR OHIO SURFACE WATERS

Applicability

The rationale and general concept of biological criteria for the protection of aquatic life is discussed in detail elsewhere (Ohio EPA 1987b). Derivation of biological criteria follows the tiered aquatic life use hierarchy in the Ohio WQS (OAC 3745-1). Since the biological criteria are a direct indication of use attainment/non-attainment they logically supercede the accompanying chemical criteria surrogates for determining if the applicable aquatic life use designation is attained. This applies to the chemical criteria for aquatic life protection purposes only and to biological data that has been collected and analyzed according to the procedures outlined in this manual and in Ohio EPA (1987a).

The 25th percentile index values for the reference site data base is the minimum WWH criterion for each ecoregion (with the exception of HELP). The EWH criterion is the 75th percentile value of the combined statewide database. The Modified Warmwater Habitat (MWH) use designation is based on a reference site data base of physically altered streams and rivers within an ecoregion that support the semblance of a WWH community, yet cannot fully attain the quantitative WWH biological criteria due to long-term and essentially irreversible physical macro-habitat modifications. Examples of such modifications include widespread channelization (e.g. L. Auglaize R. subbasin) and extensive sedimentation due to non-acidic mine runoff impacts (e.g. Wills Creek). MWH criteria for the IBI and Iwb were established using the 25th percentile values of the MWH reference sites data base for the HELP ecoregion and the remaining four ecoregions combined. For the purposes of the WQA the MWH designation is considered to be a "fishable/swimmable" use. The biological criteria are listed in Table 7-1 following the same format as the WQS.

Ecoregion Definitions

Although it has been demonstrated that attainable biological conditions differ between ecoregions, the ecoregion boundaries do not represent abrupt changes in biological potential. This section describes the method of determining which ecoregional criteria should be used to evaluate sites that lie close to an ecoregional boundary and that are on cross-boundary streams or rivers. To determine which ecoregion a site should be considered a part of, the following procedure should be used:

1) Compare the site to the Ecoregion map (Fig. 2-1) to determine which ecoregions it borders.

2) Compare the terrestrial characteristics of the watershed with the summary from the five ecoregions of Ohio (Table 2-1; also see Whittier *et al*. 1987).

Table 7-1. Format for biological criteria in the Ohio Water Quality Standards regulations, OAC 3745-1-07, Table 12.

	Modified Warmater Habitat			Warmwater	Exceptional
Index/Ecoregion	Channel Mod.	Mine Affected	Impounded	Habitat	Warmwater Habitat
I. Index of Biotic Integrity (Fish)					
A. Wading Sites[1]					
Huron/Erie Lake Plain	22			32	50
Interior Plateau	28			36	50
Erie/Ontario Lake Plain	28			38	50
Western Allegheny Plateau	28	26		42	50
Eastern Corn Belt Plains	28			40	50
B. Boat Sites[1]					
Huron/Erie Lake Plain	22		24	34	50
Interior Plateau	26		30	38	50
Erie/Ontario Lake Plain	26		30	36	50
Western Allegheny Plateau	26	24	30	38	50
Eastern Corn Belt Plains	26		30	42	50

[1] Sampling methods descriptions are found in the Ohio EPA Manual of Surveillance Methods and Quality Assurance Practices (Ohio EPA 1987a).

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Table 7-1 continued.

Index/Ecoregion	Modified Warmwater Habitat Channel Mod.	Modified Warmwater Habitat Mine Affected	Modified Warmwater Habitat Impounded	Warmwater Habitat	Exceptional Warmwater Habitat
C. Headwaters Sites[3]					
Huron/Erie Lake Plain	22			32	50
Interior Plateau	26			40	50
Erie/Ontario Lake Plain	26			40	50
Western Allegheny Plateau	26	26		40	50
Eastern Corn Belt Plains	26			40	50
II. Modified Index of Well-Being (Fish)[2]					
A. Wading Sites[1]					
Huron/Erie Lake Plain	5.6			7.3	9.4
Interior Plateau	6.2			8.4	9.4
Erie/Ontario Lake Plain	6.2			8.0	9.4
Western Allegheny Plateau	6.2	5.9		8.5	9.4
Eastern Corn Belt Plains	6.2			8.5	9.4

1 Sampling methods descriptions are found in the Ohio EPA Manual of Surveillance Methods and Quality Assurance Practices (Ohio EPA 1987a).
2 Does not apply to sites with drainage areas less than 20 square miles.
3 Modification of the IBI that applies to sites with drainage areas less than 20 square miles.

Table 7-1 continued.

Index/Ecoregion	Modified Warmwater Habitat Channel Mod.	Modified Warmwater Habitat Mine Affected	Modified Warmwater Habitat Impounded	Warmwater Habitat	Exceptional Warmwater Habitat
B. Boat Sites[1]					
Huron/Erie Lake Plain	5.5		6.7	8.6	9.5
Interior Plateau	5.8		6.9	8.8	9.5
Erie/Ontario Lake Plain	5.8		6.9	8.3	9.5
Western Allegheny Plateau	5.8	5.3	6.9	8.4	9.5
Eastern Corn Belt Plains	5.8		6.9	8.7	9.5
IV. Invertebrate Community Index (Macroinvertebrates)					
A. Artificial Substrate Samplers[1,2]					
Huron/Erie Lake Plain				34	48
Interior Plateau				34	48
Erie/Ontario Lake Plain				36	48
Western Allegheny Plateau				38	48
Eastern Corn Belt Plains				38	48

1 Sampling methods descriptions are found in the Ohio EPA Manual of Surveillance Methods and Quality Assurance Practices (Ohio EPA 1987a).

2 ICI criteria for macroinvertebrates do not apply to the Modified Warmwater Habitat use designation.

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3) Compare the physical habitat found at the site with the predominant habitat characteristics of the bordering ecoregions. Stream habitat is largely determined by the characteristics of the parent watershed (Hynes 1975). Figure 20 in Whittier et al. (1987) describes a preliminary analysis and profiles of cover and substrate from each Ohio ecoregion.

4) Compare the biological communities found at the site with what was found in the ecoregion (see Whittier et al. 1987). This may be difficult if the site is severely impacted; however, certain fish and macroinvertebrate species appear to be predominant in certain ecoregions (Macroinvertebrates: see Fig. 10; Fish: see Figs. 2 and 3, in Whittier et al. 1987). The classification of nearby, unimpacted sites can also be examined and compared to ecoregional expectations.

5) Based on the physical habitat and biological characteristics the site in question should then be considered a part of the ecoregion to which it compares best.

This approach recognizes that most ecoregional "boundaries" are more transitional than they are discrete. Some boundaries are defined by more abrupt changes in land-surface form. This situation may produce a physical habitat that supports biological communities characteristic of the EWH use.

Site-specific Criteria Modification

In situations where the biological criteria are not met because of the natural attributes of the surface water and/or watershed a site-specific modification of the criteria may be performed. This procedure recognizes that there may be habitats that do not meet the ecoregional criteria due to unique, site and/or watershed specific characteristics. A possible example of this are some of the low gradient "swamp" or wetlands streams in the Erie/Ontario Lake Plains ecoregion. Some of these sites were selected in the original SRP study design, but were later rejected as reference sites because of their "atypical" habitat characteristics. These habitats generally yield results that translate into inherently lower scores for the biological indices. Other similar situations may exist throughout the state. These should not be confused with sites affected by macro-habitat modifications which are handled with the Modified Warmwater Habitat (MWH) use designation. Any proposal to modify a criterion must be approved by Ohio EPA and be included in the WQS rulemaking process.

Possible Future Changes to the Biological Criteria

The biological criteria are based on the prevailing background conditions at "least impacted" reference sites across the state during the period 1979-1986. This follows the guidance of Hughes et al. (1986) and recognizes that attainable biological community structure and function is influenced by such widespread activities as intensive land surface uses (e.g. row crop agriculture, surface mining), natural stream channel alterations (e.g. channelization), human settlement, roads and highways, and general land surface conversion (e.g. deforestation) to suit socioeconomic desires. The "least impacted" conditions are not intended to represent pristine, wilderness or pre-Columbian conditions (Hughes et al. 1982; Whittier et al. 1987). Instead we recognize that the aforementioned factors together have influenced the ability of watersheds to support a certain level of biological performance. Thus the current biological criteria are set to reflect what is reasonably attainable given these background conditions. This does not mean that the criteria cannot change if it becomes apparent that these pervasive influences have changed through improved control programs or other means. To determine if the reference site database has changed significantly, periodic monitoring of selected sites and watersheds may be necessary. Much of this can be accomplished via the routine activities of Ohio EPA and other state agencies (e.g. ODNR, ODOT). If it becomes apparent that the biological condition of most of these sites is "improved" then a recalculation of the biological criteria would be in order. The current criteria represent the base or floor that can be expected for the ecoregions of Ohio. Any modification of the criteria would be subjected to the requirements of the WQS rulemaking process.

SECTION 8: GUIDELINES FOR BIOLOGICAL CRITERIA USE AND APPLICATION

This section describes general guidance on biological database development, general study design, and results interpretation for using the Ohio WQS biological criteria. This is not an attempt to convey a "cook book" approach to determining how to use the biological criteria. It is designed to assist a trained biologist in deciding which field methods to use, which organism groups to sample, which data analyses to use, how to interpret the results, evaluating use attainment/non-attainment, and the designation of appropriate aquatic life uses.

Guidelines for Minimum Acceptable Data

Guidelines for generating an acceptable biological database are outlined in Table 8-1. The minimum acceptable information for evaluating compliance with biological criteria in "simple" situations is either fish or macroinvertebrate data generated using methods described in this manual and Ohio EPA (1987a). As the complexity of the environmental setting and accompanying influences increase, the complexity of the database also increases. We recommend that both fish and macroinvertebrate community analyses based on quantitative field methods (Ohio EPA 1987a) be used in these more complex situations. Table 8-1 includes many of the situations that Ohio EPA has encountered during the past eight years; however, it should not be considered all inclusive. A list of Ohio EPA study areas with the current availability of reports that detail the results of each is listed in Appendix F. The reports included in this listing provide examples of study design, sampling site location, and biological data evaluation. It is recommended that Ohio EPA be consulted prior to conducting field work so that these types of issues can be resolved prior to field sampling.

Study Design and Data Interpretation

The usefulness of any biological evaluation designed to determine use attainment/non-attainment is as dependent on proper study design as it is on the quality of the field sampling and data analysis. One driving principle behind the interpretation of biological results in flowing waters is an examination of those results along a longitudinal "continuum". Sampling sites should be located upstream from the potential influences (or at a suitable reference site in an adjacent water body), adjacent to the zone of initial mixing (point sources, sewer overflows, tributaries), in the recovery zone, and at points downstream sufficient to detect full recovery, if possible. Upon completing index calculations the results are plotted in a classic "x vs. y" manner where the x variable is distance downstream (i.e. river mile) and the y variable is the biological index value (e.g. IBI, I_{wb}, or ICI). It should be understood that the upstream site(s) do not necessarily represent a true control for evaluating what biological performance is attainable at downstream sites. Ecoregional reference sites are to be used for this purpose as well. A sufficient number of sites must also be sampled to ensure a credible evaluation of any environmental impacts. Too often stream and river

Table 8-1. Guidelines for determining the complexity of the biological database for evaluating compliance with the biological criteria in the Ohio WQS.

Situation	Fish Community IBI	Fish Community Iwb	Macroinvertebrates Quant.	Macroinvertebrates Qual.
1. "Simple" - single influence, <20-50 sq. mi. drainage area.	X, or		X	
2. "Complex" - multiple influences, larger streams, rivers.	X, and	X, and	X	
3. Toxicity evaluations	X, or	X, and	X	
4. Macro-habitat modification	X, or	X	-[a]	
5. Nonpoint subbasin assessment	X, and		X	
6. General problem discovery (i.e previously unknown or poorly understood problems are suspected)	X, or	X, and	X	
7. Intermittent influences (e.g. CSO, stormwater, batch discharges)	X, or	X, and	X	
8. Large river assessments (i.e. use of boat methods for fish)	X, and	X, and	X	

a Quantitative macroinvertebrate evaluation using multiple-plate (artificial substrate) samplers does not apply to macro-habitat modifications; a macroinvertebrate evaluation procedure is under development.

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studies contain too few sites. The position of potential physical and chemical influences is included on the "top" x axis and the corresponding biological response is then interpreted. Significant departures below the biological criteria for the surface water body in question are an indication of use non-attainment. This method not only answers the question of whether or not the use is or is not attained, but shows how significant any partial attainment or non-attainment is. This is known as assessing the magnitude (i.e. distance downstream) and severity (i.e. vertical departure from the criterion) of an observed impairment. This type of information can then be factored into regulatory decisions on how much additional pollutant removal is needed to achieve aquatic life use attainment in a direct sense.

It is also possible to evaluate results on an individual site basis as a reflection of attainment/non-attainment in a particular watershed or subbasin. This is particularly true in evaluating the effect of land use practices and potential changes with the implementation of Best Management Practices (BMPs). Study design and data interpretation are somewhat different from the longitudinal design in that one site is used to evaluate the integrated characteristics of the watershed above the site. The effects of different land use practices in two different basins could conceivably be evaluated with as few as two sites. This of course is dependent on the size of the watershed and the inherent complexities of the situation. This also demands careful selection of sites that are representative of the watershed as a whole.

Other information may be needed to supplement the use of biological data in making regulatory decisions. Evaluation of the physical habitat using the Qualitative Habitat Evaluation Index (QHEI) is performed routinely by Ohio EPA field biologists. This information is critical in determining whether or not the observed biological response is partly or wholly affected by habitat. Chemical data from the stream and effluent will be needed in the evaluation of point and nonpoint sources. Event related data may be needed in the evaluation of intermittent sources such as combined sewer overflows, storm water discharges, and nonpoint sources. In situations involving toxic discharges whole effluent bioassay testing may be necessary. These data provide the "link" between the physical and chemical nature of the perturbation and the magnitude and severity of the corresponding use impairment (biological degradation).

The role of a trained biologist in the use of the biological criteria approach is critical to its successful implementation. The underlying basis for the criteria themselves are complex and the requirements for basic data collection and analysis demand the use of a skilled professional. Karr et al. (1986) provide further details about this issue.

Proper study design, sampling, and data analysis are also essential for determining the appropriate aquatic life use. Other programmatic uses of biological criteria include the evaluation of anti-degradation applications, assessing the significance of non-compliance, and the ranking and prioritization of issues for grant awards or regulatory action. Thus quality study design and data interpretation are crucial given the potentially broad applications of the biological criteria.

Establishing Aquatic Life Use Designations

Determining which aquatic life use designation applies to a given water body is primarly based on the ability of the available habitat to support a given use. Two important factors are involved and include an assessment of the physical habitat and a knowledge of what the habitat will biologically support. First and foremost a showing that sufficient sites in a study area are biologically achieving a particular use is direct evidence that the use is appropriate. This is particularly important for designating waters as Exceptional Warmwater Habitat (EWH). Physical habitat is evaluated using the Qualitative Habitat Evaluation Index (QHEI). Although it is not an exact predictor of the biological indices there are threshold values above or below which we can be certain that a given use is appropriate. The proposed Ohio WQS list six different aquatic life uses: Exceptional Warmwater Habitat (EWH), Warmwater Habitat (WWH), Modified Warmwater Habitat (MWH), Coldwater Habitat (CWH), Seasonal Salmonid Habitat (SSH), and Limited Resource Waters (LRW). All except the LRW use reflect "fishable/swimmable" uses. The WWH, EWH, and MWH criteria for the IBI, I_{wb}, and ICI (by method) are listed as they appear in the proposed Ohio WQS (Table 7-1).

Exceptional Warmwater Habitat (EWH)

These are waters capable of supporting unusual or exceptional populations of warmwater fish and associated vertebrate and invertebrate organisms and plants on an annual basis. This includes waters of exceptional chemical quality that support sensitive species of fish, exceptionally diverse aquatic communities, and/or outstanding recreational or commercial fisheries. The biological criteria for the EWH use reflect this being set at the 75th percentile of the biological index results for the least impacted reference sites. This use designation is applied to waters that demonstrate the ability to sustain EWH levels by achieving the criteria at a sufficient number of sites for one or more of the biological indices. It is not necessary for both fish and macroinvertebrates to demonstrate attainment for a water body to be designated EWH. In our experience both organism groups usually demonstrate EWH in the majority of EWH designated waters.

Warmwater Habitat (WWH)

These waters are capable of supporting balanced, reproducing populations of warmwater fish and associated vertebrate and invertebrate organisms and plants on an annual basis. WWH is the most widely applied of any of the aquatic life use designations. This use is applied to those waters that either demonstrate biological attainment at a sufficient number of sites <u>or</u> provide adequate habitat for supporting the use. QHEI values that exceed the ecoregion 25th percentile values (Table 6-2) recorded at the least impacted reference sites demonstrate the capability to support WWH. QHEI values below the ecoregion 25th percentile of the least impacted reference sites, but above the 75th percentile value of the Modified Warmwater Habitat (MWH) reference sites (Table 6-5) indicate the potential for marginal habitat. Application of WWH to these sites will be determined on a case-by-case basis by the investigating biologists. Factors such as the pervasiveness of the marginal conditions and the biological performance of similar sites outside of areas directly influenced by chemical pollution sources will be considered. QHEI scores less than the 75th percentile of the MWH reference sites are an indication that WWH may not be attainable. This should be confirmed by a biological showing that WWH is not attained outside of areas directly influenced by chemical pollution sources. Options include retaining the WWH use, but modifying the biological criteria, or designation as a Modified Warmwater Habitat (MWH) water. The former will likely include unique natural conditions (e.g. swamp stream habitat) while the latter must include extensive modifications to the macro-habitat of anthropogenic origin.

Modified Warmwater Habitat (MWH)

This use is applied to streams and rivers that have been subjected to extensive macro-habitat modification. This includes, but is not limited to, channel maintenance activities approved under Section 404 of the WQA, instream impoundment (excluding publically owned reservoirs), and sedimentation resulting from non-acidic runoff from surface mining activities. A decision making flow chart directed primarily at this use is presented in Figure 8-2. The MWH use is based solely on the fish community; the ICI criteria do not apply to this use. As stated previously, a showing that the WWH criteria for the IBI and I_{wb} are attained means that WWH could apply, even though the macro-habitats have been modified. Therefore, non-attainment of the WWH fish community criteria must be demonstrated before the MWH use can be considered and designated. A QHEI less than the 75th percentile of the MWH reference sites is insufficient alone.

Coldwater Habitat (CWH)

These are waters capable of supporting populations of coldwater fish and associated vertebrate and invertebrate organisms and plants on an annual basis. Successful reproduction of salmonids is not essential. The existence of a put-and-take salmonid fishery may also be used to designate CWH, but this activity must be sanctioned by the Ohio Division of Wildlife. Table 8-2 provides a list of fish and macroinvertebrates that are characteristic of CWH. Designating a stream CWH based on non-salmonid species and taxa requires a showing of predominance, not mere presence in the community. Presently there are no IBI, modified I_{wb}, or ICI criteria for the CWH use.

Seasonal Salmonid Habitat (SSH)

These waters are capable of supporting the passage of salmonids from October through May. There are no biological criteria for this use since the WWH or EWH use jointly apply with SSH.

Limited Resource Waters

These are waters that have extremely limited physical habitat due to natural limitations or extreme alterations of anthropogenic origin. An example of the former are small, ephemeral streams of with drainage areas less than 3 sq. mi. An example of the latter are streams affected by chronic acid runoff from

Table 8-2. A list of fish species and macroinvertebrate taxa that have been collected by Ohio EPA and are considered to be indicative of cool and coldwater habitats in Ohio.

Fish	Macroinvertebrates
Brown trout (Salmo trutta)[1]	Crustacea
Rainbow trout (Salmo gairdneri)[1]	Gammarus minus
Brook trout (Salvelinus fontinalis)	Ephemeroptera
Brook stickleback (Culaea inconstans)	Ameletus sp.
Redside dace (Clinostomus elongatus)	Odonata
Mottled sculpin (Cottus bairdi)	Lanthus parvulus
	Plecoptera
	Leuctra sp.
	Megaloptera
	Nigronia fasciatus
	Trichoptera
	Diplectrona sp.
	Hydropsyche (Ceratopsyche) slossonae
	Rhyacophila sp.
	Glossosoma sp.
	Frenesia sp.
	Diptera
	Krenopelopia sp.
	Macropelopia sp.
	Trissopelopia sp.
	Diamesa sp.
	Eukiefferiella devonica group
	Heterotrissocladius marcidus group
	Thienemanniella Type 2

1 species is introduced and usually the result of a put-and-take fishery.

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surface mines with sustained pH values less than 4.1 S.U. or severe streambed sedimentation. As the result of severe habitat limitations LRW waters are not able to attain even the MWH biological criteria (Fig. 8-2) outside of areas of chemical pollution. QHEI alone may be sufficient to determine the appropriateness of the LRW designation if the score is less than the 25th percentile of the MWH headwaters reference sites.

Evaluating Use Attainment/Non-attainment

Determining whether or not a stream or river segment is attaining its designated aquatic life use usually involves plotting the biological index values in the aforementioned x vs. y manner. Figure 8-1 provides an example of this type of analysis. Aquatic life use attainment is principally judged on the ability of a water body to achieve the biological criteria. Traditionally this has been done using best professional judgement in evaluating the attainment of chemical criteria surrogates. In the absence of sound biological data these criteria may suffice, but at a lower level of evaluation.

The significance of any observation of non-attainment is based on the magnitude of the vertical departure of the index value from the ecoregion criterion and the distance downstream over which it is sustained. The area of departure can be quantified as a value termed the Area of Degradation Value (ADV). Guidance for calculating the ADV is currently under development. The example in Figure 8-1 shows both attainment and significant non-attainment of the WWH use. Ranges of exceptional, good, fair, poor, and very poor biological community condition have been defined for each of the three biological indices (Figures 8-3 thru 8-4; Tables 8-2 and 8-4). These are labled on Figure 8-1 to assist with interpreting the magnitude and severity of the non-attainment and portray it in terms understandable to non-biologists. The shaded boundaries reflect the area of insignificant departure for each index and assist in interpreting the significance of deviations below the applicable biological criterion. This is based on the variability inherent to each index as discussed in Appendix D. Values that lie above the shading indicate full attainment and those below indicate increasingly significant non-attainment. Values within the shaded boundary indicate insignificant departure, but this should be evaluated against what adjacent sites achieve. Sites of marked habitat contrast (e.g. free-flowing vs. impounded) should not be connected. The "odd" sites should be disconnected from the more predominant types. QHEI results can also be used to assist with deciding whether or not contiguous sites should be connected.

Generally, attainment of WWH and MWH is achieved when all of the biological criteria (IBI, ICI, and I_{wb}) are met. Thus if one organism group or index meets the WWH criteria, but the other group or index does not the use is only partially attained. This has been observed between organism groups (see Ohio EPA 1987b), but can also take place between the IBI and I_{wb} based on fish. Non-attainment is reflected by a failure of <u>all</u> indices to meet the applicable criterion. For EWH <u>designation</u> only one of the three biological indices need demonstrate attainment of EWH criteria outside of any areas of chemical degradation. For EWH <u>use attainment</u> the same procedure for WWH and MWH applies.

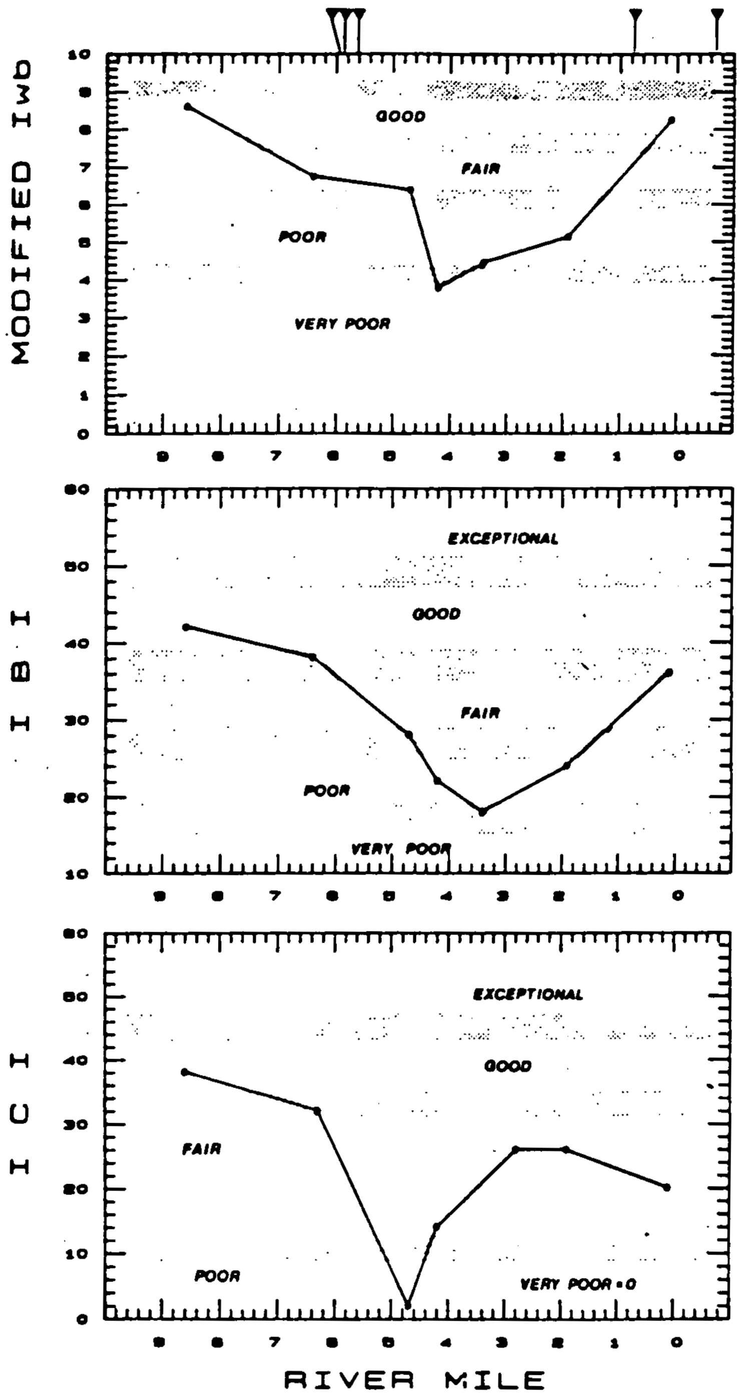

Figure 8-1: Example of how biological index results are plotted in an "x vs. y" manner to enable the interpretation of the significance of an environemtal impact. Chemical pollution sources are indicated at the top of the figure. The stream is designated WWH and is located in the EOLP ecoregion; wading sites criteria apply to the IBI and modified I_{wb}.

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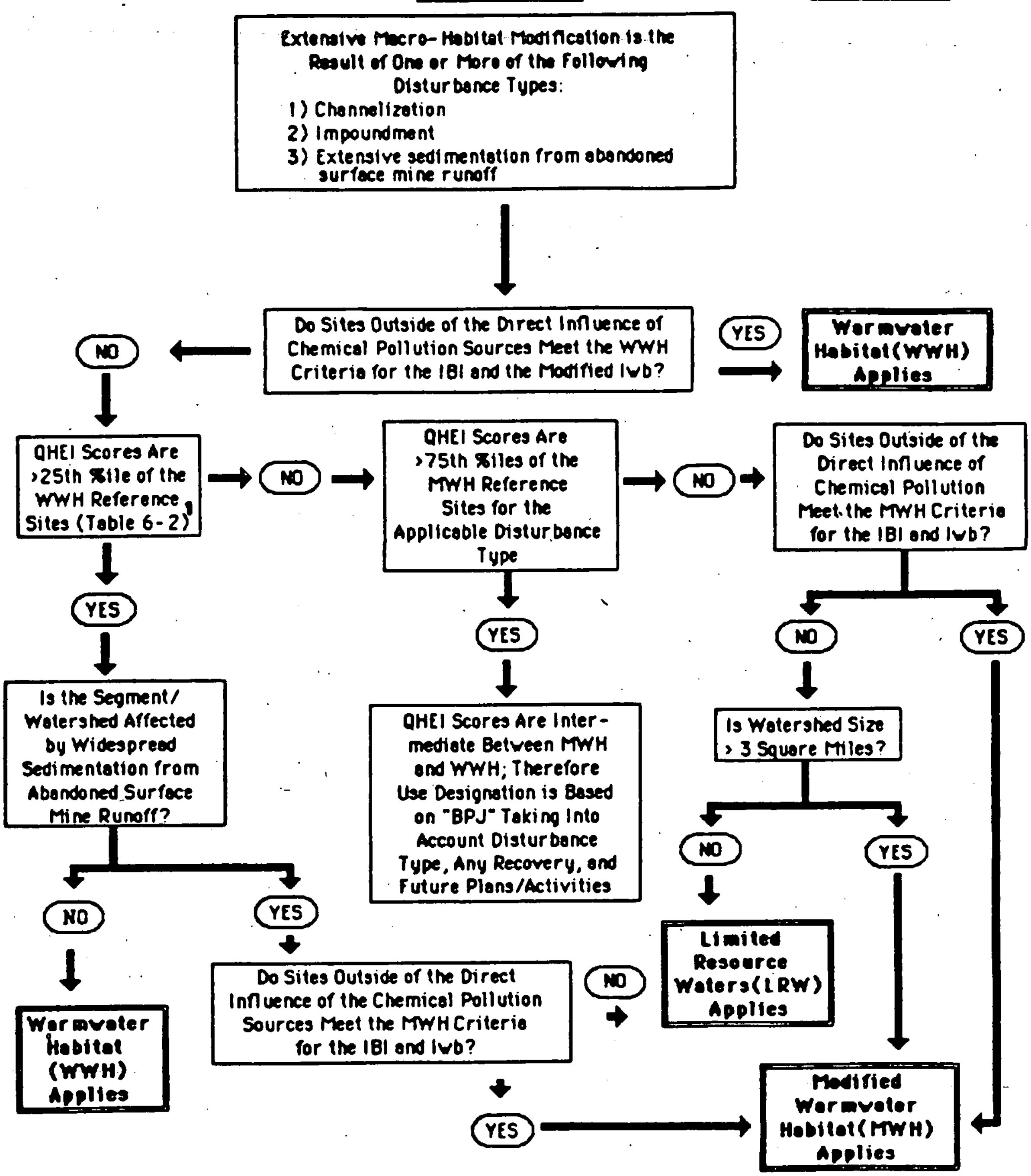

1 the median QHEI from the HELP ecoregion reference sites is used as an alternative value for the wading and headwaters sites.

Figure 8-2. Flow chart for determining the use designation of stream and river segments that have been subjected to extensive macro-habitat modification (emphasis is on the Modified Warmwater Habitat use designation).

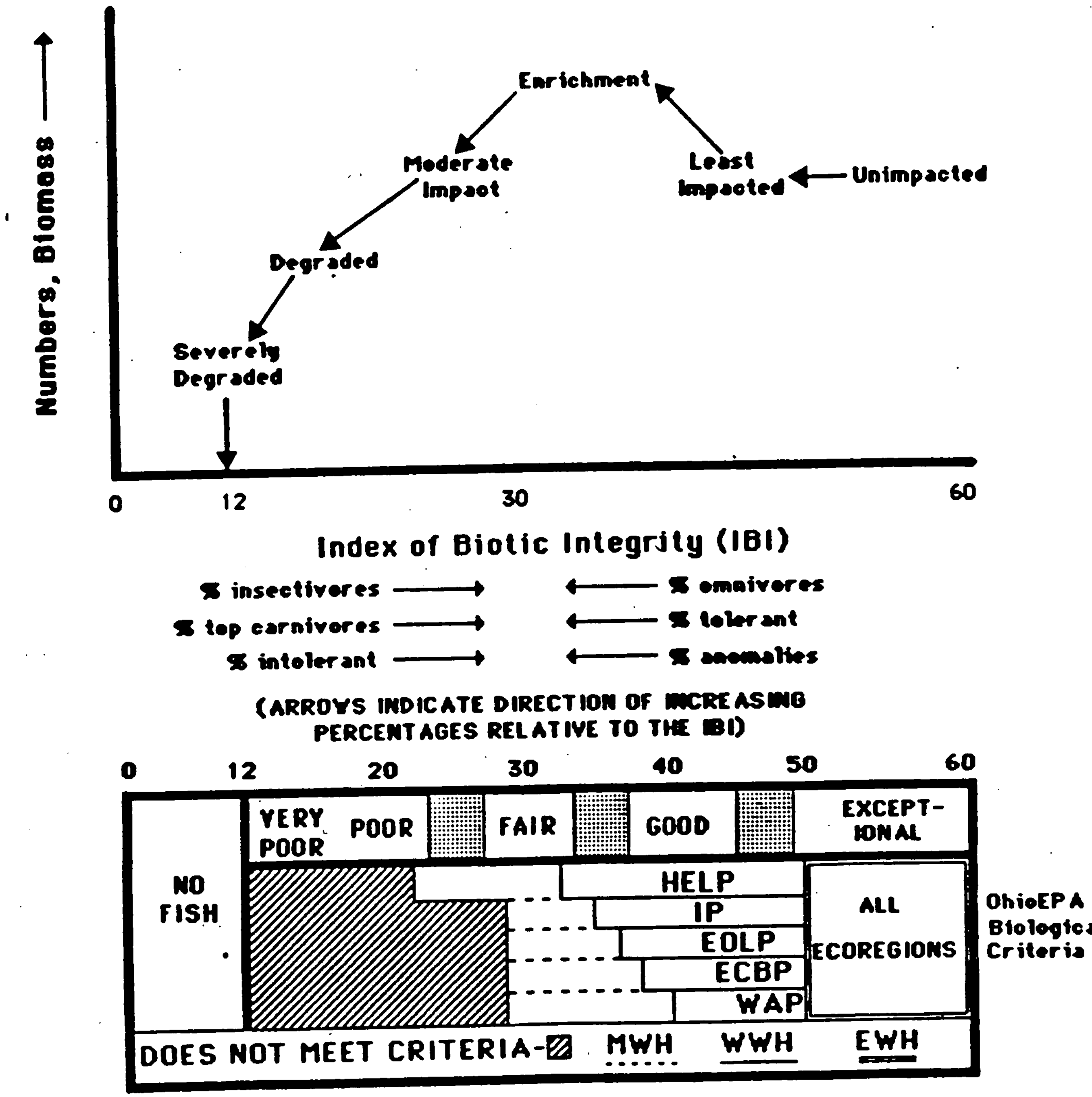

Figure 8-3. Conceptual response of fish community structural and functional attributes as portrayed by selected Index of Biotic Integrity metrics and the total IBI score. Narrative descriptions of fish community condition are correlated with varying levels and types of environmental perturbation. The WWH, MWH, and EWH biological criteria and exceptional, good, fair, poor, and very poor ranges are indicated for the IBI.

000156

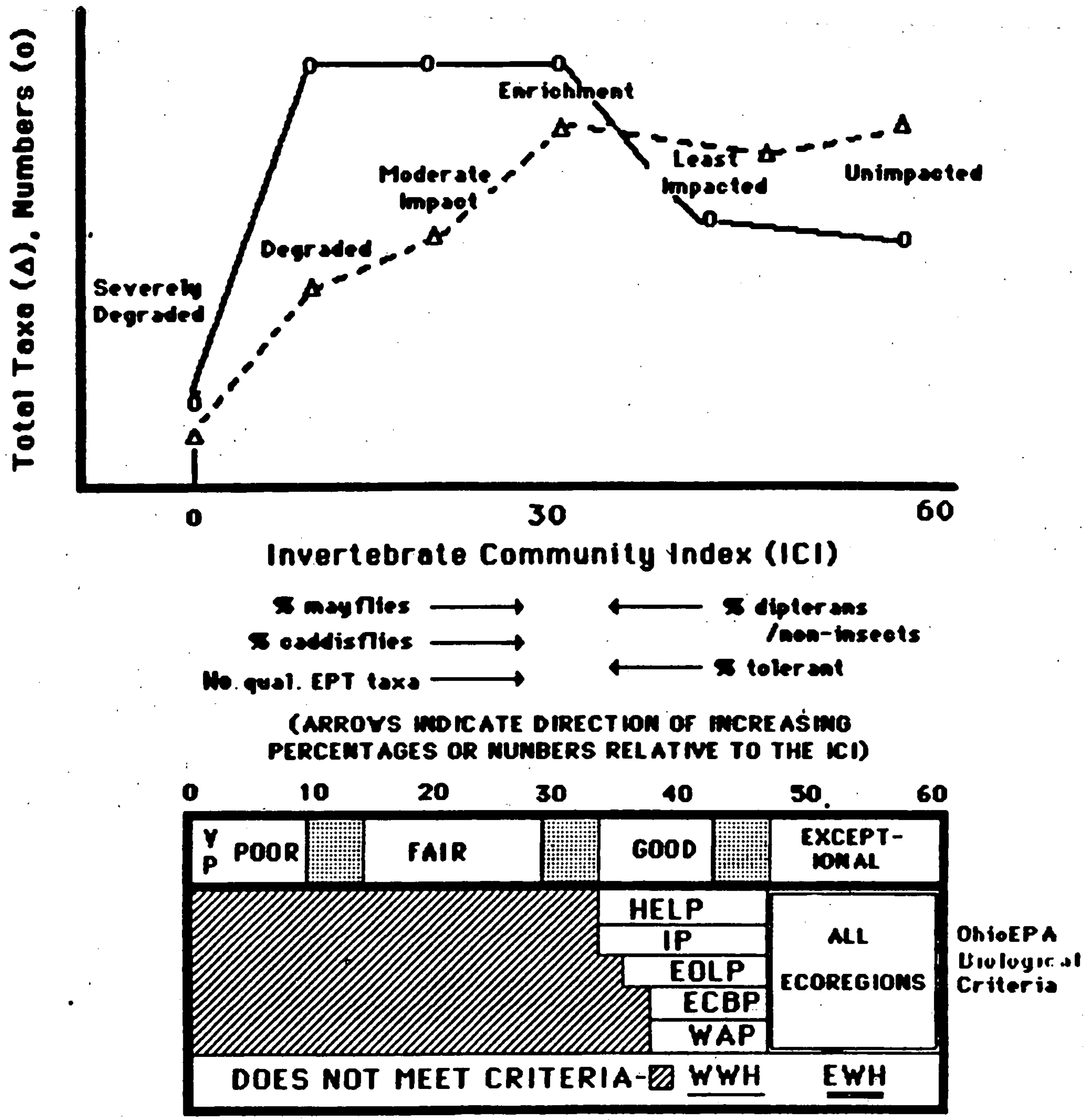

Figure 8-4. Conceptual response of macroinvertebrate community structural and functional attributes as portrayed by selected Invertebrate Community Index metrics and the total ICI score. Narrative descriptions of macroinvertebrate community condition are correlated with varying levels and types of environmental perturbation. The WWH and EWH biological criteria and exceptional, good, fair, poor, and very poor ranges are indicated for the ICI.

Table 8-2. Conceptual response of fish community structural and functional attributes as portrayed by modified Index of Well-Being (I_{wb}). Narrative descriptions of fish community condition for good, fair, poor, and very poor ranges are indicated.

Category	--- MEETS CWA GOALS ---		------ DOES NOT MEET CWA GOALS ------		
	"Exceptional"	"Good"	"Fair"	"Poor"	"Very Poor"
1.[a]	Exceptional, or unusual assemblage of species	Usual association of expected species	Some expected species absent, or in low abundance	Many expected species absent, or in low abundance	Most expected species absent
2.	Sensitive species abundant	Sensitive species present	Sensitive species absent, or in very low abundance	Sensitive species absent,	Only most tolerant species remain
3.	Exceptionally high species richness	High species richness	Declining species richness	Low species richness	Very low species richness
4.[b]	Composite index Greater than 9.5	Composite index Greater than 7.4 - 8.6[b], Less than 9.4	Composite index Greater than 5.3 - 6.3[b], Less than 7.4-8.6[b]	Composite index Greater than 4.5 - 5.0[b], Less than 5.3-6.3[b]	Composite index Less than 4.5 or 5.0[b]
5.	Outstanding recreational fishery		Tolerant species increasing, beginning to predominate	Tolerant species predominate	Community organization lacking
6.	Species with an endangered, threatened, or special concern status are present				

[a] Conditions: Categories 1, 2, 3 and 4 (if data is available) must be met and 5 or 6 must also be met in order to be designated in that particular class.

[b] encompasses range of ecoregional values; area of insignificant departure is - 0.5 from ecoregional criterion.

Table 8-3. Ranges and areas of insignificant departure (in parentheses) for IBI, modified Iwb, and ICI values representing exceptional, good, fair, poor, and very poor community condition.

Index/Site Category	Exceptional	Good[1]	Fair[1]	Poor	Very Poor
Index of Biotic Integrity					
Wading Sites	50-60 (45-49)	36-48 (31-41)	28-34 (23-27)	18-26 (13-17)	<18
Boat Sites	50-60 (45-49)	36-48 (31-39)	26-34 21-25)	16-24 (11-15)	<16
Headwaters Sites	50-60 (45-49)	40-48 (35-39)	26-38 (21-25)	16-24 (11-15)	<16
Modified Index of Well-Being (Iwb)					
Wading Sites	≥9.4 (8.8-9.3)	8.0-9.3 (7.4-8.4)	5.9-7.9 (5.3-5.8)	4.5-5.9 (3.9-4.4)	≤4.5
Boat Sites	≥9.5 (8.9-9.4)	8.3-9.4 (7.7-8.6)	6.4-8.7 (5.9-6.3)	5.0-6.4 (4.4-4.9)	≤5.0
Invertebrate Community Index (ICI)					
Artificial Substrates	48-60 (43-47)	34-46 (29-39)	14-32 (9-13)	2-12	0

1 area of insignificant departure is the range encompassing all ecoregions, excluding the HELP ecoregion for the IBI and modified Iwb.

APPENDIX A:

List of Ohio Reference Sites

Appendix A-1. List of Ohio Reference Sites (Wading Sites; > 20 sq.mi.).

River mile	Year	Sampler type	Eco-region	Drainage Area (sq.mi.)	Mean No. Species	Modified Iwb	IBI	SRP
FEDERAL CREEK								
1.3	84	D	WAP	138.0	32.5	9.4	47	Y
MCDOUGALL BRANCH								
2.4	83	D	WAP	29.0	30.0	8.7	42	Y
CLEAR CREEK								
2.0	84	D	WAP	89.0	22.8	8.2	38	Y
LITTLE WALNUT CREEK								
0.5	82	S	ECBP	44.0	22.0	9.4	47	
MILL CREEK								
28.1	84	D	ECBP	64.0	21.3	8.9	48	
FULTON CREEK								
10.4	85	D	ECBP	23.0	19.5	9.2	42	
LITTLE SCIOTO RIVER								
11.2	83	D	ECBP	47.0	23.0	7.5	39	Y
RUSH CREEK								
4.2	84	D	ECBP	85.0	25.3	8.0	41	Y
BIG DARBY CREEK								
76.6	86	D	ECBP	32.0	27.0	9.6	51	
63.7	86	D	ECBP	119.0	26.7	9.4	45	
55.1	86	D	ECBP	135.0	29.7	9.2	52	
LITTLE DARBY CREEK								
15.2	83	D	ECBP	162.0	27.0	9.5	51	Y
DEER CREEK								
51.4	85	D	ECBP	82.0	25.0	8.8	45	
OLENTANGY RIVER								
14.7	85	D	ECBP	483.0	22.0	9.0	38	
PAINT CREEK								
79.9	84	D	ECBP	39.0	22.0	8.1	48	Y
N. FK. PAINT CREEK								
17.6	83	D	ECBP	156.0	36.0	10.4	51	Y
COMPTON CREEK								
1.4	83	D	ECBP	59.0	33.7	10.1	52	Y
ROCKY FK PAINT CREEK								
18.1	85	D	IP	34.0	30.0	9.9	38	
RATTLESNAKE CREEK								
15.0	84	D	ECBP	123.0	16.7	9.2	33	Y
SALT CREEK								
25.9	83	D	WAP	175.0	29.3	9.3	51	Y
S FK SCIOTO BRUSH CR								
0.6	84	D	WAP	112.0	27.0	9.2	53	Y
SUNFISH CREEK								
8.0	83	D	WAP	132.0	31.0	8.9	51	Y
GRAND RIVER								
83.5	83	D	EOLP	85.0	24.0	8.3	40	Y
MILL CREEK								
17.2	83	D	EOLP	47.0	24.0	8.1	41	Y

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Appendix A-1. List of Ohio Reference Sites (Wading Sites; > 20 sq.mi.).

River mile	Year	Sampler type	Eco-region	Drainage Area (sq.mi.)	Mean No. Species	Modified Iwb	IBI	SRP
MILL CREEK								
10.0	84	D	EOLP	78.0	21.3	7.5	39	Y
KONZEN DITCH								
0.7	84	S	HELP	24.0	11.0	6.5	24	Y
BLUE CREEK								
3.5	84	D	HELP	107.0	24.0	8.6	26	Y
L. AUGLAIZE RIVER								
41.1	83	D	HELP	34.0	17.3	7.5	30	Y
TOWN CREEK								
3.5	83	D	HELP	49.0	20.0	8.4	25	
BLANCHARD RIVER								
78.0	83	D	ECBP	112.0	21.0	8.0	29	Y
71.8	83	D	ECBP	145.0	24.0	8.1	39	Y
OTTAWA RIVER								
46.1	85	D	ECBP	103.0	18.0	8.8	39	
SUGAR CREEK								
3.5	85	D	HELP	58.0	19.0	7.4	35	
MUD CREEK								
1.6	84	D	HELP	55.0	17.5	7.1	27	Y
HONEY CREEK								
12.5	83	D	ECBP	149.0	28.5	9.4	42	Y
MUDDY CREEK								
21.1	84	D	HELP	86.0	13.7	6.6	27	Y
CAPTINA CREEK								
20.5	83	D	WAP	91.0	32.3	10.0	57	
14.5	83	D	WAP	134.0	30.7	10.4	55	Y
6.7	83	D	WAP	154.0	26.0	9.5	50	
BEND FORK								
0.6	83	D	WAP	27.0	19.5	9.0	49	Y
S. FK. CAPTINA CREEK								
0.2	83	D	WAP	36.0	30.5	6.3	57	
N. FK. CAPTINA CREEK								
0.5	83	D	WAP	33.0	27.0	9.7	47	
MCINTYRE CREEK								
0.1	83	S	WAP	27.0	14.5	8.0	40	
L. MUSKINGUM RIVER								
17.3	83	D	WAP	234.0	34.0	9.2	53	Y
WITTEN FORK								
1.1	84	D	WAP	43.0	25.7	9.2	49	Y
SUNFISH CREEK								
23.9	83	D	WAP	22.0	20.0	9.7	46	
17.3	83	D	WAP	49.0	21.0	9.7	46	
5.0	83	D	WAP	101.0	28.0	10.0	51	
N. FK. YELLOW CREEK								
6.2	83	D	WAP	41.0	20.5	9.0	44	
0.8	83	D	WAP	58.0	25.0	8.5	48	

Appendix A-1. List of Ohio Reference Sites (Wading Sites; > 20 sq.mi.).

River mile	Year	Sampler type	Eco-region	Drainage Area (sq.mi.)	Mean No. Species	Modified Iwb	IBI	SRP
ELKHORN CREEK								
0.5	83	D	WAP	33.0	24.7	8.1	34	
ASHTABULA RIVER								
27.2	83	D	EOLP	65.0	21.0	8.1	43	Y
W. BR. ASHTABULA R.								
1.9	83	D	EOLP	27.0	20.0	8.1	47	Y
BULL CREEK								
1.9	85	E	EOLP	40.0	12.0	8.0	38	
M. FK. L. BEAVER CRK								
9.0	85	D	EOLP	114.0	22.3	9.2	45	
1.9	85	D	WAP	141.0	26.5	8.7	48	
W. FK. L. BEAVER CRK								
12.9	85	D	WAP	74.0	31.0	9.9	57	
0.8	85	D	WAP	111.0	26.7	10.2	55	
PINE CREEK								
20.5	83	D	WAP	102.0	31.0	8.9	41	Y
EAGLE CREEK								
11.6	83	D	IP	115.0	23.0	8.2	35	Y
OHIO BRUSH CREEK								
15.2	84	D	IP	371.0	24.3	8.5	46	Y
WHITEOAK CREEK								
12.8	83	D	IP	213.0	26.5	8.8	35	Y
LITTLE MIAMI RIVER								
85.4	83	D	ECBP	104.0	26.7	8.7	51	
O'BANNON CREEK								
0.3	83	D	IP	58.0	25.0	8.3	36	
E. FK. LITTLE MIAMI								
75.3	82	S	ECBP	23.0	19.7	8.4	44	
41.2	82	S	IP	216.0	27.0	9.6	52	
35.6	82	S	IP	236.0	33.0	9.7	56	
STONELICK CREEK								
1.2	84	D	IP	76.0	22.5	8.4	41	Y
W FK, E FK L MIAMI R								
0.2	82	S	IP	28.0	21.0	8.4	46	
DODSON CREEK								
0.2	82	S	IP	32.0	27.0	10.4	46	
TODD FORK								
20.3	84	D	ECBP	54.0	25.3	9.1	45	
ANDERSON FORK								
5.0	84	D	ECBP	77.0	29.7	10.0	51	Y
W. BR. HURON RIVER								
3.7	84	D	ECBP	236.0	22.0	8.8	37	
E. BR. ROCKY RIVER								
21.9	81	G	EOLP	31.0	22.5	9.1	45	
INDIAN CREEK								
9.4	85	D	ECBP	45.0	25.5	10.3	46	

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Appendix A-1. List of Ohio Reference Sites (Wading Sites; > 20 sq.mi.).

River mile	Year	Sampler type	Eco-region	Drainage Area (sq.mi.)	Mean No. Species	Modified Iwb	IBI	SRP
INDIAN CREEK								
4.1	83	D	ECBP	77.0	26.3	8.9	43	Y
HONEY CREEK								
10.0	82	S	ECBP	34.0	19.0	9.0	43	
3.2	82	S	ECBP	86.0	19.0	9.5	48	
LOST CREEK								
9.7	82	S	ECBP	31.0	21.0	10.2	48	
8.2	82	S	ECBP	44.0	15.0	9.2	40	
2.5	82	S	ECBP	58.0	20.0	9.6	41	
SPRING CREEK								
1.1	82	S	ECBP	26.0	18.0	9.2	50	
1.0	83	S	ECBP	26.0	15.3	8.7	44	Y
BEAVER CREEK								
0.7	84	D	ECBP	39.0	14.3	8.4	33	
STILLWATER RIVER								
51.2	83	D	ECBP	106.0	30.7	8.9	45	Y
TWIN CREEK								
42.2	83	D	ECBP	28.0	23.7	8.8	41	Y
35.5	86	D	ECBP	68.0	24.7	9.3	49	
19.2	86	D	ECBP	225.0	24.7	9.1	48	
BANTAS FORK								
1.3	86	E	ECBP	34.0	21.0	8.6	44	
S. FK. GREAT MIAMI								
1.5	84	D	ECBP	51.0	27.3	8.7	43	Y
CHAGRIN RIVER								
33.4	86	D	EOLP	54.0	21.3	8.3	46	
S. FK. WOLF CREEK								
4.9	84	D	WAP	72.0	21.5	8.3	46	Y
W. BR. WOLF CREEK								
3.5	84	D	WAP	140.0	30.0	9.6	52	Y
OLIVE GREEN CREEK								
2.7	84	D	WAP	80.0	32.5	9.9	49	Y
APPLE CREEK								
6.4	83	S	EOLP	24.0	12.7	7.6	32	
ROCKY FK. LICKING R.								
16.0	86	D	EOLP	20.1	24.7	8.7	39	
2.1	83	D	WAP	76.0	32.0	9.4	51	Y
2.0	86	D	WAP	76.0	29.0	9.6	53	
LOST RUN								
0.3	86	E	EOLP	23.0	22.0	9.0	47	
S. FK. LICKING RIVER								
27.6	84	D	EOLP	32.0	23.0	9.9	37	
N. FK. LICKING RIVER								
24.0	84	D	EOLP	64.0	22.7	8.7	47	Y
LAKE FK. LICKING R.								
0.1	84	D	EOLP	34.0	21.0	8.3	45	Y

Appendix A-1. List of Ohio Reference Sites (Wading Sites; > 20 sq.mi.).

River mile	Year	Sampler type	Eco-region	Drainage Area (sq.mi.)	Mean No. Species	Modified Iwb	IBI	SRP
JONATHAN CREEK								
12.3	84	D	WAP	105.0	19.3	8.4	35	Y
SUGAR CREEK								
3.8	83	D	WAP	337.0	32.0	9.3	52	
WHITE EYES CREEK								
0.3	83	D	WAP	53.0	24.5	8.5	39	
MUDDY FK. MOHICAN R.								
18.5	84	D	EOLP	20.1	21.7	8.3	39	Y
12.8	83	D	EOLP	42.0	27.0	9.1	40	Y
JEROME FORK								
13.0	84	D	EOLP	38.0	24.5	8.6	35	
WAKATOMIKA CREEK								
2.0	84	D	WAP	231.0	31.3	9.8	50	Y
MAHONING RIVER								
91.5	84	D	EOLP	44.0	22.0	9.4	43	Y
BREAKNECK CREEK								
6.8	83	D	EOLP	40.0	19.7	8.3	45	Y
6.8	84	D	EOLP	40.0	17.5	7.9	39	Y
VERMILION RIVER								
10.7	83	D	ECBP	249.0	27.7	9.5	45	Y

Appendix A-2. List of Ohio Reference Sites (Boat Sites).

River mile	Year	Sampler type	Eco-region	Drainage Area (sq.mi.)	Mean No. Species	Modified Iwb	IBI	SRP
SCIOTO RIVER								
201.2	84	A	ECBP	226.0	23.7	8.7	37	
105.2	86	A	ECBP	2610.0	21.5	9.4	43	
100.2	85	A	ECBP	3197.0	21.3	9.0	41	
56.0	85	A	WAP	5131.0	25.7	8.8	42	
9.0	85	A	WAP	6471.0	22.3	9.6	39	
WALNUT CREEK								
18.9	82	A	ECBP	183.0	20.3	8.7	43	
9.3	82	A	ECBP	212.0	24.7	9.3	49	
5.4	82	A	ECBP	272.0	22.3	8.9	51	
3.8	82	A	ECBP	273.0	25.7	9.1	53	
1.2	82	A	ECBP	285.0	20.7	8.9	42	
BIG WALNUT CREEK								
15.8	86	A	ECBP	272.0	23.0	9.6	41	
BIG DARBY CREEK								
42.0	81	A	ECBP	240.0	18.0	9.0	49	
31.8	79	A	ECBP	446.0	23.0	10.1	46	
30.1	79	A	ECBP	448.0	21.0	9.2	56	
29.3	81	A	ECBP	449.0	20.0	8.8	45	
[illegible]6.7	79	A	ECBP	457.0	20.0	9.6	56	
[illegible].0	79	A	ECBP	496.0	23.0	9.4	54	
24.0	81	A	ECBP	498.0	19.0	8.8	52	
7.4	81	A	ECBP	546.0	20.0	9.2	46	
3.7	81	A	ECBP	553.0	27.5	9.4	45	
PAINT CREEK								
5.0	85	A	ECBP	1137.0	25.3	9.6	44	
SALT CREEK								
9.9	84	A	WAP	281.0	34.3	10.4	52	
GRAND RIVER								
13.4	87	A	EOLP	630.0	22.0	9.2	48	
9.0	87	A	EOLP	685.0	24.0	8.1	42	
MAUMEE RIVER								
54.7	84	A	HELP	5559.0	19.7	8.4	33	
AUGLAIZE RIVER								
67.0	85	A	HELP	202.0	28.0	10.7	40	
39.7	85	A	HELP	327.0	29.0	9.8	41	
3.2	84	A	HELP	2428.0	22.7	8.6	32	
OTTAWA RIVER								
1.2	85	A	HELP	364.0	25.3	8.5	31	
LITTLE BEAVER CREEK								
4.5	85	A	WAP	496.0	19.5	9.3	45	
LITTLE SCIOTO RIVER								
12.6	83	A	WAP	200.0	27.0	9.7	51	Y
W FK OHIO BRUSH CRK								
1.3	84	A	IP	116.0	27.3	8.9	39	Y
[illegible]TTLE MIAMI RIVER								
[illegible]3.1	83	A	ECBP	122.0	23.7	9.4	49	

Appendix A-2. List of Ohio Reference Sites (Boat Sites).

River mile	Year	Sampler type	Eco-region	Drainage Area (sq.mi.)	Mean No. Species	Modified Iwb	IBI	SRP
LITTLE MIAMI RIVER								
44.2	83	A	IP	680.0	22.0	9.2	39	
36.0	83	A	IP	959.0	22.7	9.5	45	
24.2	83	A	IP	1145.0	21.0	9.2	39	
E. FK. LITTLE MIAMI								
44.1	82	A	IP	195.0	25.0	9.1	47	
42.3	84	A	IP	212.0	28.3	9.4	45	Y
15.5	82	A	IP	359.0	19.0	9.1	49	
HURON RIVER								
12.3	84	A	HELP	371.0	22.7	9.7	44	
GREAT MIAMI RIVER								
130.0	82	A	ECBP	540.0	25.3	9.0	49	
116.9	82	A	ECBP	845.0	21.3	8.8	45	
98.5	82	A	ECBP	1030.0	21.5	9.2	52	
95.6	82	A	ECBP	1137.0	21.7	9.1	49	
91.0	80	A	ECBP	1150.0	20.7	8.3	37	
88.1	80	A	ECBP	1161.0	18.7	8.6	33	
MAD RIVER								
2.0	84	A	ECBP	650.0	26.5	9.5	49	
1.2	84	A	ECBP	655.0	17.0	8.7	33	
STILLWATER RIVER								
41.4	84	A	ECBP	189.0	28.7	9.4	43	Y
32.9	82	A	ECBP	233.0	21.5	8.4	45	
28.1	82	A	ECBP	503.0	21.0	9.1	49	
26.7	82	A	ECBP	505.0	23.0	9.2	50	
24.4	82	A	ECBP	516.0	26.0	9.5	52	
21.2	82	A	ECBP	528.0	24.3	8.6	54	
18.0	82	A	ECBP	599.0	21.7	8.9	49	
16.0	82	A	ECBP	607.0	22.7	9.1	49	
GREENVILLE CREEK								
0.1	82	A	ECBP	201.0	17.0	8.6	47	
FOURMILE CREEK								
0.3	80	A	ECBP	315.0	18.7	8.8	49	
TWIN CREEK								
0.2	86	A	ECBP	316.0	21.7	9.1	49	
PORTAGE RIVER								
17.6	85	A	HELP	435.0	24.3	9.4	41	
CONOTTON CREEK								
22.0	84	A	WAP	90.0	23.0	8.6	37	Y
KILLBUCK CREEK								
50.4	85	A	EOLP	137.0	18.7	8.6	34	
35.6	83	A	EOLP	367.0	17.3	8.5	39	
LICKING RIVER								
28.1	85	A	EOLP	533.0	26.0	10.0	38	
S. FK. LICKING RIVER								
13.1	84	A	EOLP	117.0	13.7	9.0	39	

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Appendix A-2. List of Ohio Reference Sites (Boat Sites).

River mile	Year	Sampler type	Eco-region	Drainage Area (sq.mi.)	Mean No. Species	Modified Iwb	IBI	SRP
N. FK. LICKING RIVER								
2.4	82	A	EOLP	229.0	24.7	9.1	39	
STILLWATER CREEK								
1.2	83	A	WAP	483.0	17.5	8.2	37	
TUSCARAWAS RIVER								
17.7	83	A	WAP	2473.0	18.5	8.4	39	
6.9	83	A	WAP	2577.0	20.0	8.7	34	
WALHONDING RIVER								
8.0	83	A	WAP	1576.0	18.0	8.7	45	
3.8	83	A	WAP	2192.0	21.0	8.5	44	
1.2	83	A	WAP	2255.0	17.7	8.7	41	
KOKOSING RIVER								
25.5	0	A	EOLP	251.0	22.0	9.4	46	
20.9	87	A	EOLP	276.0	22.0	9.7	52	
CUYAHOGA RIVER								
64.5	84	A	EOLP	187.0	16.7	8.3	42	

Appendix A-3. List of Ohio Reference Sites (Headwater Sites; < 20 sq.mi.).

River mile	Year	Sampler type	Eco-region	Drainage Area (sq.mi.)	Mean No. Species	Modified Iwb	IBI	SRP
SCOTTS CREEK								
8.9	78	S	WAP	1.0	7.0	7.4	48	
8.1	78	S	WAP	3.0	11.0	7.3	46	
MCDOUGALL BRANCH								
2.4	83	D	WAP	15.0	29.3	8.7	47	
TURKEY RUN								
1.4	82	S	EOLP	9.0	9.0	4.9	33	
SYCAMORE CREEK								
4.7	84	D	ECBP	19.0	18.0	6.0	46	
TAYLOR CREEK								
4.4	84	D	ECBP	12.0	21.3	8.9	39	
SILVER CREEK								
2.4	84	D	ECBP	9.0	21.0	7.4	39	
W. FORK W. MANSFIELD								
0.8	81	H	ECBP	5.0	14.0	4.5	34	
BIG DARBY CREEK								
79.2	79	G	ECBP	5.0	16.0	7.5	49	
SPAIN CREEK								
0.4	81	G	ECBP	10.0	19.0	7.9	56	
TRIB TO GEORGES CRK								
6.0	84	D	ECBP	1.0	5.5	4.4	42	
ROCKY FK PAINT CREEK								
23.3	85	E	IP	18.0	24.0	9.4	57	
CLEAR CREEK								
8.5	85	D	ECBP	13.0	22.0	9.0	57	
MOBERLY BR CLEAR CRK								
0.9	85	D	IP	2.0	15.0	6.8	49	
BAUGHMAN CREEK								
3.0	84	D	EOLP	20.0	19.7	7.2	38	
TRIB TO MILLS CREEK								
0.5	85	F	HELP	5.0	6.0	4.9	26	
MUDDY CREEK								
37.3	82	G	HELP	4.0	12.0	4.5	28	
LEITH RUN								
2.8	83	S	WAP	7.0	17.0	7.5	50	
WILLS CREEK								
4.0	83	G	WAP	3.0	3.0	3.1	36	
CAT RUN								
3.3	83	D	WAP	7.0	6.5	3.7	33	
BEND FORK								
12.3	83	D	WAP	1.0	7.0	3.7	36	
CEDAR LICK CREEK								
0.1	83	G	WAP	6.0	11.5	4.3	52	
WILLIAMS CREEK								
1.4	83	D	WAP	11.0	16.5	8.7	51	
PINEY FORK								
0.3	83	D	WAP	15.0	16.5	5.7	55	

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• ~endix A-3. List of Ohio Reference Sites (Headwater Sites; < 20 sq.mi.).

River mile	Year	Sampler type	Eco-region	Drainage Area (sq.mi.)	Mean No. Species	Modified Iwb	IBI	SRP
BAKER FORK								
0.4	83	D	WAP	12.0	18.0	8.6	56	
ELKHORN CREEK								
6.6	83	S	WAP	3.0	9.0	5.4	49	
STRAWCAMP RUN								
0.4	83	S	WAP	5.0	15.0	7.5	52	
CENTER FORK								
0.1	83	S	WAP	12.0	19.0	9.0	60	
TRAIL RUN								
0.3	83	S	WAP	3.0	14.0	7.7	56	
TRIB TO N.F. YELLOW								
0.1	83	G	WAP	4.0	7.0	3.5	40	
COWLES CREEK								
7.2	81	G	EOLP	6.0	12.0	4.3	42	
E FK STATELINE CREEK								
0.1	85	E	EOLP	2.0	6.3	5.1	45	
STONE MILL RUN								
2.0	85	E	EOLP	8.0	14.0	7.2	46	
E BR M FK L BEAVER								
.0	85	D	EOLP	14.0	20.3	8.0	43	
..K CREEK								
4.1	80	G	IP	7.0	12.0	5.1	46	
TREBOR RUN								
0.1	80	G	IP	7.0	16.0	5.7	58	
CAVE RUN								
0.2	80	G	IP	4.0	15.0	5.1	58	
LOUISE TRIBUTARY								
2.8	80	G	IP	2.0	15.0	4.5	40	
0.2	80	G	IP	7.0	15.0	5.2	42	
TURTLE CREEK								
6.3	83	D	IP	18.0	19.0	8.3	36	
DRY RUN								
1.8	83	F	IP	5.0	10.0	8.9	40	
NEWMAN RUN								
0.3	83	F	ECBP	9.0	18.0	8.2	47	
MILL RUN								
0.4	83	D	ECBP	8.0	17.5	8.2	49	
GLADY RUN								
5.8	83	G	ECBP	3.0	5.5	4.0	35	
FIVEMILE CREEK								
0.4	82	S	IP	10.0	16.3	6.2	36	
OLDTOWN CREEK								
0.1	83	S	ECBP	10.0	16.5	7.5	49	
E. BR. ROCKY RIVER								
~6.7	81	G	EOLP	12.0	16.0	7.5	46	
.LY CREEK								
0.8	81	G	EOLP	4.0	12.0	5.7	37	

Appendix A-3. List of Ohio Reference Sites (Headwater Sites; < 20 sq.mi.).

River mile	Year	Sampler type	Eco-region	Drainage Area (sq.mi.)	Mean No. Species	Modified Iwb	IBI	SRP
W. BR. ROCKY RIVER								
33.6	81	G	EOLP	8.0	20.5	8.1	40	
BEAR CREEK								
12.1	81	G	ECBP	5.0	16.0	4.8	43	
MCKEES CREEK								
0.5	82	S	ECBP	17.0	14.5	8.3	45	
CHEROKEE MANS RUN								
3.5	82	S	ECBP	16.0	13.0	6.9	40	
CHAPMAN CREEK								
4.0	84	D	ECBP	18.0	14.0	8.8	43	
BRUSH CREEK								
0.1	82	G	ECBP	16.0	16.0	5.1	48	
LITTLE TWIN CREEK								
6.3	86	E	ECBP	5.0	19.7	8.4	47	
BANTAS FORK								
9.4	86	E	ECBP	9.0	16.7	8.0	48	
DOUGHTY CREEK								
15.4	83	G	EOLP	12.0	18.5	5.0	49	
11.7	83	D	EOLP	17.0	25.0	8.4	48	
L. KILLBUCK CREEK								
0.8	83	G	EOLP	20.0	10.0	4.9	36	
ROCKY FK. LICKING R.								
16.0	86	D	EOLP	18.0	24.7	8.7	44	
LONG RUN								
0.4	86	D	EOLP	6.0	15.7	8.3	53	
E BR NIMISHILLEN CRK								
8.6	85	E	EOLP	12.0	18.7	8.6	39	
TRIB TO L. CHIPPEWA								
0.1	86	E	EOLP	1.0	6.0	4.6	34	
E. BR. JELLOWAY CRK.								
2.3	85	E	EOLP	3.0	17.0	8.2	52	
LANG CREEK								
3.2	84	D	EOLP	14.0	17.3	8.2	47	
AX FACTORY RUN								
0.1	82	G	EOLP	3.0	7.0	3.9	36	
EAGLE CREEK								
22.5	81	G	EOLP	9.0	15.0	6.9	43	
SILVER CREEK								
2.3	81	G	EOLP	7.0	14.0	6.6	45	
0.8	81	G	EOLP	11.0	16.0	7.6	48	
LITTLE DEER CREEK								
0.5	84	D	EOLP	7.0	16.0	6.9	37	

Appendix A-4. List of Ohio Reference Sites (Macroinvertebrate Data).

River mile	Year	Eco-region	Drainage area (sq.mi.)	ICI	SRP
HOCKING RIVER					
92.0	82	EOLP	18	48	
FEDERAL CREEK					
0.9	84	WAP	150	44	Y
MCDOUGALL BRANCH					
1.1	83	WAP	15	32	Y
CLEAR CREEK					
16.1	82	ECBP	20	40	
2.1	83	WAP	87	52	Y
2.1	84	WAP	87	46	Y
2.0	82	WAP	89	46	
MUDDY PRAIRIE RUN					
0.4	82	EOLP	8	50	
SCIOTO RIVER					
216.7	84	ECBP	128	44	
203.3	84	ECBP	223	40	
101.4	81	ECBP	2641	50	
101.4	81	ECBP	2641	46	
78.7	81	ECBP	3819	50	
78.7	81	ECBP	3819	46	
70.4	81	ECBP	3849	44	
56.2	85	WAP	5131	46	
25.9	85	WAP	6082	46	
WALNUT CREEK					
47.0	82	EOLP	27	36	
5.3	82	ECBP	272	40	
4.1	82	ECBP	273	46	
1.2	82	ECBP	285	44	
BIG WALNUT CREEK					
60.0	82	ECBP	37	34	
54.6	82	ECBP	67	38	
15.9	86	ECBP	272	46	
12.8	85	ECBP	539	50	
ALUM CREEK					
17.9	86	ECBP	146	38	
RUSH CREEK					
5.9	84	ECBP	85	12	Y
BIG DARBY CREEK					
62.6	86	ECBP	121	54	
54.2	86	ECBP	136	50	
43.9	86	ECBP	220	36	
LITTLE DARBY CREEK					
15.3	83	ECBP	162	36	Y
OLENTANGY RIVER					
20.3	83	ECBP	453	48	
20.3	85	ECBP	453	48	
20.3	86	ECBP	453	52	

Appendix A-4. List of Ohio Reference Sites (Macroinvertebrate Data).

River mile	Year	Eco-region	Drainage area (sq.mi.)	ICI	SRP
OLENTANGY RIVER					
19.6	83	ECBP	455	50	
19.6	86	ECBP	455	52	
19.6	85	ECBP	455	46	
WHETSTONE CREEK					
16.1	84	ECBP	43	26	
9.9	84	ECBP	61	42	
PAINT CREEK					
75.3	84	ECBP	55	48	Y
5.1	85	WAP	1140	56	
N. FK. PAINT CREEK					
17.5	83	ECBP	140	46	Y
COMPTON CREEK					
1.4	83	ECBP	66	50	Y
ROCKY FK PAINT CREEK					
23.3	85	IP	14	46	
18.1	85	IP	34	28	
CLEAR CREEK					
8.2	85	ECBP	14	50	
6.8	85	ECBP	19	28	
RATTLESNAKE CREEK					
13.3	84	ECBP	137	48	Y
W BR RATTLESNAKE CRK					
4.3	84	ECBP	20	22	Y
SALT CREEK					
25.7	83	WAP	170	46	Y
5.9	84	WAP	280	44	Y
M. FK. SALT CREEK					
4.7	86	WAP	58	38	
S FK SCIOTO BRUSH CR					
0.6	84	WAP	114	34	Y
SUNFISH CREEK					
8.1	83	WAP	104	40	Y
GRAND RIVER					
83.5	84	EOLP	95	26	Y
BAUGHMAN CREEK					
4.1	84	EOLP	20	48	Y
MILL CREEK					
18.2	84	EOLP	86	30	Y
12.1	83	EOLP	54	20	Y
MAUMEE RIVER					
100.6	84	HELP	2128	32	
91.5	84	HELP	2169	42	
69.3	84	HELP	2311	44	
58.1	84	HELP	5544	44	
BLUE CREEK					
3.4	84	HELP	114	36	Y

Appendix A-4. List of Ohio Reference Sites (Macroinvertebrate Data).

River mile	Year	Eco-region	Drainage area (sq.mi.)	ICI	SRP
BAD CREEK					
19.9	84	HELP	39	34	Y
KONZEN DITCH					
0.7	84	HELP	76	42	Y
GORDON CREEK					
6.7	84	HELP	74	26	Y
AUGLAIZE RIVER					
96.8	83	ECBP	65	32	Y
67.0	85	HELP	202	40	
39.3	85	HELP	327	36	
28.8	85	HELP	717	50	
POWELL CREEK					
4.3	84	HELP	112	18	Y
TOWN CREEK					
3.6	83	HELP	49	34	
BLANCHARD RIVER					
97.5	83	ECBP	43	32	
95.6	83	ECBP	69	22	Y
76.4	83	ECBP	113	20	
71.9	83	ECBP	158	38	
EAGLE CREEK					
13.9	83	HELP	31	38	
SUGAR CREEK					
0.6	84	HELP	69	34	Y
EAGLE CREEK					
0.5	84	ECBP	38	46	Y
TWELVEMILE CREEK					
1.7	83	HELP	35	24	Y
TIFFIN RIVER					
37.6	84	ECBP	386	28	
0.9	84	HELP	776	22	
MUD CREEK					
1.5	84	HELP	66	38	Y
LICK CREEK					
11.0	84	HELP	36	34	
BRUSH CREEK					
5.8	83	HELP	68	34	Y
BEAVER CREEK					
2.9	83	ECBP	44	48	Y
SANDUSKY RIVER					
47.8	81	ECBP	774	44	
31.9	81	HELP	1047	48	
23.9	81	HELP	1068	50	
21.3	81	HELP	1071	48	
HONEY CREEK					
34.1	83	ECBP	28	42	Y
12.4	84	ECBP	144	46	Y

Appendix A-4. List of Ohio Reference Sites (Macroinvertebrate Data).

River mile	Year	Eco-region	Drainage area (sq.mi.)	ICI	SRP
MUDDY CREEK					
23.3	84	HELP	86	38	Y
GRIES DITCH					
1.0	84	HELP	15	42	Y
CAPTINA CREEK					
17.6	83	WAP	163	48	Y
BEND FORK					
0.7	83	WAP	29	44	Y
L. MUSKINGUM RIVER					
16.9	83	WAP	276	46	Y
ARCHERS FORK					
0.7	83	WAP	20	24	Y
WITTEN FORK					
1.2	84	WAP	34	26	Y
SUNFISH CREEK					
9.3	83	WAP	87	46	Y
ASHTABULA RIVER					
25.9	83	EOLP	72	38	Y
W. BR. ASHTABULA R.					
1.8	84	EOLP	27	42	Y
LITTLE BEAVER CREEK					
15.0	85	WAP	261	56	
8.0	85	WAP	294	54	
4.5	85	WAP	496	40	
N. FK. L. BEAVER CRK					
7.6	85	WAP	106	40	
0.1	85	WAP	487	46	
M. FK. L. BEAVER CRK					
9.0	85	EOLP	118	38	
1.9	85	WAP	141	46	
W. FK. L. BEAVER CRK					
12.9	85	WAP	74	50	
0.8	85	WAP	111	48	
LITTLE SCIOTO RIVER					
12.7	83	WAP	200	40	Y
PINE CREEK					
20.4	83	WAP	107	34	Y
SHADE RIVER					
17.6	84	WAP	120	42	Y
EAGLE CREEK					
11.4	83	IP	128	34	Y
OHIO BRUSH CREEK					
17.4	84	IP	173	42	Y
W FK OHIO BRUSH CRK					
1.2	84	IP	140	42	Y
WHITEOAK CREEK					
12.8	83	IP	233	36	Y

Appendix A-4. List of Ohio Reference Sites (Macroinvertebrate Data).

River mile	Year	Eco-region	Drainage area (sq.mi.)	ICI	SRP
N. FK. WHITEOAK CRK					
7.0	83	IP	51	22	Y
LITTLE MIAMI RIVER					
86.4	83	ECBP	102	38	
83.1	83	ECBP	121	42	
35.9	83	IP	959	42	
23.9	83	IP	1145	54	
TURTLE CREEK					
6.2	83	IP	18	30	
E. FK. LITTLE MIAMI					
54.4	83	IP	179	42	Y
44.1	82	IP	195	34	
41.0	82	IP	209	44	
41.0	84	IP	221	50	Y
34.9	82	IP	238	36	
15.4	82	IP	358	48	
9.1	82	IP	380	52	
6.6	82	IP	458	56	
STONELICK CREEK					
1.0	84	IP	80	38	Y
TODD FORK					
19.5	84	ECBP	55	44	
17.2	84	ECBP	80	44	
HURON RIVER					
13.1	84	HELP	352	48	
12.3	84	HELP	365	30	
SLATE RUN					
4.1	84	ECBP	40	40	Y
ROCKY RIVER					
2.9	81	EOLP	291	38	
E. BR. ROCKY RIVER					
26.6	81	EOLP	12	50	
15.2	81	EOLP	57	54	
8.4	81	EOLP	64	52	
W. BR. ROCKY RIVER					
33.5	81	EOLP	8	34	
N. BR. ROCKY RIVER					
5.5	81	EOLP	35	50	
GREAT MIAMI RIVER					
158.3	82	ECBP	119	46	
130.1	82	ECBP	540	50	
118.5	82	ECBP	840	48	
100.8	82	ECBP	972	48	
95.7	82	ECBP	1137	50	
92.6	82	ECBP	1149	50	
INDIAN CREEK					
10.3	85	ECBP	92	48	

Appendix A-4. List of Ohio Reference Sites (Macroinvertebrate Data).

River mile	Year	Eco-region	Drainage area (sq.mi.)	ICI	SRP
INDIAN CREEK					
4.4	85	ECBP	113	28	
4.3	83	ECBP	77	44	Y
MAD RIVER					
1.6	84	ECBP	654	48	Y
0.2	84	ECBP	656	46	Y
STILLWATER RIVER					
62.0	84	ECBP	42	34	Y
50.2	83	ECBP	107	30	Y
44.2	84	ECBP	197	24	Y
33.5	82	ECBP	232	48	
27.8	82	ECBP	501	54	
25.1	82	ECBP	514	48	
18.3	82	ECBP	599	42	
14.9	82	ECBP	609	48	
PAINTER CREEK					
0.9	84	ECBP	47	44	Y
GREENVILLE CREEK					
34.5	82	ECBP	6	50	
28.9	82	ECBP	68	40	
26.8	84	ECBP	76	52	Y
22.3	82	ECBP	106	38	
1.4	82	ECBP	200	44	
N. FK. STILLWATER R.					
0.4	82	ECBP	18	42	
TWIN CREEK					
41.3	84	ECBP	29	30	Y
38.0	83	ECBP	42	40	Y
35.8	86	ECBP	68	46	
19.1	86	ECBP	225	50	
1.0	86	ECBP	315	50	
S. FK. GREAT MIAMI					
3.6	84	ECBP	44	46	Y
CHAGRIN RIVER					
33.4	86	EOLP	54	46	
30.7	86	EOLP	56	46	
13.0	86	EOLP	166	46	
AURORA BRANCH					
3.8	86	EOLP	37	46	
PORTAGE RIVER					
27.3	85	HELP	428	40	
18.1	85	HELP	435	46	
17.1	85	HELP	494	42	
17.0	85	HELP	494	46	
S. FK. WOLF CREEK					
6.1	84	WAP	80	38	Y
W. BR. WOLF CREEK					
13.8	83	WAP	126	38	Y

Appendix A-4. List of Ohio Reference Sites (Macroinvertebrate Data).

River mile	Year	Eco-region	Drainage area (sq.mi.)	ICI	SRP
W. BR. WOLF CREEK					
3.5	84	WAP	152	46	Y
OLIVE GREEN CREEK					
2.2	84	WAP	75	36	Y
CONOTTON CREEK					
20.5	83	WAP	154	40	Y
IRISH CREEK					
2.5	84	WAP	16	36	Y
KILLBUCK CREEK					
55.4	81	EOLP	87	52	
51.6	83	EOLP	117	30	
51.6	81	EOLP	117	48	
35.6	83	EOLP	367	50	
24.8	83	WAP	463	46	
13.3	83	WAP	582	42	
ROCKY FK. LICKING R.					
3.0	83	WAP	68	46	Y
S. FK. LICKING RIVER					
31.6	84	ECBP	12	44	
28.5	84	ECBP	31	30	
27.6	84	ECBP	32	40	
21.3	84	EOLP	58	44	Y
13.0	84	EOLP	117	28	
N. FK. LICKING RIVER					
14.9	84	EOLP	70	42	Y
LAKE FK. LICKING R.					
0.2	84	EOLP	39	40	Y
JONATHAN CREEK					
12.2	84	WAP	105	44	Y
SUGAR CREEK					
25.0	83	EOLP	88	36	Y
3.6	83	WAP	340	46	
LITTLE SUGAR CREEK					
4.2	84	EOLP	9	30	Y
SANDY CREEK					
10.3	86	WAP	289	30	
10.3	85	WAP	289	40	
M BR NIMISHILLEN CRK					
6.8	85	EOLP	34	42	
E BR NIMISHILLEN CRK					
8.6	85	EOLP	12	42	
STILL FK. SANDY CRK.					
5.7	84	WAP	74	28	Y
TUSCARAWAS RIVER					
126.9	83	EOLP	5	40	
119.3	83	EOLP	35	44	
30.9	83	WAP	2416	36	

Appendix A-4. List of Ohio Reference Sites (Macroinvertebrate Data).

River mile	Year	Eco-region	Drainage area (sq.mi.)	ICI	SRP
TUSCARAWAS RIVER					
18.4	83	WAP	2470	42	
10.7	83	WAP	2566	46	
RIVER STYX					
5.1	83	EOLP	9	34	
MUDDY FK. MOHICAN R.					
19.4	84	EOLP	20	18	Y
13.5	83	EOLP	42	28	Y
JEROME FORK					
13.0	84	EOLP	35	50	
WAKATOMIKA CREEK					
2.0	84	WAP	252	48	Y
MAHONING RIVER					
90.9	84	EOLP	44	36	Y
PYMATUNING CREEK					
22.7	83	EOLP	38	42	Y
CUYAHOGA RIVER					
64.3	84	EOLP	187	54	
TINKERS CREEK					
28.3	84	EOLP	4	40	
BREAKNECK CREEK					
7.0	83	EOLP	15	36	Y
6.9	84	EOLP	40	32	
POTTER CREEK					
1.5	84	EOLP	40	36	Y
VERMILION RIVER					
10.7	84	ECBP	272	46	Y
WABASH RIVER					
476.0	85	ECBP	102	26	

Appendix A-5. List of Modified Ohio Reference Sites (Wading Sites; >20 sq.mi.)

River mile	Year	Sampler type	Eco-region	Drainage Area (sq.mi.)	Mean No. Species	Modified Iwb	IBI	SRP
HOCKING RIVER								
96.2	82	S	ECBP	24.0	9.0	6.1	29	
SUGAR CREEK								
26.8	86	D	ECBP	30.0	11.0	6.9	36	
KONZEN DITCH								
0.7	83	S	HELP	25.0	11.0	6.5	24	Y
0.7	84	S	HELP	24.0	11.0	6.5	24	Y
GORDON CREEK								
6.8	84	D	HELP	37.0	17.5	7.8	23	Y
NORTH POWELL CREEK								
7.4	84	D	HELP	40.0	11.5	5.2	19	Y
BLUE CREEK								
3.5	83	D	HELP	114.0	24.0	8.6	26	Y
HOAGLIN CREEK								
5.8	83	G	HELP	41.0	13.0	5.3	23	
TOWN CREEK								
19.8	83	S	HELP	22.0	8.5	5.0	21	
BLANCHARD RIVER								
97.5	83	D	ECBP	43.0	21.5	8.0	29	
96.4	83	D	ECBP	48.0	23.0	7.8	28	
MUD CREEK								
1.6	84	D	HELP	56.0	17.5	7.1	27	Y
LICK CREEK								
11.0	84	D	HELP	36.0	14.0	5.9	26	
MUDDY CREEK								
21.1	84	D	HELP	86.0	13.7	6.6	27	Y
TYMOCHTEE CREEK								
8.6	79	G	ECBP	229.0	23.0	7.7	38	
6.1	79	G	ECBP	232.0	19.0	5.7	32	
MCINTYRE CREEK								
0.1	83	S	WAP	27.0	14.5	8.0	40	
MCMAHON CREEK								
5.6	83	D	WAP	80.0	21.7	6.9	30	
2.3	83	D	WAP	85.0	20.0	6.4	32	
YELLOW CREEK								
27.5	83	D	WAP	29.0	17.3	6.7	28	
N. FK. LITTLE MIAMI								
0.4	83	D	ECBP	37.0	16.5	7.1	30	
STONY CREEK								
4.3	82	S	ECBP	25.0	15.5	7.7	45	
STILLWATER RIVER								
63.0	82	S	ECBP	26.0	15.7	6.2	29	
SWAMP CREEK								
4.5	82	G	ECBP	25.0	15.0	3.7	25	
MUCHINIPPI CREEK								
2.3	82	S	ECBP	85.0	14.5	7.1	42	

Appendix A-5. List of Modified Ohio Reference Sites (Wading Sites; >20 sq.mi.)

River mile	Year	Sampler type	Eco-region	Drainage Area (sq.mi.)	Mean No. Species	Modified Iwb	IBI	SRP
L. CHIPPEWA CREEK								
0.1	83	D	EOLP	29.0	9.0	5.2	30	
BUFFALO CREEK								
0.8	84	D	WAP	49.0	15.0	5.1	25	

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Appendix A-6. List of Modified Ohio Reference Sites (Boat Sites).

River mile	Year	Sampler type	Eco-region	Drainage Area (sq.mi.)	Mean No. Species	Modified Iwb	IBI	SRP
SCIOTO RIVER								
150.0	79	A	ECBP	977.0	12.7	7.6	29	
142.8	79	A	ECBP	1021.0	13.3	8.2	34	
142.8	80	A	ECBP	1021.0	10.0	6.5	25	
140.0	79	A	ECBP	1042.0	10.3	7.2	33	
133.0	86	A	ECBP	1068.0	16.0	8.3	37	
EVERSOLE RUN								
0.3	79	A	ECBP	1040.0	12.7	8.1	35	
MILL CREEK								
0.2	79	A	ECBP	179.0	15.3	7.9	33	
MAUMEE RIVER								
49.6	84	A	HELP	5581.0	17.3	7.9	31	
45.7	86	A	HELP	5655.0	18.0	8.7	39	
38.5	86	A	HELP	5697.0	11.3	6.5	31	
33.0	86	A	HELP	6052.0	11.7	6.5	25	
AUGLAIZE RIVER								
65.0	86	A	HELP	207.0	16.7	8.2	26	
15.2	84	A	HELP	1932.0	17.3	7.1	23	
BLANCHARD RIVER								
13.5	83	A	HELP	704.0	13.0	5.4	22	
TIFFIN RIVER								
34.8	84	A	ECBP	410.0	12.7	6.4	26	
26.0	84	A	HELP	422.0	11.7	5.9	27	
23.2	84	A	HELP	471.0	13.7	6.4	25	
14.1	84	A	HELP	556.0	10.3	5.6	28	
6.5	84	A	HELP	737.0	14.3	6.4	32	
1.0	84	A	HELP	777.0	15.0	7.2	25	
MIAMI-ERIE CANAL								
55.4	84	A	HELP	200.0	16.0	5.6	20	
SANDUSKY RIVER								
43.0	81	A	ECBP	957.0	9.3	6.4	33	
30.2	81	A	HELP	1049.0	11.3	7.1	33	
26.6	81	A	HELP	1065.0	10.0	5.7	28	
19.0	81	A	HELP	1253.0	9.3	5.2	24	
HONEY CREEK								
0.4	81	A	ECBP	176.0	10.3	5.4	27	
LITTLE RACCOON CREEK								
30.9	84	A	WAP	37.0	5.3	4.0	26	
28.1	84	A	WAP	48.0	12.0	6.8	27	
GREAT MIAMI RIVER								
115.3	82	A	ECBP	849.0	13.3	7.4	38	
107.6	82	A	ECBP	904.0	13.7	7.5	35	
83.3	80	A	ECBP	1174.0	13.7	7.6	30	
77.1	80	A	ECBP	2591.0	13.3	6.5	27	
GREENVILLE CREEK								
22.6	82	A	ECBP	106.0	14.3	7.1	33	

Appendix A-6. List of Modified Ohio Reference Sites (Boat Sites).

River mile	Year	Sampler type	Eco-region	Drainage Area (sq.mi.)	Mean No. Species	Modified Iwb	IBI	SRP
CONOTTON CREEK								
22.0	84	A	WAP	90.0	21.0	8.0	37	
FEEDER CANAL								
0.6	84	A	EOLP	200.0	12.0	6.7	29	
N. FK. LICKING RIVER								
3.4	82	A	EOLP	227.0	16.3	8.6	39	
TUSCARAWAS RIVER								
39.3	83	A	WAP	2374.0	19.7	7.6	33	
CHIPPEWA CREEK								
17.2	83	A	EOLP	33.0	12.0	6.1	29	
6.5	83	A	EOLP	146.0	11.0	6.1	24	
0.5	83	A	EOLP	188.0	11.7	6.0	29	
WILLS CREEK								
46.6	84	A	WAP	554.0	11.3	6.2	26	
37.7	84	A	WAP	671.0	13.0	6.5	28	
27.0	84	A	WAP	738.0	11.5	5.8	26	
LEATHERWOOD CREEK								
0.8	84	A	WAP	91.0	10.3	5.4	22	
MAHONING RIVER								
46.3	80	A	EOLP	424.0	17.7	7.9	38	
MOSQUITO CREEK								
11.3	80	A	EOLP	101.0	13.0	6.3	26	

Appendix A-7. List of Modified Ohio Reference Sites (Headwater Sites; < 20 sq.mi.)

River mile	Year	Sampler type	Eco-region	Drainage Area (sq.mi.)	Mean No. Species	Modified Iwb	IBI	SRP
M. FK. GORDON CREEK								
3.8	84	D	ECBP	6.0	10.5	6.3	29	
S. POWELL CREEK								
14.1	84	D	HELP	4.0	8.0	2.6	23	
CARTER CREEK								
2.1	84	D	HELP	10.0	12.0	7.2	24	Y
BRUSH CREEK								
19.1	84	D	HELP	17.0	10.0	5.8	23	
PARAMOUR CREEK								
6.3	85	D	ECBP	4.5	11.0	7.2	34	
PPG TRIB TO PARAMOUR								
3.7	85	E	HELP	1.0	9.0	6.9	32	
ELK FORK								
17.6	81	G	WAP	7.5	11.0	3.6	30	
16.2	81	G	WAP	9.5	13.0	4.0	32	
LITTLE MIAMI RIVER								
101.3	83	F	ECBP	9.0	14.5	6.9	31	
PAINTER CREEK								
16.2	82	G	ECBP	3.5	13.5	3.6	27	
INDIAN CREEK								
0.5	82	G	ECBP	20.0	16.5	4.6	24	
N. FK. STILLWATER R.								
0.4	82	S	ECBP	18.0	13.3	6.2	26	
BLACK FORK CREEK								
2.7	87	D	WAP	7.8	12.5	5.3	29	
OGG RUN								
1.5	87	E	WAP	4.0	11.5	5.5	36	
SWARTZ DITCH								
0.2	85	E	EOLP	16.0	19.7	6.0	31	
RIVER STYX								
3.9	83	D	EOLP	14.0	16.7	8.3	27	
L. CHIPPEWA CREEK								
11.4	86	E	EOLP	0.8	10.0	5.9	30	
11.4	81	G	EOLP	0.8	8.0	3.4	35	

Appendix A-8. List of Relatively Unimpacted Ohio Sites Used to Judge the Performance of the ICI (Macroinvertebrate Data).

River mile	Year	Eco-region	Drainage area (sq.mi.)	ICI	SRP
HOCKING RIVER					
92.0	82	EOLP	18	48	
CLEAR CREEK					
16.1	82	ECBP	20	40	
14.2	82	ECBP	22	36	
13.1	82	ECBP	27	40	
9.5	82	EOLP	52	34	
2.0	82	WAP	89	46	
MUDDY PRAIRIE RUN					
0.4	82	EOLP	8	50	
SCIOTO RIVER					
221.5	84	ECBP	77	18	
220.1	84	ECBP	98	24	
216.7	84	ECBP	128	44	
212.5	84	ECBP	160	24	
211.4	84	ECBP	161	22	
210.1	84	ECBP	167	30	
207.7	84	ECBP	178	28	
203.3	84	ECBP	223	40	
136.7	81	ECBP	1052	48	
133.0	81	ECBP	1068	34	
129.3	81	EOLP	1620	26	
116.3	81	ECBP	2267	30	
116.3	81	EOLP	2267	30	
101.4	81	ECBP	2641	50	
101.4	81	ECBP	2641	46	
98.4	81	ECBP	3219	48	
98.4	81	ECBP	3219	38	
85.4	81	ECBP	3349	44	
85.4	81	ECBP	3349	46	
78.7	81	ECBP	3819	50	
78.7	81	ECBP	3819	46	
70.4	81	ECBP	3849	44	
WALNUT CREEK					
47.0	82	EOLP	27	36	
42.5	82	EOLP	41	44	
36.9	82	EOLP	63	32	
32.3	82	ECBP	82	42	
28.9	82	ECBP	138	42	
23.5	82	ECBP	152	48	
16.9	82	ECBP	188	44	
13.7	82	ECBP	198	40	
5.3	82	ECBP	272	40	
4.1	82	ECBP	273	46	
1.2	82	ECBP	285	44	
BIG WALNUT CREEK					
66.6	82	ECBP	17	28	

Appendix A-8. List of Relatively Unimpacted Ohio Sites Used to Judge the Performance of the ICI (Macroinvertebrate Data).

River mile	Year	Eco-region	Drainage area (sq.mi.)	ICI	SRP
BIG WALNUT CREEK					
65.1	82	ECBP	27	28	
60.0	82	ECBP	37	34	
54.6	82	ECBP	67	38	
50.4	82	ECBP	101	28	
WHETSTONE CREEK					
21.8	84	ECBP	35	20	
20.9	84	ECBP	36	20	
16.1	84	ECBP	43	26	
12.8	84	ECBP	51	46	
9.9	84	ECBP	61	42	
SHAW CREEK					
0.4	84	ECBP	30	30	
MAUMEE RIVER					
100.6	84	HELP	2128	32	
91.5	84	HELP	2169	42	
69.3	84	HELP	2311	44	
58.1	84	HELP	5544	44	
TOWN CREEK					
3.6	83	HELP	49	34	
BLANCHARD RIVER					
97.5	83	ECBP	43	32	
95.6	83	ECBP	50	38	
88.3	83	ECBP	83	26	
79.2	83	ECBP	106	26	
76.4	83	ECBP	113	20	
71.9	83	ECBP	158	38	
61.4	83	ECBP	237	40	
35.7	83	HELP	488	38	
EAGLE CREEK					
13.9	83	HELP	31	38	
TIFFIN RIVER					
37.6	84	ECBP	386	28	
31.0	84	HELP	414	32	
26.2	84	HELP	422	38	
23.0	84	HELP	470	46	
18.7	84	HELP	563	24	
7.1	84	HELP	736	50	
0.9	84	HELP	776	22	
LICK CREEK					
11.0	84	HELP	36	34	
8.0	84	HELP	61	22	
1.3	84	HELP	105	28	
SANDUSKY RIVER					
47.8	81	ECBP	774	44	
41.8	81	ECBP	962	46	

Appendix A-8. List of Relatively Unimpacted Ohio Sites Used to Judge the Performance of the ICI (Macroinvertebrate Data).

River mile	Year	Eco-region	Drainage area (sq.mi.)	ICI	SRP
SANDUSKY RIVER					
38.9	81	ECBP	1008	40	
38.1	81	ECBP	1029	38	
36.5	81	ECBP	1031	36	
31.9	81	HELP	1047	48	
23.9	81	HELP	1068	50	
21.3	81	HELP	1071	48	
RACCOON CREEK					
11.7	83	HELP	12	20	
LITTLE MIAMI RIVER					
101.4	83	ECBP	9	38	
86.4	83	ECBP	102	38	
83.1	83	ECBP	121	42	
80.0	83	ECBP	130	36	
76.2	83	ECBP	229	42	
72.3	83	ECBP	295	32	
66.6	83	ECBP	308	38	
63.2	83	ECBP	360	38	
53.9	83	ECBP	402	42	
52.8	83	ECBP	407	36	
35.9	83	IP	959	42	
33.0	83	IP	1035	42	
30.7	83	IP	1057	46	
29.2	83	IP	1064	52	
28.0	83	IP	1069	48	
23.9	83	IP	1145	54	
20.9	83	IP	1161	46	
18.5	83	IP	1187	46	
13.1	83	IP	1203	50	
8.8	83	IP	1713	52	
TURTLE CREEK					
6.2	83	IP	18	30	
0.7	83	IP	58	36	
E. FK. LITTLE MIAMI					
70.1	82	ECBP	88	32	
56.2	82	IP	151	36	
54.4	82	IP	158	36	
44.1	82	IP	195	34	
41.0	82	IP	209	44	
34.9	82	IP	238	36	
19.6	82	IP	343	38	
15.4	82	IP	358	48	
13.2	82	IP	374	50	
11.5	82	IP	376	54	
9.1	82	IP	380	52	
6.6	82	IP	458	56	

Appendix A-8. List of Relatively Unimpacted Ohio Sites Used to Judge the Performance of the ICI (Macroinvertebrate Data).

River mile	Year	Eco-region	Drainage area (sq.mi.)	ICI	SRP
E. FK. LITTLE MIAMI					
4.1	82	IP	483	50	
1.2	82	IP	498	44	
0.8	82	IP	498	46	
TODD FORK					
19.5	84	ECBP	55	44	
17.2	84	ECBP	80	44	
LYTLE CREEK					
8.6	84	ECBP	4	38	
8.1	84	ECBP	4	48	
0.6	84	ECBP	20	40	
HURON RIVER					
13.1	84	HELP	352	48	
12.3	84	HELP	365	30	
ROCKY RIVER					
7.7	81	EOLP	287	28	
4.7	81	EOLP	290	44	
2.9	81	EOLP	291	38	
E. BR. ROCKY RIVER					
26.6	81	EOLP	12	50	
17.5	81	EOLP	50	48	
15.2	81	EOLP	57	54	
11.6	81	EOLP	61	46	
10.7	81	EOLP	62	38	
8.4	81	EOLP	64	52	
6.4	81	EOLP	66	36	
5.1	81	EOLP	67	46	
4.9	81	EOLP	77	42	
W. BR. ROCKY RIVER					
33.5	81	EOLP	8	34	
27.3	81	EOLP	69	40	
17.2	81	EOLP	133	46	
N. BR. ROCKY RIVER					
5.5	81	EOLP	35	50	
0.5	81	EOLP	37	40	
GREAT MIAMI RIVER					
158.3	82	ECBP	119	46	
148.6	82	ECBP	290	40	
142.2	82	ECBP	415	48	
130.1	82	ECBP	540	50	
127.6	82	ECBP	547	44	
126.0	82	ECBP	550	42	
123.9	82	ECBP	562	40	
118.5	82	ECBP	840	48	
114.3	82	ECBP	873	34	
113.5	82	ECBP	877	46	

Appendix A-8. List of Relatively Unimpacted Ohio Sites Used to Judge the Performance of the ICI (Macroinvertebrate Data).

River mile	Year	Eco-region	Drainage area (sq.mi.)	ICI	SRP
GREAT MIAMI RIVER					
110.1	82	ECBP	894	46	
106.1	82	ECBP	926	46	
104.7	82	ECBP	939	46	
100.8	82	ECBP	972	48	
95.7	82	ECBP	1137	50	
92.6	82	ECBP	1149	50	
MAD RIVER					
53.2	84	ECBP	35	44	
52.1	84	ECBP	36	52	
51.2	84	ECBP	56	52	
50.7	84	ECBP	58	50	
38.4	84	ECBP	188	44	
35.9	84	ECBP	242	28	
32.7	84	ECBP	264	38	
29.5	84	ECBP	310	44	
29.1	84	ECBP	310	44	
25.6	84	ECBP	464	44	
24.1	84	ECBP	490	20	
21.1	84	ECBP	495	46	
17.5	84	ECBP	528	46	
11.5	84	ECBP	554	44	
8.7	84	ECBP	617	30	
6.3	84	ECBP	627	46	
3.9	84	ECBP	642	38	
1.6	84	ECBP	654	48	
0.2	84	ECBP	656	46	
STILLWATER RIVER					
63.0	82	ECBP	26	34	
59.8	82	ECBP	39	48	
57.0	82	ECBP	72	44	
55.4	82	ECBP	77	38	
52.4	82	ECBP	99	40	
37.8	82	ECBP	207	40	
33.5	82	ECBP	232	48	
31.1	82	ECBP	441	50	
27.8	82	ECBP	501	54	
25.1	82	ECBP	514	48	
18.3	82	ECBP	599	42	
14.9	82	ECBP	609	48	
11.4	82	ECBP	638	46	
9.0	82	ECBP	650	44	
7.9	82	ECBP	651	50	
4.7	82	ECBP	664	50	
0.8	82	ECBP	675	50	
GREENVILLE CREEK					
34.5	82	ECBP	6	50	

Appendix A-8. List of Relatively Unimpacted Ohio Sites Used to Judge the Performance of the ICI (Macroinvertebrate Data).

River mile	Year	Eco-region	Drainage area (sq.mi.)	ICI	SRP
GREENVILLE CREEK					
28.9	82	ECBP	68	40	
22.3	82	ECBP	106	38	
19.5	82	ECBP	140	32	
16.2	82	ECBP	153	32	
13.7	82	ECBP	174	40	
10.5	82	ECBP	188	46	
5.6	82	ECBP	196	54	
1.4	82	ECBP	200	44	
SWAMP CREEK					
4.4	82	ECBP	25	36	
N. FK. STILLWATER R.					
0.4	82	ECBP	18	42	
KILLBUCK CREEK					
55.4	81	EOLP	87	52	
51.6	81	EOLP	117	48	
51.6	83	EOLP	117	30	
45.9	81	EOLP	210	32	
35.6	83	EOLP	367	50	
28.9	83	WAP	397	36	
24.8	83	WAP	463	46	
23.7	83	WAP	464	32	
20.7	83	WAP	497	32	
13.3	83	WAP	582	42	
APPLE CREEK					
0.1	81	EOLP	55	24	
S. FK. LICKING RIVER					
31.6	84	ECBP	12	44	
28.5	84	ECBP	31	30	
27.6	84	ECBP	32	40	
13.0	84	EOLP	117	28	
12.9	84	EOLP	117	26	
SUGAR CREEK					
3.6	83	WAP	340	46	
1.8	83	WAP	350	54	
0.6	83	WAP	356	42	
TUSCARAWAS RIVER					
126.9	83	EOLP	5	40	
119.3	83	EOLP	35	44	
73.7	83	WAP	586	28	
68.7	83	WAP	1105	42	
61.4	83	WAP	1408	34	
58.3	83	WAP	1413	34	
58.1	83	WAP	1413	38	
57.8	83	WAP	1770	34	
56.8	83	WAP	1772	44	

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Appendix A-8. List of Relatively Unimpacted Ohio Sites Used to Judge the Performance of the ICI (Macroinvertebrate Data).

River mile	Year	Eco-region	Drainage area (sq.mi.)	ICI	SRP
TUSCARAWAS RIVER					
54.2	83	WAP	1814	44	
52.3	83	WAP	1816	50	
47.2	83	WAP	1870	40	
30.9	83	WAP	2416	36	
21.1	83	WAP	2443	40	
18.4	83	WAP	2470	42	
10.7	83	WAP	2566	46	
RIVER STYX					
5.1	83	EOLP	9	34	
L. CHIPPEWA CREEK					
2.1	81	EOLP	26	40	
0.1	81	EOLP	30	32	
JEROME FORK					
13.0	84	EOLP	35	50	
0.9	84	EOLP	161	28	
WILLS CREEK					
75.8	84	WAP	281	34	
71.0	84	WAP	287	36	
62.7	84	WAP	408	22	
60.1	84	WAP	470	28	
58.6	84	WAP	472	20	
56.5	84	WAP	480	22	
53.5	84	WAP	486	36	
46.6	84	WAP	554	20	
MILL CREEK					
11.3	82	EOLP	28	24	
CUYAHOGA RIVER					
64.3	84	EOLP	187	54	
55.8	84	EOLP	291	34	
54.3	84	EOLP	293	46	
52.6	84	EOLP	309	22	
48.4	84	EOLP	327	32	
46.4	84	EOLP	332	36	
42.6	84	EOLP	340	38	
TINKERS CREEK					
28.3	84	EOLP	4	40	
27.1	84	EOLP	11	36	
25.4	84	EOLP	16	36	
24.5	84	EOLP	20	24	
23.1	84	EOLP	24	26	
22.1	84	EOLP	41	24	
16.7	84	EOLP	56	30	
14.3	84	EOLP	62	22	
12.5	84	EOLP	67	28	
BRANDYWINE CREEK					
	84	EOLP	25	20	

Appendix A-8. List of Relatively Unimpacted Ohio Sites Used to Judge the Performance of the ICI (Macroinvertebrate Data).

River mile	Year	Eco-region	Drainage area (sq.mi.)	ICI	SRP
BREAKNECK CREEK					
6.9	84	EOLP	40	32	
3.1	84	EOLP	73	38	
1.8	84	EOLP	74	40	
0.5	84	EOLP	78	44	
FRENCH CREEK					
3.2	82	EOLP	27	42	

Appendix A-9. List of Moderately Impacted Ohio Sites Used to Judge the Performance of the ICI (Macroinvertebrate Data).

River mile	Year	Eco-region	Drainage area (sq.mi.)	ICI	SRP
RUSH CREEK					
2.1	82	WAP	234	16	
WALNUT CREEK					
40.1	82	EOLP	65	24	
38.9	82	EOLP	69	24	
L. AUGLAIZE RIVER					
14.3	83	HELP	119	28	
3.9	83	HELP	399	28	
MIDDLE CREEK					
1.4	83	HELP	102	16	
BLANCHARD RIVER					
57.4	83	ECBP	336	18	
55.2	83	ECBP	346	14	
53.8	83	ECBP	355	16	
49.8	83	ECBP	379	16	
44.9	83	ECBP	454	16	
EAGLE CREEK					
0.3	83	ECBP	51	16	
BRUSH CREEK					
13.3	84	HELP	38	16	
11.7	84	HELP	40	16	
8.7	84	HELP	58	16	
3.3	84	HELP	64	8	
LITTLE RACOOON CREEK					
28.4	84	WAP	45	12	
24.5	84	WAP	67	16	
LITTLE MIAMI RIVER					
98.7	83	ECBP	30	16	
TURTLE CREEK					
4.4	83	IP	31	8	
0.5	83	IP	58	18	
LYTLE CREEK					
7.1	84	ECBP	6	22	
HURON RIVER					
9.5	84	HELP	386	14	
ROCKY RIVER					
11.5	81	EOLP	267	24	
10.8	81	EOLP	268	16	
9.9	81	EOLP	268	14	
E. BR. ROCKY RIVER					
3.4	81	EOLP	75	20	
1.1	81	EOLP	76	28	
W. BR. ROCKY RIVER					
31.4	81	EOLP	16	32	
29.4	81	EOLP	61	22	
5.4	81	EOLP	151	30	

Appendix A-9. List of Moderately Impacted Ohio Sites Used to Judge the Performance of the ICI (Macroinvertebrate Data).

River mile	Year	Eco-region	Drainage area (sq.mi.)	ICI	SRP
W. BR. ROCKY RIVER					
0.4	81	EOLP	188	20	
GREAT MIAMI RIVER					
153.5	82	ECBP	236	20	
GREENVILLE CREEK					
18.9	82	ECBP	141	18	
18.0	82	ECBP	142	16	
SWAMP CREEK					
0.3	82	ECBP	63	18	
KILLBUCK CREEK					
48.3	81	EOLP	191	18	
47.8	83	EOLP	192	16	
44.6	83	EOLP	217	6	
41.5	83	EOLP	248	10	
APPLE CREEK					
0.1	83	EOLP	55	8	
TUSCARAWAS RIVER					
114.3	83	EOLP	63	8	
100.2	83	EOLP	397	18	
94.2	83	EOLP	435	18	
89.7	83	EOLP	511	16	
89.4	83	EOLP	511	12	
89.0	83	EOLP	511	18	
84.5	83	EOLP	541	16	
78.1	83	EOLP	567	24	
CHIPPEWA CREEK					
19.6	83	EOLP	23	14	
16.3	83	EOLP	40	22	
8.9	83	EOLP	80	8	
RIVER STYX					
2.3	83	EOLP	24	18	
L. CHIPPEWA CREEK					
0.1	83	EOLP	30	12	
JEROME FORK					
5.6	84	EOLP	120	14	
WILLS CREEK					
68.1	84	WAP	292	14	
66.7	84	WAP	313	20	
65.1	84	WAP	314	18	
MOSQUITO CREEK					
9.1	83	EOLP	107	24	
7.1	83	EOLP	115	14	
3.0	83	EOLP	128	18	
CUYAHOGA RIVER					
40.2	84	EOLP	404	26	
20.8	84	EOLP	583	22	

Appendix A-9. List of Moderately Impacted Ohio Sites Used to Judge the Performance of the ICI (Macroinvertebrate Data).

River mile	Year	Eco-region	Drainage area (sq.mi.)	ICI	SRP
CUYAHOGA RIVER					
17.3	84	EOLP	596	16	
15.6	84	EOLP	694	24	
13.1	84	EOLP	707	14	
9.5	84	EOLP	709	14	
TINKERS CREEK					
10.7	84	EOLP	70	10	
10.4	84	EOLP	72	14	
8.4	84	EOLP	74	10	
BRANDYWINE CREEK					
8.0	84	EOLP	5	18	
7.0	84	EOLP	9	10	
4.2	84	EOLP	19	12	
3.7	84	EOLP	23	20	
BLACK RIVER					
11.3	82	EOLP	411	22	
10.7	82	EOLP	412	16	

Appendix A-10. List of Severely Impacted Ohio Sites Used to Judge the Performance of the ICI (Macroinvertebrate Data).

River mile	Year	Eco-region	Drainage area (sq.mi.)	ICI	SRP
HOCKING RIVER					
91.1	82	EOLP	36	6	
89.3	82	EOLP	51	0	
88.5	82	EOLP	64	0	
87.3	82	EOLP	67	0	
85.4	82	EOLP	86	0	
82.9	82	WAP	98	0	
81.8	82	WAP	334	0	
RUSH CREEK					
15.4	82	WAP	160	6	
14.5	82	WAP	162	4	
12.7	82	WAP	190	0	
9.1	82	WAP	206	6	
SCIOTO RIVER					
124.5	81	ECBP	1640	10	
117.3	81	ECBP	1709	10	
TOWN CREEK					
14.6	83	HELP	19	4	
12.5	83	HELP	21	4	
RACCOON CREEK					
11.3	83	HELP	12	0	
10.2	83	HELP	13	4	
8.7	83	HELP	15	0	
6.5	83	HELP	18	8	
3.1	83	HELP	22	8	
LITTLE RACCOON CREEK					
31.2	84	WAP	36	4	
11.0	84	WAP	128	8	
1.8	84	WAP	150	6	
MEADOW RUN					
3.1	84	WAP	5	12	
0.9	84	WAP	10	0	
0.1	84	WAP	10	0	
TURTLE CREEK					
5.9	83	IP	18	0	
LYTLE CREEK					
6.0	84	ECBP	12	0	
4.8	84	ECBP	13	6	
4.0	84	ECBP	14	4	
W. BR. ROCKY RIVER					
33.3	81	EOLP	9	12	
4.5	81	EOLP	160	10	
3.6	81	EOLP	161	10	
2.1	81	EOLP	182	10	
GREAT MIAMI RIVER					
157.2	82	ECBP	120	6	

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Appendix A-10. List of Severely Impacted Ohio Sites Used to Judge the Performance of the ICI (Macroinvertebrate Data).

River mile	Year	Eco-region	Drainage area (sq.mi.)	ICI	SRP
SWAMP CREEK					
2.3	82	ECBP	58	14	
1.7	82	ECBP	59	8	
TUSCARAWAS RIVER					
112.6	83	EOLP	72	0	
112.5	83	EOLP	72	2	
110.8	83	EOLP	74	0	
109.5	83	EOLP	153	2	
109.0	83	EOLP	153	2	
108.0	83	EOLP	156	2	
106.0	83	EOLP	163	6	
104.2	83	EOLP	174	14	
87.4	83	EOLP	524	12	
81.4	83	EOLP	554	6	
CHIPPEWA CREEK					
19.2	83	EOLP	23	4	
14.4	83	EOLP	48	14	
6.6	83	EOLP	146	6	
RIVER STYX					
0.7	83	EOLP	28	10	
0.1	83	EOLP	28	12	
L. CHIPPEWA CREEK					
10.5	81	EOLP	2	10	
10.1	81	EOLP	3	10	
8.6	81	EOLP	7	0	
6.7	81	EOLP	11	0	
JEROME FORK					
12.1	84	EOLP	74	2	
10.5	84	EOLP	76	2	
9.1	84	EOLP	107	8	
MILL CREEK					
7.8	82	EOLP	36	0	
6.5	82	EOLP	52	2	
2.6	82	EOLP	72	0	
1.2	82	EOLP	78	2	
0.1	82	EOLP	79	4	
MOSQUITO CREEK					
5.6	83	EOLP	120	6	
0.6	83	EOLP	138	8	
CUYAHOGA RIVER					
37.2	84	EOLP	443	16	
35.3	84	EOLP	457	12	
33.2	84	EOLP	480	10	
28.9	84	EOLP	513	16	
BRANDYWINE CREEK					
0.2	84	EOLP	26	12	

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Appendix A-10. List of Severely Impacted Ohio Sites Used to Judge the Performance of the ICI (Macroinvertebrate Data).

River mile	Year	Eco-region	Drainage area (sq.mi.)	ICI	SRP
BLACK RIVER					
14.4	82	EOLP	396	2	
9.8	82	EOLP	413	6	
8.3	82	EOLP	414	2	
E. BR. BLACK RIVER					
0.2	82	EOLP	222	4	
W. BR. BLACK RIVER					
0.1	82	EOLP	174	4	

Appendix A-11. List of Moderately and Severely Impacted Ohio Reference Sites Used in the Development of IBI "Low-End" Scoring.

River mile	Year	Sampler type	Eco-region	Drainage Area (sq.mi.)	Mean No. Species	Modified Iwb	IBI	SRP
HOCKING RIVER								
89.8	82	A	EOLP	64.0	1.3	0.6	17	
82.4	82	A	WAP	334.0	6.0	2.4	19	
BALDWIN RUN								
0.5	82	S	WAP	12.0	8.0	3.4	26	
HUNTERS RUN								
0.6	82	S	WAP	10.0	11.3	5.2	27	
AMANDA CREEK								
0.1	82	G	WAP	1.2	3.0	0.7	33	
RUSH CREEK								
15.4	82	A	WAP	211.0	1.3	0.6	17	
14.3	82	A	WAP	216.0	4.0	1.4	16	
2.0	82	A	WAP	233.0	5.3	2.8	17	
SCIOTO RIVER								
117.1	85	A	ECBP	2266.0	18.0	8.9	36	
117.1	79	A	ECBP	2266.0	5.0	5.3	16	
117.1	86	A	ECBP	2266.0	25.0	10.1	36	
117.1	80	A	ECBP	2266.0	9.0	5.7	23	
117.1	86	A	ECBP	2266.0	16.0	8.4	36	
117.1	81	A	ECBP	2266.0	19.0	8.6	34	
117.1	81	A	ECBP	2266.0	11.0	6.9	18	
117.1	85	A	ECBP	2266.0	25.0	9.6	36	
117.1	79	A	ECBP	2266.0	9.0	4.5	20	
117.1	80	A	ECBP	2266.0	15.0	7.4	28	
117.1	85	A	ECBP	2266.0	22.0	8.4	38	
117.1	81	A	ECBP	2266.0	9.0	6.0	24	
117.1	86	A	ECBP	2266.0	19.0	9.0	30	
117.1	79	A	ECBP	2266.0	6.0	4.5	22	
98.3	80	A	ECBP	3222.0	6.0	5.8	16	
98.3	81	A	ECBP	3222.0	10.0	6.3	23	
98.3	79	A	ECBP	3222.0	5.5	4.8	22	
98.3	81	A	ECBP	3222.0	12.0	7.6	30	
98.3	80	A	ECBP	3222.0	9.0	6.1	18	
98.3	79	A	ECBP	3222.0	9.0	5.5	22	
WALNUT CREEK								
20.5	80	S	ECBP	177.0	11.5	4.6	26	
PAWPAW CREEK								
0.9	82	S	EOLP	11.0	9.7	5.4	31	
0.5	82	S	EOLP	17.0	9.3	4.4	25	
PRAIRIE RUN								
1.5	82	G	ECBP	3.0	9.0	3.8	40	
0.1	82	G	ECBP	4.4	1.0	0.4	14	
COTTONWOOD DITCH								
2.5	84	D	ECBP	17.0	13.7	6.7	25	
0.7	84	D	ECBP	19.0	6.7	3.9	25	

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Appendix A-11. List of Moderately and Severely Impacted Ohio Reference Sites Used in the Development of IBI "Low-End" Scoring.

River mile	Year	Sampler type	Eco-region	Drainage Area (sq.mi.)	Mean No. Species	Modified Iwb	IBI	SRP
OAK RUN								
14.7	85	D	ECBP	3.0	2.0	1.3	24	
13.5	85	E	ECBP	2.2	10.3	4.9	37	
12.4	85	E	ECBP	5.5	8.0	3.6	25	
11.6	85	D	ECBP	7.0	7.3	2.7	23	
10.3	85	E	ECBP	7.8	5.7	2.0	22	
8.1	85	E	ECBP	14.0	11.3	3.3	27	
7.8	85	D	ECBP	21.0	11.0	3.7	26	
OLENTANGY RIVER								
86.3	86	D	ECBP	9.0	9.0	3.6	22	
LITTLE SALT CREEK								
26.9	86	E	WAP	18.2	13.3	7.1	34	
DUCK CREEK								
2.1	86	D	HELP	4.0	2.0	0.4	19	
SWAN CREEK								
3.9	86	A	HELP	199.0	9.3	4.6	15	
2.6	86	A	HELP	201.0	5.3	2.9	14	
1.2	86	A	HELP	203.0	3.3	2.5	18	
M. FK. GORDON CREEK								
3.8	84	D	ECBP	5.0	10.5	6.3	29	
DISHER DITCH								
2.0	85	G	HELP	0.5	3.0	0.6	34	
0.3	85	G	HELP	1.5	3.0	1.1	16	
0.1	85	G	HELP	1.5	1.0	0.0	16	
SIXMILE CREEK								
1.2	85	D	HELP	7.1	1.7	0.8	13	
EVANS DITCH								
1.6	86	E	HELP	1.5	4.0	3.5	28	
OTTAWA RIVER								
36.7	79	A	ECBP	131.0	3.0	0.9	16	
36.7	85	A	ECBP	131.0	9.0	3.5	18	
28.9	85	A	HELP	160.0	11.0	4.3	17	
28.9	79	A	HELP	160.0	4.0	2.8	16	
CRESTLINE WWTP TRIB.								
0.1	85	D	ECBP	7.0	1.0	0.6	15	
BIG RUN								
1.0	83	D	WAP	4.0	2.0	0.4	22	
SALLY BUFFALO CREEK								
0.7	85	E	WAP	5.0	5.0	2.5	26	
MEADOW RUN								
3.1	84	D	WAP	5.0	0.3	0.0	15	
E. FK. LITTLE MIAMI								
85.3	82	S	ECBP	2.0	3.0	1.4	32	
RATTLESNAKE CREEK								
1.4	84	D	HELP	2.0	2.7	1.5	22	

Appendix A-11. List of Moderately and Severely Impacted Ohio Reference Sites Used in the Development of IBI "Low-End" Scoring.

River mile	Year	Sampler type	Eco-region	Drainage Area (sq.mi.)	Mean No. Species	Modified Iwb	IBI	SRP
GREAT MIAMI RIVER								
0.9	80	A	IP	5371.0	13.7	6.6	29	
OTTER CREEK								
7.2	86	E	HELP	0.6	0.7	0.0	25	
5.8	86	D	HELP	2.0	0.7	0.0	19	
KILLBUCK CREEK								
33.5	81	A	WAP	377.0	8.3	5.4	19	
NIMISHILLEN CREEK								
11.2	86	D	EOLP	157.0	6.0	2.3	12	
11.2	85	D	EOLP	157.0	9.7	3.3	19	
0.6	85	D	WAP	186.0	9.7	3.9	21	
E BR NIMISHILLEN CRK								
3.4	85	D	EOLP	33.0	15.3	4.4	23	
3.4	86	D	EOLP	33.0	9.0	2.4	20	
W BR NIMISHILLEN CRK								
0.1	86	D	EOLP	47.0	7.0	3.7	18	
0.1	85	D	EOLP	47.0	6.7	3.1	20	
HURFORD RUN								
1.8	85	E	EOLP	3.0	0.0	0.0	20	
1.8	86	D	EOLP	3.0	0.0	0.0	20	
1.2	85	E	EOLP	5.5	1.3	1.0	14	
0.3	85	E	EOLP	6.0	0.3	0.0	15	
0.3	86	E	EOLP	6.0	0.0	0.0	16	
0.3	86	E	EOLP	6.0	0.0	0.0	16	
0.1	86	E	EOLP	7.0	10.0	4.5	22	
0.1	86	E	EOLP	7.0	10.0	3.6	22	
0.1	85	E	EOLP	7.0	6.7	2.5	22	
OSNABURG DITCH								
0.7	85	E	EOLP	2.0	3.0	1.4	28	
MCDOWELL DITCH								
1.8	85	E	EOLP	12.0	7.7	4.0	22	
TUSCARAWAS RIVER								
108.2	83	A	EOLP	156.0	2.8	1.2	17	
103.5	83	A	EOLP	175.0	3.7	3.6	23	
69.6	83	A	WAP	1102.0	12.0	4.5	24	
MAHONING RIVER								
31.8	80	A	EOLP	612.0	1.7	1.4	17	
23.4	80	A	EOLP	1004.0	3.7	2.6	18	
15.8	86	A	EOLP	1016.0	7.0	3.2	14	
LITTLE YANKEE RUN								
4.6	84	D	EOLP	29.0	15.0	5.3	25	
2.0	84	D	EOLP	39.0	4.5	2.1	12	
YANKEE RUN								
0.3	84	A	EOLP	45.0	7.5	5.4	16	
CUYAHOGA RIVER								
48.7	84	A	EOLP	327.0	9.7	5.0	26	

Appendix A-11. List of Moderately and Severely Impacted Ohio Reference Sites Used in the Development of IBI "Low-End" Scoring.

River mile	Year	Sampler type	Eco-region	Drainage Area (sq.mi.)	Mean No. Species	Modified Iwb	IBI	SRP
CUYAHOGA RIVER								
15.9	84	A	EOLP	694.0	5.0	4.5	14	
15.9	84	A	EOLP	694.0	6.0	3.9	17	
15.9	85	A	EOLP	694.0	10.0	5.0	18	
9.8	85	A	EOLP	709.0	10.0	5.1	14	
9.8	84	A	EOLP	709.0	4.7	4.1	14	
9.8	84	A	EOLP	709.0	4.0	3.4	20	
7.5	85	A	EOLP	749.0	5.0	3.6	16	
TINKERS CREEK								
22.1	84	D	EOLP	41.0	11.0	5.0	29	
3.0	84	D	EOLP	83.0	7.7	4.3	18	
2.1	84	D	EOLP	88.0	7.0	3.9	13	
0.1	84	D	EOLP	89.0	13.0	5.3	21	
POND BROOK								
3.6	84	D	EOLP	4.0	1.3	0.7	14	
L. CUYAHOGA RIVER								
11.0	86	E	EOLP	22.0	8.3	3.8	23	
5.0	86	E	EOLP	51.0	6.3	2.8	16	
3.8	86	E	EOLP	61.0	3.3	1.5	15	
BEAVER MEADOW CREEK								
0.2	84	D	EOLP	5.0	8.3	4.6	25	

000202

APPENDIX B:

Development of Fish Community IBI Metrics

B-1: Ohio Fish Species Designations

The Index of Biotic Integrity (IBI) requires that fish species be classified by their trophic and environmental tolerance status. The modified Iwb also requires that highly tolerant species be designated. Table B-1 represents these designations of Ohio fish species. These are used in the Fish Information System (FINS) which is a computer system designed by Ohio EPA to analyze and store fish community relative abundance data.

The designations are based on a review of the literature according to the guidelines recommended by Karr et al. (1986). The designations for environmental tolerance are based on an examination of the Ohio EPA statewide data base and Trautman (1981). The rationale and method for doing this is explained below.

Designation of Fish Species Tolerances

In an effort to obtain an objective ranking of environmental tolerances for Ohio fish species the methodology suggested by Karr et al. (1986) was modified. Previous efforts to rank fish species tolerances have relied heavily on the subjective opinion and information contained in regional ichthyological texts. While such information is of value it is largely subjective and qualitative and can result in incorrect species tolerance designations. Ohio EPA has the benefit of a large data base (approximately 2000 sites sampled since 1979) that consists of quantitative relative abundance data generated by standardized sampling methods. A wide variety of environmental conditions from least impacted to severely degraded including both point and nonpoint source impacts and habitat modification have been assessed. Stream and river sizes range from headwater sites (less than 20 sq. mi. drainage area) to the largest mainstem rivers.

The use and interpretation of the Index of Biotic Integrity (IBI; Karr 1981; Karr et al. 1986) and the Modified Index of Well-Being (Iwb; Appendix C) both require that intolerant or tolerant designations be made. This requires a fundamental knowledge of the sensitivity of Ohio fishes to environmental disturbances. Regional fish references (e.g. Trautman 1981; Becker 1983) frequently discuss species tolerance to various chemical and physical disturbances, but rarely use quantitative catch data to assign or rank a particular species as tolerant or intolerant. The results of laboratory bioassays, historical distribution records, and personal observation (i.e. "best professional judgement") are generally relied on to assign tolerance rankings. It is believed that by using the Ohio EPA data base and the observations of Ohio EPA field biologists the assignment of species tolerances could be accomplished with the aid of quantitative data. A representative subsample of the Ohio EPA data base was used to develop species tolerance rankings for use with the IBI and modified Iwb.

The operating definition of an intolerant species is one that "should have disappeared, at least as a viable population, by the time the site has been degraded to the 'fair' category" (Karr et al. 1986). Therefore, species designated as intolerant in Ohio have been observed to respond negatively to a wide variety of disturbances, not just one or two specific types. Table B-1 summarizes the criteria that were used to determine intolerance/tolerance. We also relied on Trautman (1981) for historical changes in the distribution of certain species that were not abundant in our data base. This was most helpful for interpreting the application to smaller streams where Iwb has limited usefulness. The Ohio EPA catch data (1979-1985) was used for the numerical analyses. Only those sites sampled three times during each season (mid-June to mid-October) were used. The Index of Well-Being (Iwb) was used as a measure of overall environmental condition in this analysis. The 5th, 25th, 75th, and 95th percentiles, and median Iwb was calculated for each location at which a particular species was captured (Table B-2). Data generated by wading and boat methods were analyzed separately; only wading methods results are shown in Figure B-1.

A mean Iwb value was calculated for each species, weighted by relative abundance, to provide an initial estimate of intolerance/tolerance. The more intolerant a species, the more skewed its relative abundance should be toward the higher Iwb values. Weighted Iwb values were calculated as:

$$Iwb_w = (N_i \times Iwb_i) / N, \text{ where;}$$

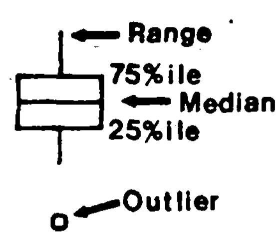
Iwb_w = mean weighted Iwb,

N_i = relative abundance of species A at site i,

Iwb_i = Iwb value at site i,

N = sum of relative abundance of species A at all sites.

The box-and-whisker plots for each species in Figures B-1 through B-3 present the range (with outliers), 25th and 75th percentiles, median, and weighted mean (triangle symbol), as follows:



The species which were designated intolerant are those for which sufficient relative abundance data was available and/or those which met the criteria in Table B-1. Species considered to be intolerant based on criteria other than the Ohio EPA data base are designated as "rare intolerant" or "special intolerant". Species with these designations fall into several categories. These include species associated with larger rivers and heavy vegetation (e.g. river darter, pugnose minnow), species with restricted geographic distributions (e.g. longhead darter), endangered species (e.g.

Table B-1. Criteria for inclusion of species on the Ohio EPA intolerant and tolerant species lists.

Intolerant Criteria

1) A distinct and rapid decreasing trend in abundance with decreasing water and habitat quality (based on graphical analysis).

2) Abundance skewed towards sites with high I_{wb} scores (which is reflected in higher weighted I_{wb} scores).

3) Absence of species from sites with I_{wb} <6.0, few sites <7.0, and the majority of sites >8.0.

4) A significant historical decrease in distribution (based on Trautman 1981).

Tolerant Criteria

1) Present at a substantial number of sites with I_{wb} values <6.0.

2) Either no change or a historical increase in abundance or distribution (based on Trautman 1981).

3) A shift towards community predominance with decreasing water and habitat quality.

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able B-2 Mean weighted Iwb, species richness, and Shannon diversity ($\bar{H}$) for all species captured by the OEPA with the sport yak electrofishing method. Only data with three passes, data collected after 1977, and data collected with quantitiative methods (weights taken) were included. Percentiles were not calculated for species where no. of site was <9. Data is sorted from lowest to highest weighted Iwb.

pecies Code	Mean Wt'd Iwb	Mean Wt'd Species	Mean Wt'd Shannon	No. of Sites	No. of Fish	5th	IQR	Percentiles 25th	95th	25th
5.001	6.65	13.6	1.14	21	364	4.89	1.73	6.23	9.14	7.96
5.045	6.95	18.7	1.73	8	19	2.05	.9	7.14	8.21	8.06
4.001	7.18	16.8	1.64	60	1276	5.49	2.06	6.46	10.02	8.51
0.023	7.32	16.81	1.62	15	144	5.84	2.01	7.46	9.93	9.47
0.003	7.34	20	1.72	1	8	*	*	*	*	*
3.002	7.59	21.2	1.58	27	303	3.32	1.88	6.25	9.16	8.13
7.005	7.68	19.9	1.97	81	626	5.69	2.31	6.73	9.94	9.04
3.016	7.7	17.4	1.61	12	309	5.84	1.28	7.11	9.07	8.4
7.007	7.72	21.8	2	51	254	5.69	2.34	6.68	10.25	9.02
7.013	7.82	20.9	1.96	103	1590	5.56	1.94	6.68	9.94	8.62
005	7.87	24.4	1.82	47	488	7.08	1.42	8.35	10.3	9.77
.013	7.93	20.68	1.74	259	4403	4.83	1.9	7.11	10.03	9.02
3.003	7.96	20.4	1.81	53	420	5.69	1.61	6.78	9.31	8.4
7.001	7.97	23.2	2.13	86	1014	5.69	1.94	7.29	9.56	8.88
7.001	7.99	23.4	2.01	90	477	5.83	1.73	7.22	10.19	8.95
3.042	7.99	17.3	1.7	80	4306	4.54	1.7	6.69	9.62	8.4
3.012	8.02	*	*	*	*	*	*	*	*	*
1.002	8.04	24	2.47	1	29	*	*	*	*	*
7.008	8.09	22.7	1.93	282	17393	4.83	1.94	7.08	9.94	9.01
13.011	8.12	19.9	1.76	108	4862	4.89	1.93	7.11	9.93	9.04
4.002	8.13	21.6	1.91	49	1167	4.83	1.61	7.62	10.19	9.23
10.016	8.17	22.2	1.82	263	32033	5.49	1.81	7.21	10.03	9.02
13.001	8.25	23.9	1.96	182	3711	5.49	1.74	7.46	10.19	9.19
17.004	8.25	22.5	1.97	220	4739	5.68	1.5	7.41	9.8	8.91
0.003	8.26	23.88	1.96	9	23	6.84	2.08	7.08	9.36	9.16
13.026	8.27	20.1	1.87	39	2925	6.11	1.05	7.29	9.39	8.34
7.009	8.3	25.57	2.08	229	7478	4.96	1.9	7.11	10.13	9.02
7.010	8.37	23.48	1.89	31	939	7.07	1.42	7.76	10.03	9.17
7.003	8.38	23.5	2.02	8	47	7.46	1.14	7.54	9.24	8.68
17.013	8.43	23.73	1.84	18	150	7.21	.86	8.15	9.62	9.01
17.006	8.44	22.78	2.02	71	405	7.07	1.46	7.62	9.62	9.08
35.001	8.44	21.04	1.88	92	4950	5.56	1.35	7.79	9.94	9.14
30.014	8.47	22.9	2.03	206	7555	6.46	1.32	7.81	10.16	9.2
13.014	8.48	20.7	1.95	7	238	*	*	*	*	*
77.002	8.5	23.76	2.09	47	209	6.21	1.58	7.5	10.31	9.08
.001	8.5	20.1	1.92	8	85	*	*	*	*	*

Table B-2. continued.

Species Code	Mean Wt'd Iwb	Mean Wt'd Species	Mean Wt'd Shannon	No. of Sites	No. of Fish	5th	IQR	Percentiles 25th	95th	25th
70.001	8.53	35.2	2.45	13	144	7.05	.77	8.46	10.3	9.24
90.002	8.54	21.3	1.93	58	4547	6.66	.92	8.02	9.77	8.94
40.006	8.54	46	2.5	1	1	*	*	*	*	*
43.039	8.55	25.31	2.02	114	6748	6.64	1.32	8.06	10.25	9.39
01.006	8.59	20.4	2.01	10	659	7.73	.65	8.86	10.71	9.51
43.023	8.59	22.6	2.02	49	2027	6.9	1.23	7.55	9.47	8.79
01.007	8.59	20.38	2.02	10	659	6.39	.87	7.87	9.14	8.74
40.018	8.6	29.2	2.24	39	230	7.46	1.13	8.13	9.67	9.26
43.033	8.6	20.39	1.74	10	1520	*	*	*	*	*
80.007	8.64	35	2.64	1	4	*	*	*	*	*
43.030	8.65	*	*	1	7	*	*	*	*	*
80.001	8.68	36.5	2.3	5	9	*	*	*	*	*
25.002	8.69	19.25	2.05	6	258	*	*	*	*	*
43.043	8.69	26.6	2.04	273	5811	5.6	1.61	7.46	10.03	9.06
43.017	8.71	22.9	2.02	16	221	6.84	.95	8.09	9.49	9.04
43.041	8.72	*	*	2	17	*	*	*	*	*
43.004	8.74	27.33	2.28	23	613	7.46	1.19	7.89	9.61	9.08
80.005	8.76	27.6	2.23	85	1400	7.21	1.19	8.04	9.86	9.23
43.035	8.82	27.6	2.27	27	1161	7.66	1.3	8.42	10.3	9.72
43.020	8.86	35.3	2.31	47	4041	7.07	1.24	7.96	10.25	9.2
20.003	8.86	29.5	2.21	92	5639	*	*	*	*	*
74.001	8.89	*	*	2	2	*	*	*	*	*
43.012	8.9	32.6	2.3	33	360	7.07	.91	8.35	10.3	9.26
43.015	8.9	29.8	2.12	47	1335	7.03	1.48	7.89	10.25	9.37
77.003	8.94	28.28	2.24	193	6567	6.54	1.22	8.04	10.19	9.26
77.006	8.95	32	2.31	14	43	8.13	.72	8.54	9.66	9.26
80.022	8.96	28.06	2.28	139	5461	7.46	1.05	8.33	10.29	9.39
43.006	8.97	38	2.46	1	1	*	*	*	*	*
77.005	8.97	35.2	2.39	39	753	7.56	.93	8.58	10.3	9.51
43.044	8.98	27	2.12	234	3467	5.49	1.58	7.6	10.13	9.18
80.024	9	27.7	2.22	149	6764	7.07	1.09	8.22	10.29	9.31
77.011	9.01	32.9	2.31	85	9035	7.03	1.05	8.49	10.29	9.54
47.007	9.04	35.6	2.3	4	22	8.07	.08	9.16	9.24	9.24
43.032	9.04	32.3	2.22	117	5238	6.65	1.2	8.34	10.3	9.54
63.001	9.04	31.89	2.2	20	508	7.57	.93	8.39	9.67	9.31
80.004	9.05	39.13	2.44	5	56	*	*	*	*	*
43.007	9.08	28	2.43	9	282	7.46	.2	8.35	9.77	8.54
80.015	9.1	29.3	2.3	170	11059	7.03	1.27	8.06	10.25	9.33
43.025	9.12	28.2	2.2	195	28068	6.25	1.3	7.95	10.19	9.25
43.031	9.13	37.7	2.46	13	216	4.54	.7	8.54	9.51	9.24
47.002	9.13	36	2.44	52	396	6.86	1.4	7.61	9.66	9.02

Table B-2. continued.

Species Code	Mean Wt'd Iwb	Mean Wt'd Species	Mean Wt'd Shannon	No. of Sites	No. of Fish	Percentiles 5th	IQR	25th	95th	25th
80.013	9.14	44	2.68	1	9	*	*	*	*	*
40.013	9.14	44	2.67	1	2	*	*	*	*	*
43.008	9.15	38.4	2.5	3	15	*	*	*	*	*
40.015	9.15	30.1	2.3	181	15829	7.46	1.13	8.16	10.19	9.29
40.008	9.16	35.5	2.54	46	296	7.56	1.01	8.49	10.3	9.5
40.011	9.17	35.6	2.5	19	242	7.82	.72	8.52	10.19	9.24
43.024	9.18	27.34	2.15	13	1860	8.13	.69	8.54	9.8	9.23
47.008	9.19	32	2.4	88	1133	7.07	1.16	8.38	10.3	9.54
01.003	9.2	45	2.68	1	1	*	*	*	*	*
43.034	9.25	31.03	2.31	127	11251	7.07	1.29	8.22	10.29	9.51
80.020	9.25	39.02	2.55	3	83	*	*	*	*	*
80.002	9.26	38.05	2.71	3	5	*	*	*	*	*
80.011	9.31	33.3	2.4	112	1494	7.09	1.1	8.39	10.3	9.49
37.004	9.31	38	2.57	1	1	*	*	*	*	*
43.005	9.33	31.2	2.32	45	5649	7.59	1.34	8.46	10.39	9.8
43.021	9.33	33.1	2.44	73	2101	7.91	1.06	8.58	10.31	9.64
80.017	9.34	33.5	2.51	31	1794	7.59	1.74	8.38	10.41	10.13
77.004	9.34	32.1	2.39	138	3623	7.43	1.07	8.36	10.29	9.43
80.016	9.38	34.1	2.42	94	4212	7.58	1.08	8.46	10.31	9.54
80.019	9.39	30.6	2.61	3	51	*	*	*	*	*
40.007	9.4	35.13	2.56	2	5	*	*	*	*	*
10.004	9.46	39.5	2.67	4	8	*	*	*	*	*
40.010	9.48	33.6	2.44	136	5522	7.38	1.12	8.39	10.29	9.5
15.001	9.5	35	2.43	1	1	*	*	*	*	*
43.022	9.54	33.4	2.41	65	6045	7.59	1.11	8.5	10.31	9.61
43.	9.72	33.9	2.55	15	29	6.63	1.36	8.79	10.41	10.16
40.009	9.88	35.02	2.49	59	2108	7.88	1.07	8.86	10.39	9.93

blue sucker, tonguetied minnow), and species requiring special habitat conditions (e.g. blackchin shiner). Some species in this group (e.g. crystal darter) fall into most of these categories.

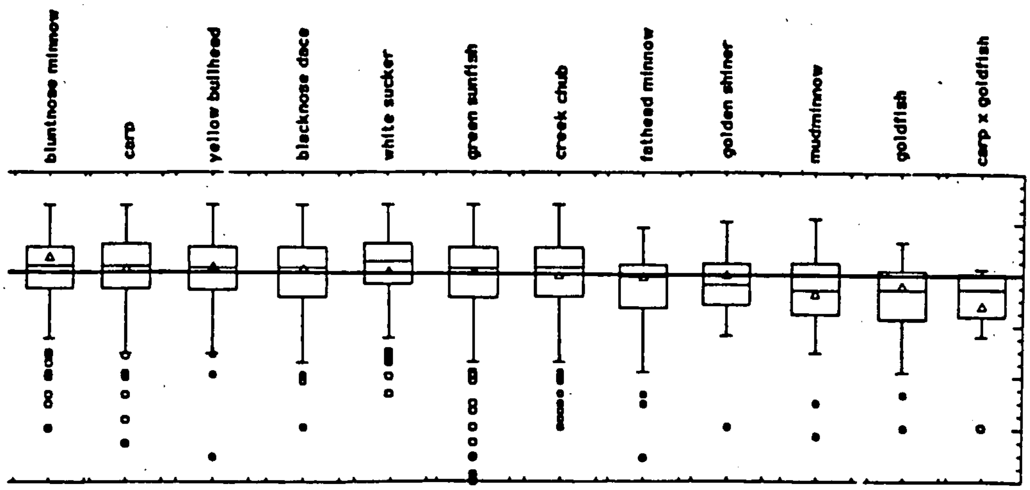
The intolerant designation (including "rare" and "special") is predominated by minnow, sucker, catfish (madtoms), and darter species. Populations of many of these species have been negatively affected by environmental perturbations in Ohio (Trautman 1981).

The moderately intolerant designation includes species which are commonly observed and strongly associated with healthy fish communities, but are occasionally recorded from areas that are slightly degraded. Sucker, minnow, and darter species predominate this category. Two sunfish species appear in this grouping, the first appearance for this family in the classification scheme. Intolerant and moderately intolerant species are together considered as a broader group termed "sensitive". This designation replaces the intolerant metric in the Headwaters version of the IBI.

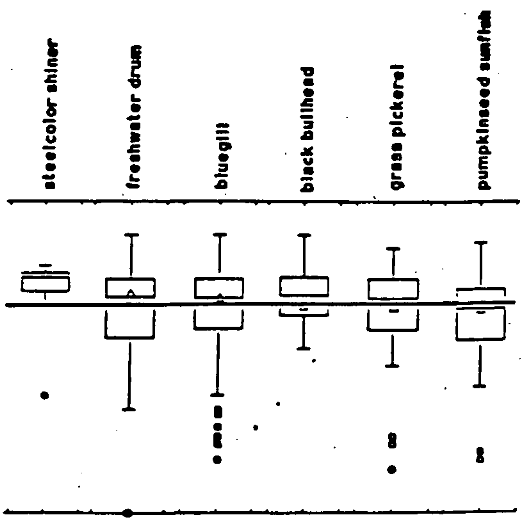
The largest grouping of Ohio fish species is the intermediate tolerance ranking. All gar, temperate basses, most pickerel, sunfish, and sculpin species fall into this classification. All species for which adequate information was available and which did not display a tendency toward association with a high or low I_{wb}, or environmental degradation were classified intermediate. Also, species which lacked any information, quantitative or otherwise are placed in this designation.

The fewest species were classified as tolerant and moderately tolerant. Seven species are designated moderately tolerant and include those which can maintain viable populations in highly degraded areas. Thirteen species are considered tolerant because they have the ability to survive and even prosper in areas of significant environmental stress.

In general the more intolerant a species, the more specialized is its feeding behavior. In contrast tolerant and moderately tolerant species show feeding plasticity and are either omnivores or generalist feeders (i.e. they can change feeding strategy with changing environmental conditions). Distinctions can also be made with spawning behavior. Intolerant species tend to exhibit less parental care and generally spawn in the sands and gravels of riffle habitats (i.e. simple lithophilic spawners). Tolerant species display nest guarding behavior, have adhesive eggs which adhere to objects, pelagic eggs that drift, or lay their eggs on the undersides of submerged objects.

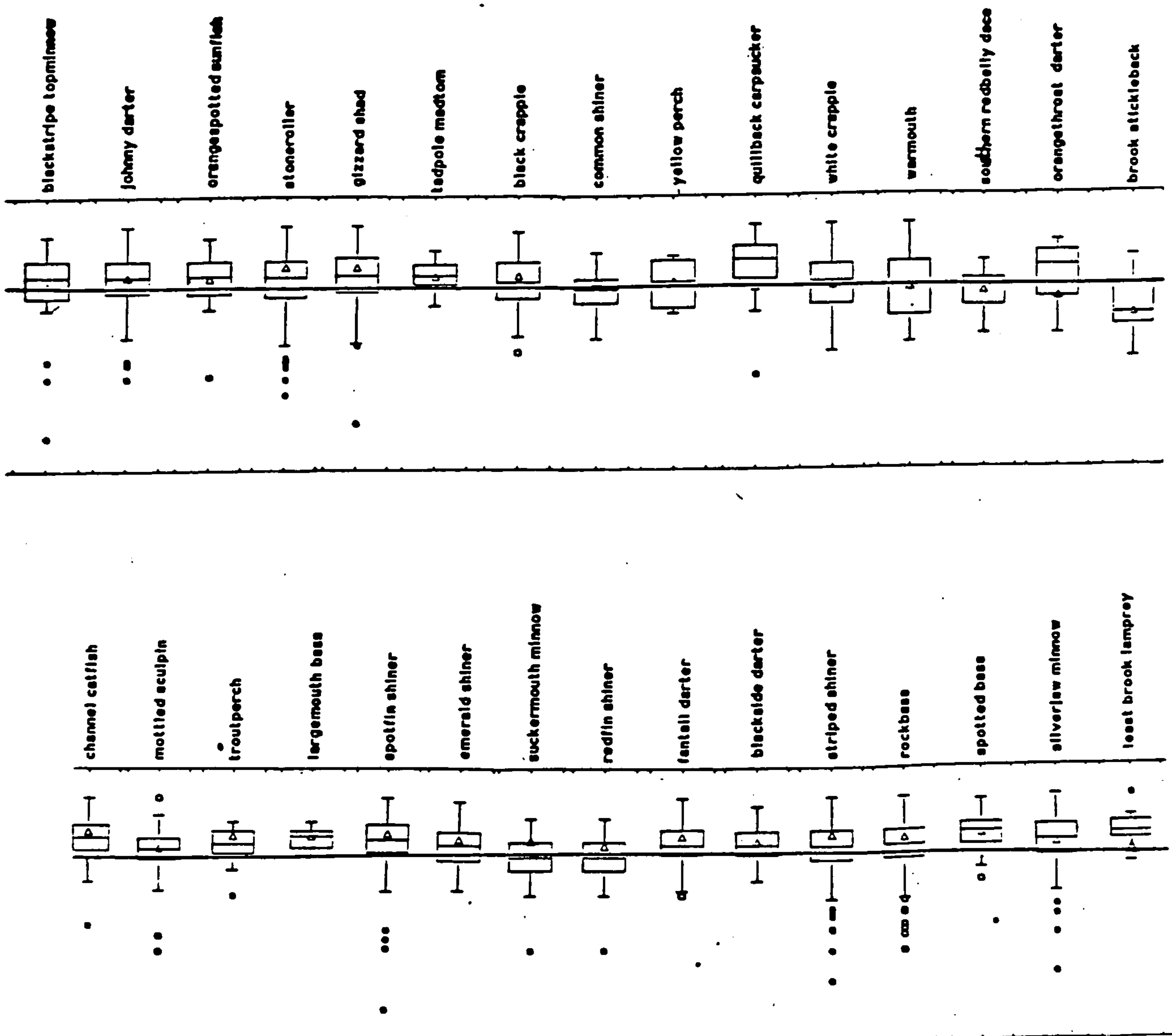


Tolerant



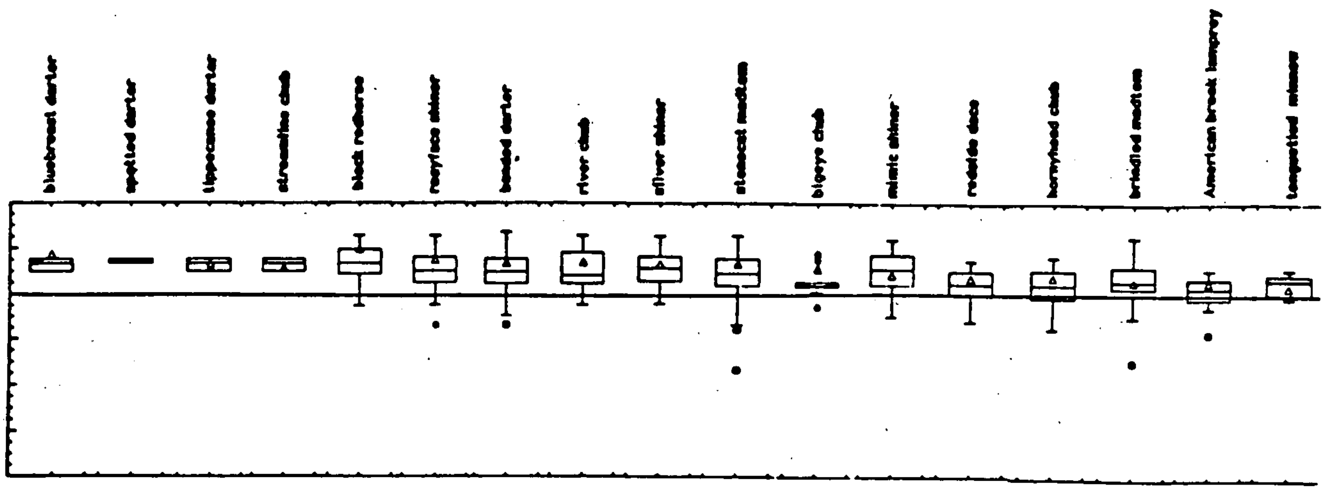
Moderately Tolerant

Figure B-1. Box-and-whisker plots showing the maximum, minumum, 25th and 75th percentile, median, and outlier Iwb values (weighted for relative abundance) for species designated as tolerant and moderately intolerant.

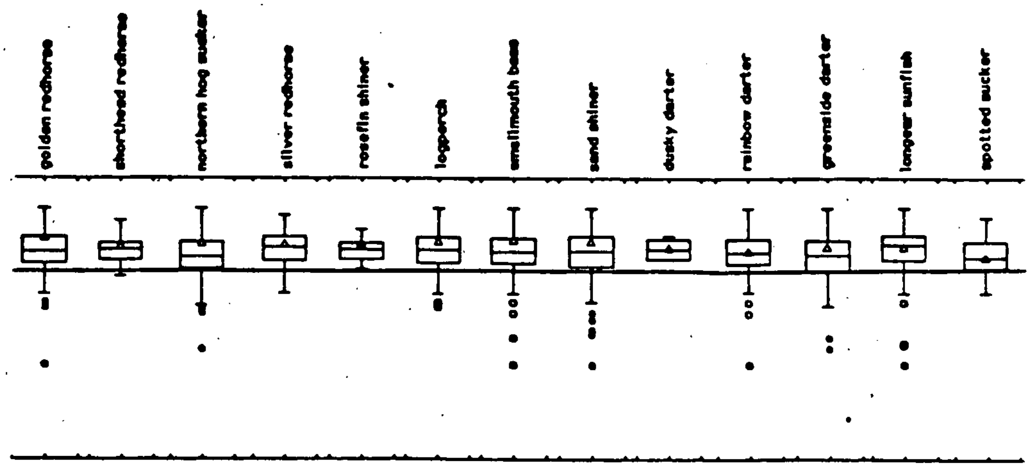


Intermediate Tolerance

Figure B-2. Box-and-whisker plots showing the maximum, minumum, 25th and 75th percentile, median, and outlier Iwb values (weighted for relative abundance) for species designated as intermediate in their tolerance.



Intolerant



Moderately Intolerant

Figure B-3. Box-and-whisker plots showing the maximum, minumum, 25th and 75th percentile, median, and outlier Iwb values (weighted for relative abundance) for species designated as intolerant and moderately intolerant.

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Table B-3. Designation of Ohio fish species for the purposes of the Index of Biotic Integrity, the Modified Index of Well-Being (I_{wb}), and the Fish Information System (FINS). Explanation of column headings appears at the end of the table.

FINS Code	Species	Spc Grp	Feed Guild	TOL	IBI Grp	Riv Size	Brd Gld	Hab Pref	Family
01001	Silver lamprey	O	P	-	-	L	N	B	Petromyzontidae
01002	Northern brook lamprey	O	F	R	-	-	N	P	Petromyzontidae
01003	Ohio lamprey	O	P	S	-	-	N	B	Petromyzontidae
01004	Mountain brook lamprey	O	F	S	-	-	N	P	Petromyzontidae
01005	Sea lamprey	O	P	-	E	-	N	B	Petromyzontidae
01006	Least brook lamprey	O	F	-	-	H	N	P	Petromyzontidae
01007	American brook lamprey	O	F	R	-	H	N	P	Petromyzontidae
04001	Paddlefish	O	F	S	-	L	S	B	Polyodontidae
08001	Lake sturgeon	O	V	-	-	L	S	B	Acipenseridae
08002	Shovelnose sturgeon	O	I	-	-	L	S	P	Acipenseridae
10001	Alligator gar	L	P	-	-	L	M	P	Lepisosteidae
10002	Shortnose gar	L	P	-	-	L	M	P	Lepisosteidae
10003	Spotted gar	L	P	-	-	L	M	P	Lepisosteidae
10004	Longnose gar	L	P	-	-	L	M	P	Lepisosteidae
15001	Bowfin	O	P	-	-	-	C	P	Amiidae
18001	Goldeye	W	I	R	-	L	M	B	Hiodontidae
18002	Mooneye	W	I	R	-	L	M	B	Hiodontidae
20001	Skipjack herring	W	P	-	-	L	M	B	Clupeidae
20002	Alewife	O	-	-	E	-	M	P	Clupeidae
20003	Gizzard shad	GS	O	-	-	-	M	P	Clupeidae
20004	Threadfin shad	GS	O	-	-	L	M	P	Clupeidae
25001	Brown trout	SA	-	-	E	-	N	B	Salmonidae
25002	Rainbow trout	SA	-	-	E	-	N	B	Salmonidae
25003	Brook trout	SA	-	-	-	-	N	B	Salmonidae
25004	Lake trout	SA	P	-	F	-	N	P	Salmonidae
25005	Coho salmon	SA	-	-	E	-	N	P	Salmonidae
25006	Chinook salmon	SA	-	-	E	-	N	P	Salmonidae
25007	Cisco or Lake Herring	WF	-	-	-	-	M	P	Salmonidae
25008	Lake whitefish	WF	V	-	-	-	M	P	Salmonidae
30001	Rainbow smelt	O	-	-	-	-	M	P	Osmeridae
34001	Central mudminnow	T	I	T	-	-	C	P	Umbridae
37001	Grass pickerel	P	P	P	-	-	M	P	Esocidae
37002	Chain pickerel	P	P	-	F	-	M	P	Esocidae
37003	Northern pike	P	P	-	F	-	M	P	Esocidae
37004	Muskellunge	P	P	-	F	-	M	P	Esocidae
37005	N. Pike x Muskellunge	P	P	-	E	-	-	-	Esocidae
37006	Grass P. x Chain P.	P	P	-	F	-	-	-	Esocidae
40001	Blue sucker	R	I	R	R	L	S	R	Catostomidae
40002	Bigmouth buffalo	C	I	-	C	L	M	P	Catostomidae
40003	Black buffalo	C	I	-	C	L	M	P	Catostomidae

000214

Table B-3. (continued)

FINS Code	Species	Spc Grp	Feed Guild	TOL	IBI Grp	Riv Size	Brd Gld	Hab Pref	Family
40004	Smallmouth buffalo	C	I	-	C	L	M	P	Catostomidae
40005	Quillback	C	O	-	C	-	M	P	Catostomidae
40006	River carpsucker	C	O	-	C	L	M	P	Catostomidae
40007	Highfin carpsucker	C	O	-	C	L	M	P	Catostomidae
40008	Silver redhorse	R	I	M	R	-	S	P	Catostomidae
40009	Black redhorse	R	I	I	R	-	S	P	Catostomidae
40010	Golden redhorse	R	I	M	R	-	S	P	Catostomidae
40011	Shorthead redhorse	R	I	M	R	-	S	P	Catostomidae
40012	Greater redhorse	R	I	R	R	-	S	P	Catostomidae
40013	River redhorse	R	I	I	R	-	S	P	Catostomidae
40014	Harelip sucker	R	-	S	R	-	S	P	Catostomidae
40015	Northern hog sucker	R	I	M	R	-	S	R	Catostomidae
40016	White sucker	R	O	T	W	-	S	B	Catostomidae
40017	Longnose sucker	R	I	-	R	-	S	P	Catostomidae
40018	Spotted sucker	R	I	-	R	-	S	P	Catostomidae
40019	Lake chubsucker	R	I	-	R	-	M	P	Catostomidae
40020	Creek chubsucker	R	I	-	R	P	M	P	Catostomidae
43001	Common carp	G	O	T	G	-	M	P	Cyprinidae
43002	Goldfish	G	O	T	G	-	M	P	Cyprinidae
43003	Golden shiner	N	I	T	N	-	M	P	Cyprinidae
43004	Hornyhead chub	M	I	I	N	-	N	B	Cyprinidae
43005	River chub	M	I	I	N	-	N	B	Cyprinidae
43006	Silver chub	M	I	-	N	L	M	P	Cyprinidae
43007	Bigeye chub	M	I	I	N	-	S	R	Cyprinidae
43008	Streamline chub	M	I	R	N	L	S	R	Cyprinidae
43009	Gravel chub	M	I	M	N	L	S	R	Cyprinidae
43010	Speckled chub	M	I	S	N	L	M	R	Cyprinidae
43011	Blacknose dace	M	G	T	N	H	S	R	Cyprinidae
43012	Longnose dace	M	I	R	N	-	S	R	Cyprinidae
43013	Creek chub	M	G	T	N	P	N	B	Cyprinidae
43014	Tonguetied minnow	M	I	S	N	-	N	P	Cyprinidae
43015	Suckermouth minnow	M	I	-	N	-	S	R	Cyprinidae
43016	Southern redbelly dace	M	H	-	N	H	S	B	Cyprinidae
43017	Redside dace	M	I	I	N	H	S	P	Cyprinidae
43018	Rosyside dace	M	I	S	N	H	S	P	Cyprinidae
43019	Pugnose minnow	N	I	R	N	-	M	P	Cyprinidae
43020	Emerald shiner	N	I	-	N	-	S	P	Cyprinidae
43021	Silver shiner	N	I	I	N	-	S	P	Cyprinidae
43022	Rosyface shiner	N	I	I	N	-	S	R	Cyprinidae
43023	Redfin shiner	N	I	-	N	-	N	P	Cyprinidae
43024	Rosefin shiner	N	I	M	N	-	S	P	Cyprinidae
43025	Striped shiner	N	I	-	N	-	S	B	Cyprinidae
43026	Common shiner	N	I	-	N	-	S	P	Cyprinidae

Table B-3. (continued)

FINS Code	Species	Spc Grp	Feed Guild	TOL	IBI Grp	Riv Size	Brd Gld	Hab Pref	Family
43027	River shiner	N	I	-	N	L	S	P	Cyprinidae
43028	Spottail shiner	N	I	P	N	L	M	P	Cyprinidae
43029	Blackchin shiner	N	I	S	N	-	M	P	Cyprinidae
43030	Bigeye shiner	N	I	R	N	-	S	B	Cyprinidae
43031	Steelcolor shiner	N	I	P	N	-	M	P	Cyprinidae
43032	Spotfin shiner	N	I	-	N	-	M	B	Cyprinidae
43033	Bigmouth shiner	N	I	-	N	-	M	B	Cyprinidae
43034	Sand shiner	N	I	M	N	-	M	B	Cyprinidae
43035	Mimic shiner	N	I	I	N	-	M	B	Cyprinidae
43036	Ghost shiner	N	I	-	N	L	M	P	Cyprinidae
43037	Blacknose shiner	N	I	R	N	-	M	P	Cyprinidae
43038	Pugnose shiner	N	I	S	N	-	M	P	Cyprinidae
43039	Silverjaw minnow	M	I	-	N	P	M	B	Cyprinidae
43040	Mississippi silvery minnow	M	H	-	N	-	M	P	Cyprinidae
43041	Bullhead minnow	N	O	-	N	-	C	P	Cyprinidae
43042	Fathead minnow	M	O	T	N	P	C	B	Cyprinidae
43043	Bluntnose minnow	M	O	T	N	P	C	B	Cyprinidae
43044	Central stoneroller	M	H	-	N	-	N	B	Cyprinidae
43045	Common carp x Goldfish	G	O	T	G	-	-	-	Cyprinidae
43046	Popeye shiner	N	I	S	N	-	S	P	Cyprinidae
43047	Grass carp	G	-	-	E	-	M	B	Cyprinidae
43048	Red shiner	N	I	-	E	-	N	P	Cyprinidae
43049	Common x Rosyface Shiner	N	I	-	-	-	-	-	Cyprinidae
43057	Striped shiner/Stoneroller	M	-	-	-	-	-	-	Cyprindae
43058	Common shiner/Stoneroller	M	-	-	-	-	-	-	Cyprinidae
43059	Striped shiner/Horny chub	M	I	-	-	-	-	-	Cyprinidae
43999	Hybrid Minnow	M	-	-	-	-	-	-	Cyprinidae
47001	Blue catfish	F	C	-	F	L	C	P	Ictaluridae
47002	Channel catfish	F	-	-	F	-	C	P	Ictaluridae
47003	White catfish	F	I	-	E	-	C	P	Ictaluridae
47004	Yellow bullhead	F	I	T	-	-	C	P	Ictaluridae
47005	Brown bullhead	F	I	T	-	-	C	P	Ictaluridae
47006	Black bullhead	F	I	P	-	-	C	P	Ictaluridae
47007	Flathead catfish	F	P	-	F	L	C	B	Ictaluridae
47008	Stonecat	O	I	I	-	-	C	R	Ictaluridae
47009	Mountain madtom	O	I	R	-	-	C	R	Ictaluridae

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Table B-3. (continued)

FINS Code	Species	Spc Grp	Feed Guild	TOL	IBI Grp	Riv Size	Brd Gld	Hab Pref	Family
47010	Northern madtom	O	I	R	-	-	C	R	Ictaluridae
47011	Scioto madtom	O	I	S	-	-	C	R	Ictaluridae
47012	Brindled madtom	O	I	I	-	-	C	B	Ictaluridae
47013	Tadpole madtom	O	I	-	-	-	C	B	Ictaluridae
50001	American eel	O	C	-	-	-	M	P	Anguillidae
54000	Western Banded killifish	T	I	S	-	-	M	P	Cyprinodontidae
54001	Eastern Banded killifish	T	I	T	E	-	M	P	Cyprinodontidae
54002	Blackstripe topminnow	T	I	-	-	-	M	P	Cyprinodontidae
57001	Mosquitofish	O	I	-	E	-	N	P	Poeciliidae
60001	Burbot	O	-	-	-	-	S	B	Gadidae
63001	Trout-perch	O	I	-	-	-	M	P	Percopsidae
68001	Pirate perch	O	I	-	-	-	M	P	Aphredoderidae
70001	Brook silverside	O	I	M	-	-	M	P	Atherinidae
74001	White bass	W	P	-	F	L	M	P	Percichthyidae
74002	Striped bass	W	P	-	E	-	M	P	Percichthyidae
74003	White perch	W	-	-	E	-	M	P	Percichthyidae
74004	White bass x White perch	W	-	-	-	-	-	-	Percichthyidae
74005	Striped bass x White bass	W	-	-	E	-	-	-	Percichthyidae
77001	White crappie	B	-	-	S	-	C	P	Centrarchidae
77002	Black crappie	B	-	-	S	-	C	P	Centrarchidae
77003	Rock bass	B	C	-	S	-	C	P	Centrarchidae
77004	Smallmouth bass	B	C	M	F	-	C	P	Centrarchidae
77005	Spotted bass	B	C	-	F	-	C	P	Centrarchidae
77006	Largemouth bass	B	C	-	F	-	C	P	Centrarchidae
77007	Warmouth	S	C	-	S	-	C	P	Centrarchidae
77008	Green sunfish	S	I	T	S	P	C	P	Centrarchidae
77009	Bluegill	S	I	P	S	-	C	P	Centrarchidae
77010	Orangespotted sunfish	S	I	-	S	-	C	P	Centrarchidae
77011	Longear sunfish	S	I	M	S	-	C	P	Centrarchidae
77012	Redear sunfish	S	I	-	E	-	C	P	Centrarchidae
77013	Pumpkinseed	S	I	P	S	-	C	P	Centrarchidae
77014	Bluegill x Pumpkinseed	S	-	-	-	-	-	-	Centrarchidae
77015	Green x Bluegill	S	-	-	-	-	-	-	Centrarchidae
77016	Green x Pumpkinseed	S	-	-	-	-	-	-	Centrarchidae
77017	Longear x Bluegill	S	-	-	-	-	-	-	Centrarchidae
77018	Bluegill x Orangespotted	S	-	-	-	-	-	-	Centrarchidae
77019	Green x Orangespotted	S	-	-	-	-	-	-	Centrarchidae
77020	Pumpkinseed x Longear	S	-	-	-	-	-	-	Centrarchidae
77021	Green x Longear	S	-	-	-	-	-	-	Centrarchidae
77022	O'spotted x Pumpkinseed	S	-	-	-	-	-	-	Centrarchidae
77023	Longear x Orangespotted	S	-	-	-	-	-	-	Centrarchidae
77024	Green x Warmouth	S	-	-	-	-	-	-	Centrarchidae
77025	Warmouth x Pumpkinseed	S	-	-	-	-	-	-	Centrarchidae

000217

Table B-3. (continued)

FINS Code	Species	Spc Grp	Feed Guild	TOL	IBI Grp	Riv Size	Brd Gld	Hab Pref	Family
77998	Green Sunfish Hybrid	S	-	-	-	-	-	-	Centrarchidae
77999	Hybrid Sunfish	S	-	-	-	-	-	-	Centrarchidae
80001	Sauger	V	P	-	F	L	S	P	Percidae
80002	Walleye	V	P	-	F	-	S	P	Percidae
80003	Yellow perch	V	-	-	-	-	M	P	Percidae
80004	Dusky darter	D	I	M	D	-	S	B	Percidae
80005	Blackside darter	D	I	-	D	-	S	B	Percidae
80006	Longhead darter	D	I	S	D	-	S	R	Percidae
80007	Slenderhead darter	D	I	R	D	L	S	R	Percidae
80008	River darter	D	I	-	D	L	S	R	Percidae
80009	Channel darter	D	I	S	D	-	S	P	Percidae
80010	Gilt darter	D	I	S	D	-	S	B	Percidae
80011	Logperch	D	I	M	D	-	S	B	Percidae
80012	Crystal darter	D	I	S	D	-	S	R	Percidae
80013	Eastern sand darter	D	I	R	D	-	S	R	Percidae
80014	Johnny darter	D	I	-	D	P	C	B	Percidae
80015	Greenside darter	D	I	M	D	-	S	R	Percidae
80016	Banded darter	D	I	I	D	-	S	R	Percidae
80017	Variegate darter	D	I	I	D	-	S	R	Percidae
80018	Spotted darter	D	I	R	D	-	S	R	Percidae
80019	Bluebreast darter	D	I	R	D	-	S	R	Percidae
80020	Tippecanoe darter	D	I	R	D	-	S	R	Percidae
80021	Iowa darter	D	I	-	D	-	M	P	Percidae
80022	Rainbow darter	D	I	M	D	-	S	R	Percidae
80023	Orangethroat darter	D	I	-	D	P	S	B	Percidae
80024	Fantail darter	D	I	-	D	H	C	R	Percidae
80025	Least darter	D	I	-	D	-	N	B	Percidae
80026	Sauger x Walleye	V	P	-	E	-	-	-	Percidae
85001	Freshwater drum	F	-	P	-	L	M	P	Sciaenidae
90001	Spoonhead sculpin	SC	-	-	-	-	C	P	Cottidae
90002	Mottled sculpin	SC	I	-	-	H	C	R	Cottidae
90003	Slimy sculpin	SC	-	-	-	-	-	-	Cottidae
90004	Deepwater sculpin	SC	-	-	-	-	-	-	Cottidae
95001	Brook stickleback	O	I	-	-	H	C	P	Gasterosteidae

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Table B-3. (continued)

SPCLST - Legend for Species Designations

The following letter symbol designations are used to classify Ohio fish species according to their taxonomic, functional, structural, pollution tolerance, and ecological characteristics. These designations provide the basis for the Fish Information System (FINS) to calculate metrics for the Index of Biotic Integrity (FINIBI) and the Modified Index of Well-Being (FINLS2) as well as other uses.

SPC GRP (Species Group)[a]

- O - Other
- L - Gars
- W - Large River Species
- GS - Gizzard Shad
- SA - Salmonid
- WF - Whitefish
- T - Tolerant
- P - Pickerels
- R - Round-bodied Suckers
- C - Deep-bodied Suckers
- G - Carp/Goldfish
- N - Shiners
- M - Minnows
- F - Catfish, Drum
- B - Blackbass, Crappie
- S - Sunfish
- V - Non-darter Percidae
- D - Darters
- SC - Sculpins

FEED GUILD (Feeding Guild)[b]

- P - Piscivore
- F - Filter Feeder
- V - Invertivore
- I - Specialist Insectivore
- O - Omnivore
- G - Generalist
- H - Herbivore
- C - Carnivore

TOL (Pollution Tolerance)

- R - Rare Intolerant
- S - Special Intolerant
- I - Common Intolerant
- M - Moderately Intolerant
- T - Highly Tolerant
- P - Moderately Tolerant

BRD GLD (Breeding Guild)[c]

- N - Complex, no parental care
- C - Complex with parental care
- M - Simple, miscellaneous
- S - Simple lithophils

IBI GRP (IBI Group)[b]

- E - Exotic (non-native)
- F - Sport Species
- R - Round-bodied Sucker
- C - Deep-bodied Sucker
- W - White sucker
- G - Carp/Goldfish
- N - Cyprinidae
- S - Sunfish (less Blackbasses)
- D - Darters

RIV SIZ (River Size)

- L - Large River Species
- H - Headwaters Species
- P - Pioneering Species

HAB PRF (Habitat Pref.)[c]

- P - prefers pools
- R - prefers riffles
- B - prefers both

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[a] these designations are not for use in any FINS analytical programs.
[b] designations are patterned after Karr et al. (1986).
[c] designations are patterned after Berkman and Rabeni (1987).

APPENDIX C:

Modified Index of Well-Being (I_{wb})

Appendix C-1: Modified Index of Well-Being (I_{wb})

A Modification of the Index of Well-Being for Evaluating Fish Communities

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Introduction

The index of well-being (I_{wb}), or composite index, was developed by Gammon (1976) to evaluate the response of riverine fish communities to environmental stress. This index was first tested using data from the Wabash River in Indiana (Gammon 1976; Gammon et al. 1981) and subsequently from other rivers in Indiana, Ohio (Yoder et al. 1981; Gammon 1980), and Oregon (Hughes and Gammon 1987). Since 1979 the Ohio EPA has used the composite index to evaluate electrofishing data from nearly 2000 locations throughout Ohio. These included a wide range of stream and river types from the smaller headwater streams to the Ohio River. Study areas included a wide range of chemical and physical perturbations. Sampling methods used are described in more detail elsewhere (Ohio EPA 1987a).

Index of Well-Being

The I_{wb} incorporates four measures of fish communities that have traditionally been used separately: numbers of individuals, biomass, and the Shannon diversity index (H) based on numbers and weight. The computational formulas for the I_{wb} and Shannon index are given in Table 1. Relative abundance (numbers and weight) data are derived from pulsed D.C. electrofishing catches where sampling effort is based on distance rather than time (Gammon 1976). Ohio EPA bases relative abundance on a per kilometer basis for boat methods and on a 0.3 kilometer basis for wading methods (Ohio EPA 1987a).

The individual performance of numbers, biomass, and the Shannon index as consistent indicators of environmental stress in fish communities has been disappointing. However, when combined in the I_{wb} these individual community attributes work in a complimentary manner. For example an increase in total numbers and/or biomass caused by one or two predominant species is usually offset by a corresponding decline in the Shannon index. In addition the $\log_e$ transformation of the numbers and biomass components acts to reduce much of their inherent variability. Gammon (1976) found the individual variability of each of the four I_{wb} components to range from 20-50%, yet the variability for the I_{wb} was approximately 7%.

High numbers and/or biomass is usually perceived as a positive attribute of a fish community. This should result in a high I_{wb} provided a relative

Table 1. Computational formula for the index of well-being and the Shannon diversity index.

Composite Index

$$I_{WB} = 0.5 \ln N + 0.5 \ln B + \bar{H}\,(\text{no.}) + \bar{H}\,(\text{wt.})$$

where;
N = relative numbers of all species
B = relative weight of all species
$\bar{H}$ (no.) = Shannon index based on relative numbers
$\bar{H}$ (wt.) = Shannon index based on relative weight

Shannon Diversity Index

$$\bar{H} = -\sum \frac{(n_i)}{N} \log_e \frac{(n_i)}{N}$$

where;
n_i = relative numbers or weight of the ith species
N = total number or weight of the sample

"evenness" is maintained between the abundance of the common species. However, this is not invariable, particularly with environmental perturbations which tend to restructure fish communities without large decreases in diversity (e.g. nutrient enrichment, habitat modification). For example, we have observed fish communities in highly modified streams that have very high numbers, biomass, and moderate species richness. Such communities are predominated by species tolerant to these disturbances. Species that are intolerant to such disturbances either decline in abundance or are eliminated altogether. The net increase in the relative abundance of the tolerant species with only modest declines in species richness yields a high I_{wb} value. The increased abundance of tolerant species is not sufficiently offset by the Shannon indices because species richness is not equally influenced. The overall result is an I_{wb} evaluation that is not reflective of the actual response of the community to these types of degradation. In fact I_{wb} values at some disturbed sites equaled or exceeded those measured at reference or least impacted sites.

Modified Index of Well-Being

Several modifications of the I_{wb} were attempted to correct the problem of relatively high scores at degraded sites. These included the complete elimination of predominant species from the index calculation, selective elimination of species based on their predominance, and a different weighting of the numbers component of the I_{wb}. None of these modifications worked in a consistent manner. The problem with a total elimination of predominant species is that their presence is not considered and it is difficult to apply consistently.

Ecologically the problem is that of a predominance and high abundance of species tolerant to the environmental degradation that we are attempting to measure. Tolerant species are the last to disappear under the influence of increased environmental degradation or those that respond favorably to a radical change in the physical or chemical quality of the environment. Thus their uniform elimination from the numbers and biomass components of the I_{wb} was attempted. Ohio EPA has designated all fish species known to occur in Ohio as highly tolerant, moderately tolerant, intermediate, moderately intolerant, or highly intolerant (Thoma et al. 1987). This was accomplished by examining a large, statewide data base that includes data from nearly 2000 sites and a wide range of environmental conditions. While most attempts to designate species tolerance rely mostly on the existing technical literature and regional fish reference texts, the Ohio EPA method is based on direct observations of species response in the field. This requires a comprehensive data base and should be supplemented by information from the technical literature when necessary.

The modified I_{wb} retains the same computational formula as the conventional I_{wb} developed by Gammon (1976). The difference is that any of 13 highly tolerant species, exotics, and hybrids are eliminated from the numbers and biomass components of the I_{wb}. However, the tolerant and exotic species are included in the two Shannon index calculations. This modification eliminates the "undesired" effect caused by high abundance of tolerant species, but retains their "desired" influence on the Shannon indices. To illustrate the effect of this modification several comparisons were made between key fish community attributes, the modified I_{wb}, and the conventional I_{wb}. In addition results from different streams and rivers subjected to different types and varying levels of environmental degradation (both chemical and physical) demonstrate the influence that this modification has on an evaluation of fish community health and well-being. The comparisons were made separately for boat electrofishing and wading methods.

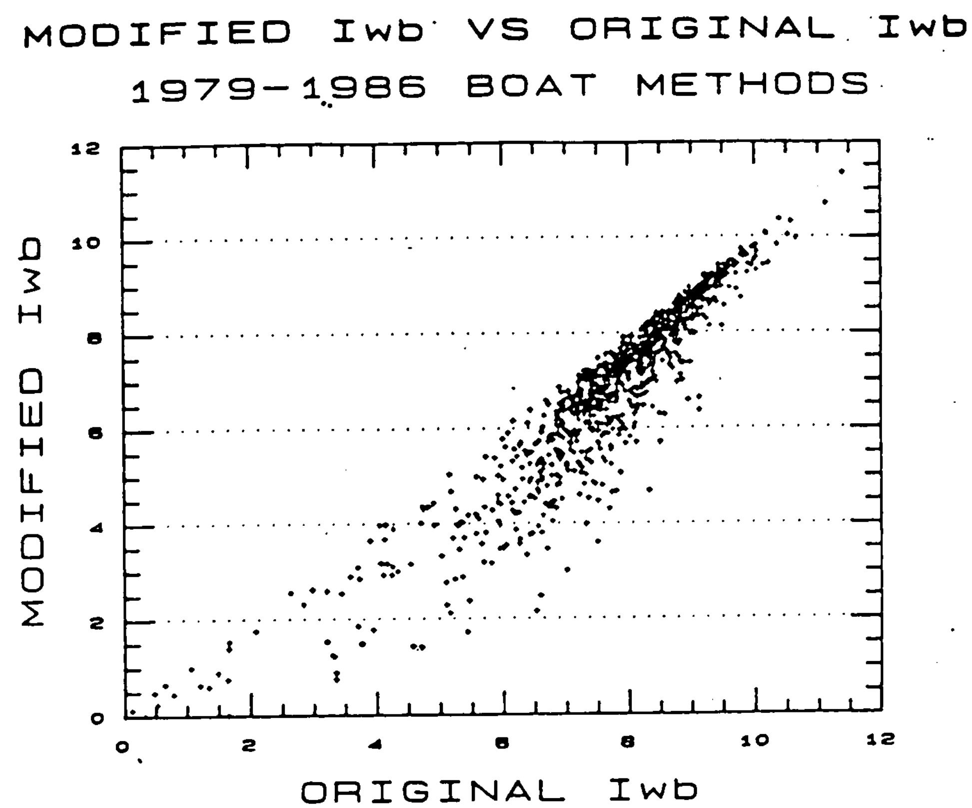
Modified Iwb and Original Iwb

Comparisons of the behavior of the modified I_{wb} and original I_{wb} were made using data from 912 boat electrofishing locations sampled between 1979-1986 and more than 972 locations sampled with wading methods between 1983-1986. These data sets were used to compare the modified I_{wb} with the original I_{wb} (Fig. 1), the difference between the modified I_{wb} and original I_{wb} with the modified I_{wb} (Fig. 2), the percent by number of tolerant species with the modified I_{wb} and the original I_{wb} for boat (Fig. 3) and wading (Fig. 4) methods. The I_{wb} is an "open ended" index in that it has no real upper limit. However, actual observations from over 2000 sites in Ohio show that I_{wb} values rarely exceed 10. Values above 8 and certainly 9 are generally regarded as being representative of healthy, unimpacted fish communities. The comparison of the modified and original I_{wb} shows a close agreement at the sites which score above 10, but an increasing departure as I_{wb} scores decline (Fig. 1). The patterns are similar for boat and wading methods. This relationship is also demonstrated in the comparison of the I_{wb} difference with the modified I_{wb} (Fig. 2). The difference between the original and modified I_{wb} values increases as the modified I_{wb} decreases.

The relationship of the percent by numbers of tolerant species with the modified and original I_{wb} was also examined (Figs. 3 and 4). A curve of best fit that approximates a 95% line was drawn on the comparisons with the modified I_{wb}. As the percent of tolerant species increases the modified I_{wb} decreases. This relationship is lacking with the original I_{wb}, a result of the previously described problem of high numbers of tolerant species inflating the original I_{wb} values. The 95% curve was superimposed on the comparisons with the original I_{wb}. The result is that many points lie above and to the right of the 95% line in the comparisons with the original I_{wb}. This means that the original I_{wb} can score high when the environment is adversely affected by certain types of physical and chemical degradation that result in a predominance of tolerant species. The result can be an incorrect evaluation of fish community condition. The treatment of tolerant species in the modified I_{wb} greatly reduces this problem and results in a consistently more accurate evaluation.

Specific Applications

The utility of any index, biological or otherwise, is in how consistently it reacts to change either positive or negative. A significant shortcoming of the original I_{wb} is in its inability to adequately characterize degraded communities where an environmental stress results in a restructured community



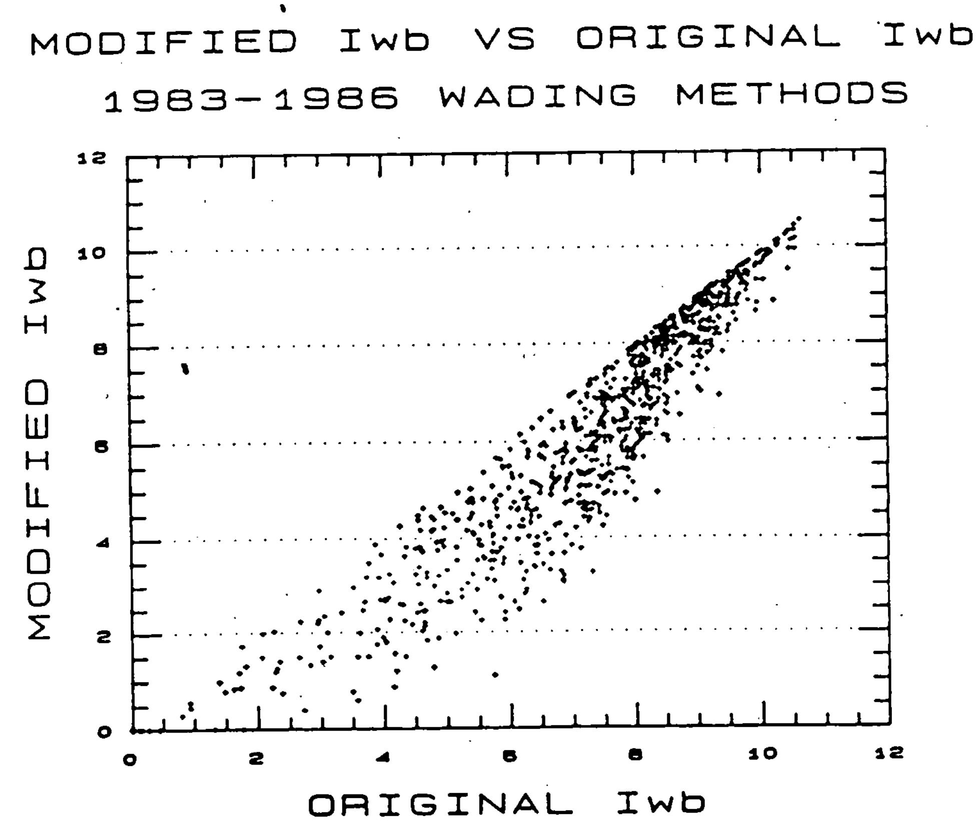


Figure 1. Comparison of the original Iwb with the modified Iwb at boat electrofishing locations sampled between 1979-1986 (top) and locations sampled with wading methods between 1983-1986 (bottom).

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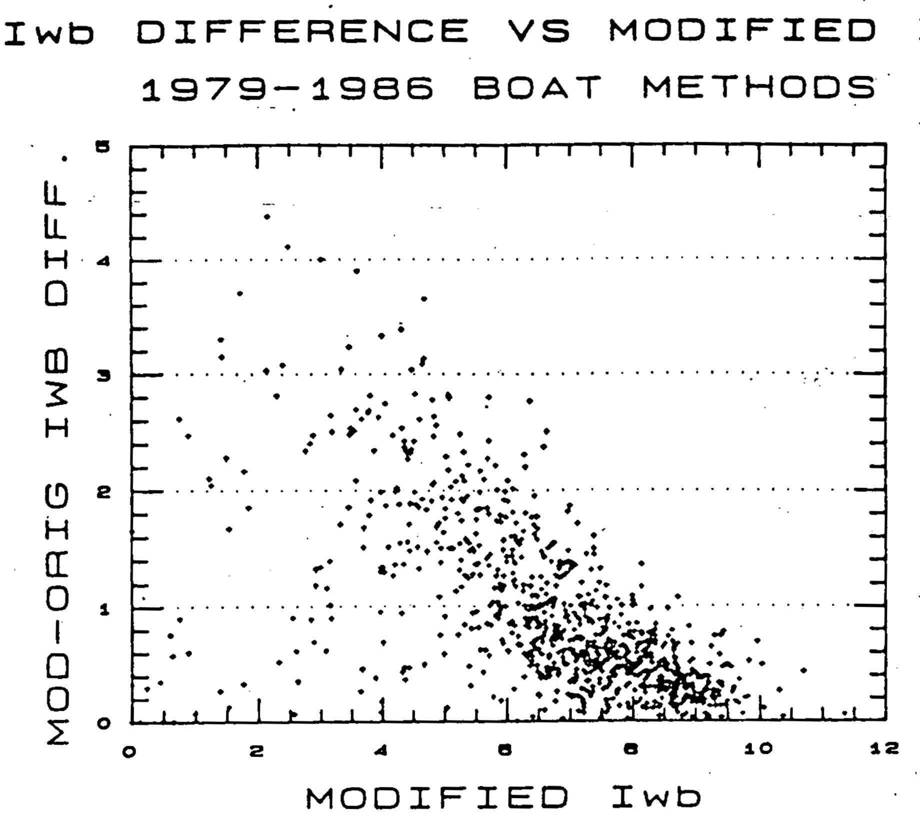

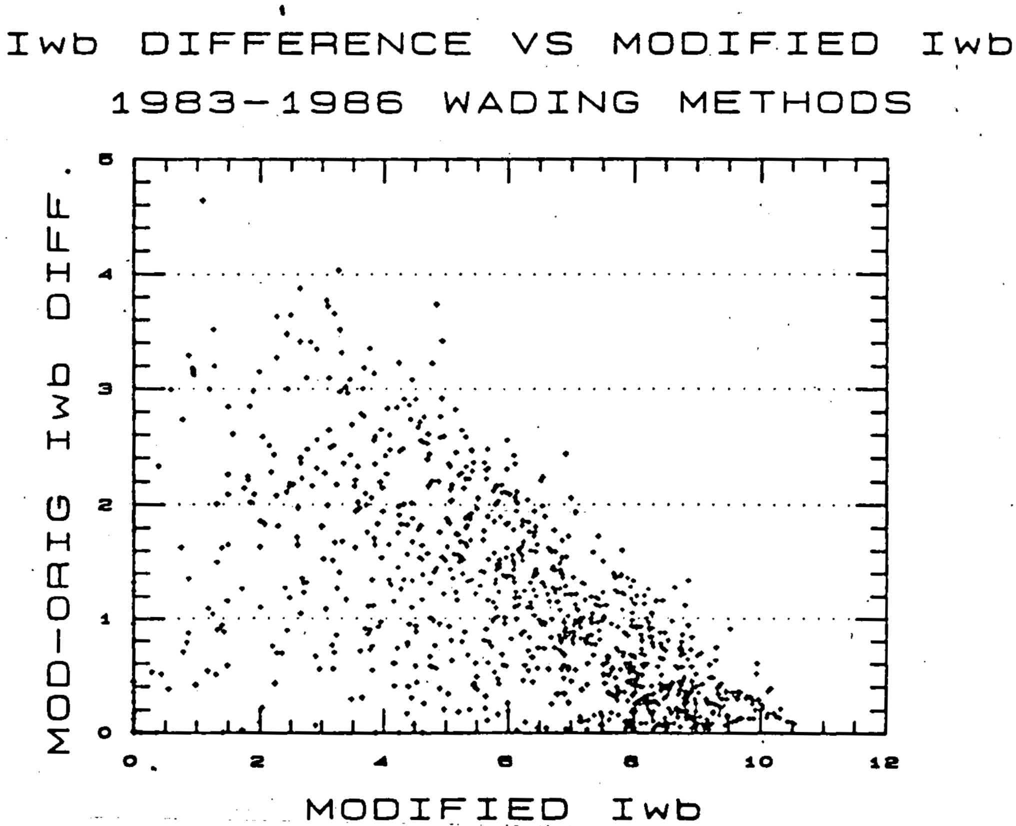

Figure 2. Relationship between the difference between the original Iwb and modified Iwb at boat electrofishing locations sampled between 1979-1986 (top) and locations sampled with wading methods between 1983-1986 (bottom).

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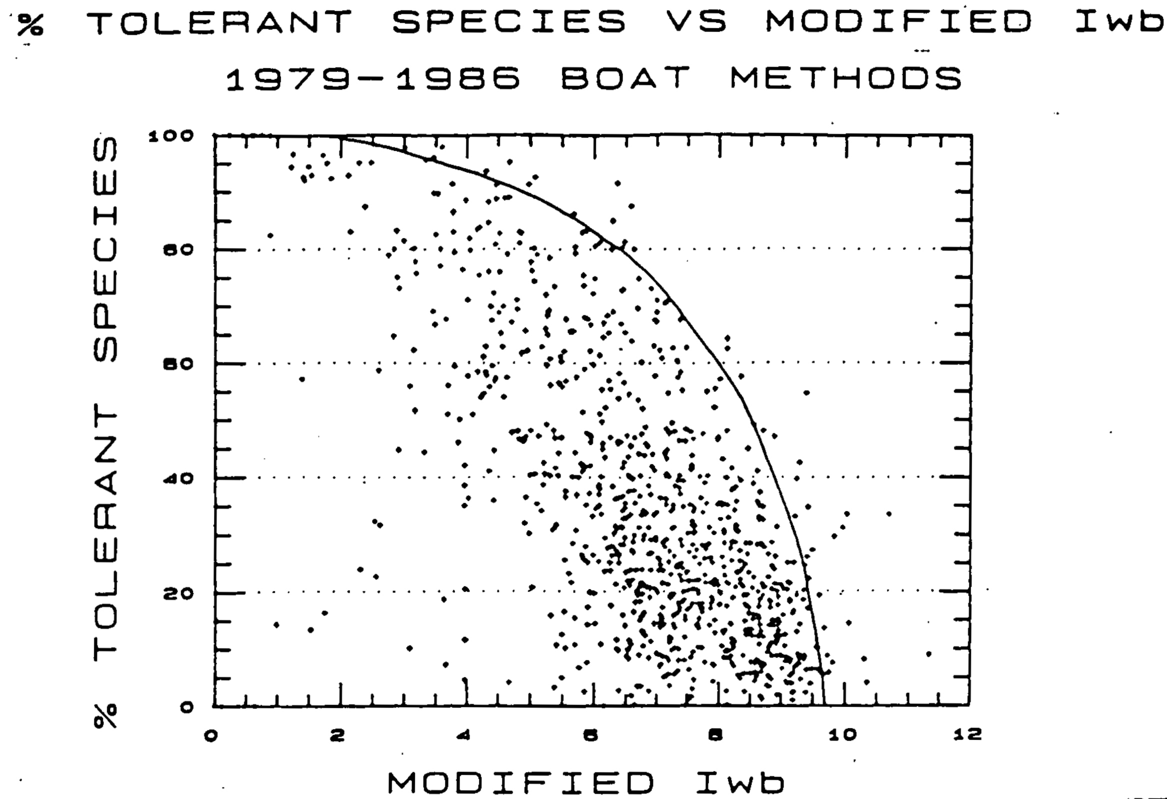

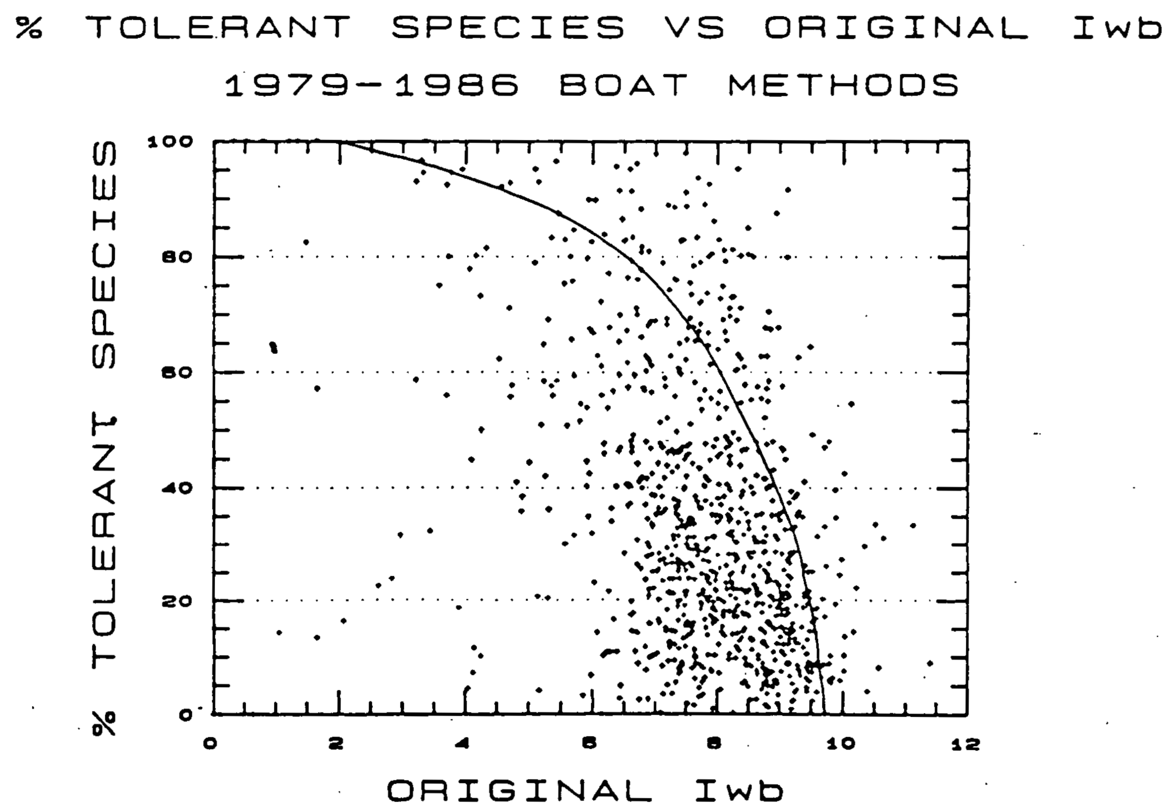

Figure 3. Comparison of percent by numbers of tolerant species with the modified and original I_{wb} for boat electrofishing locations sampled between 1979-1986. The line of best fit approximates the 95% line based on the comparison with the modified I_{wb}.

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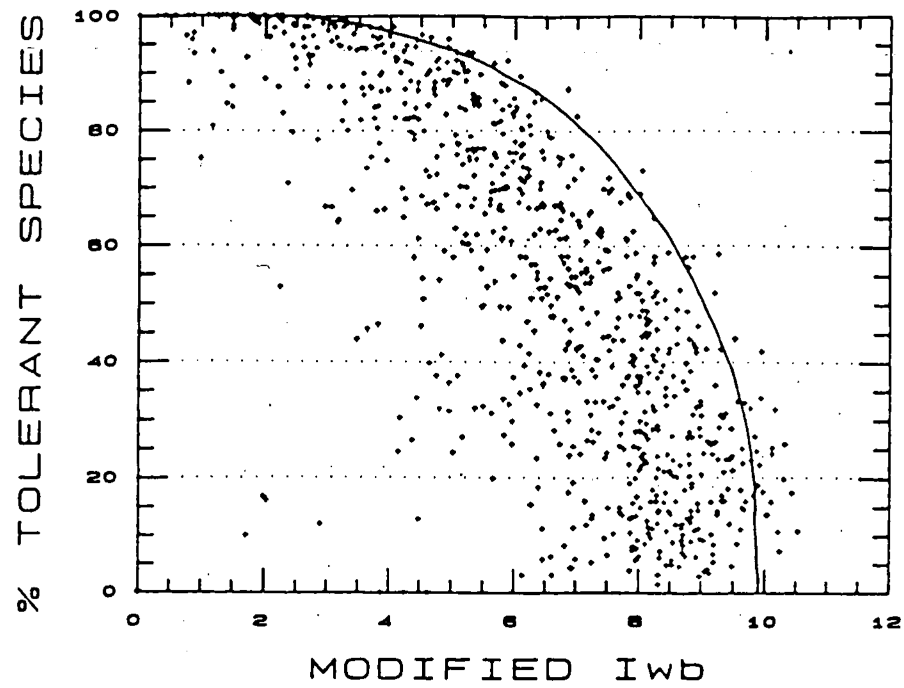
% TOLERANT SPECIES VS MODIFIED Iwb 304

1983–1986 WADING METHODS



% TOLERANT SPECIES VS ORIGINAL Iwb

1983–1986 WADING METHODS

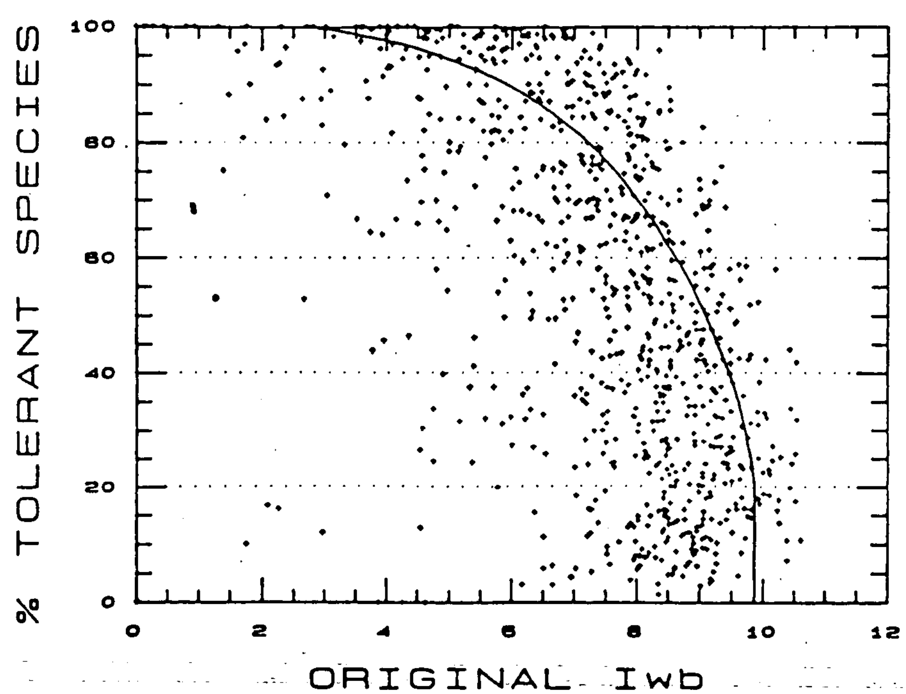


Figure 4. Comparison of percent by numbers of tolerant species with the modified and original I_{wb} for locations sampled with wading methods between 1983-1986. The line of best fit approximates the 95% line based on the comparison with the modified I_{wb}.

000228

with high numbers and/or weight of tolerant species. Table 2 shows the results of fish sampling at selected sites that are affected by a variety of environmental stresses including habitat modification, organic enrichment, and toxic chemicals. Sites that represent relatively unimpacted situations are included for comparison. The differences between the modified and original Iwb are impressive, ranging from 1.0 to more than 3.0 Iwb units at the degraded sites. The difference at the relatively unimpacted sites is negligible being less than 0.1-0.5 Iwb units.

Iwb results from a recent electrofishing survey of the Ottawa River in northwestern Ohio are depicted in Figure 5. The original Iwb, modified Iwb, and the difference between each show that the largest differences occur downstream from the variety of environmental stresses that exist in this study area. Influences include raw sewage and urban runoff from combined sewer overflows, domestic wastewater from a sewage treatment plant with industrial contributors, effluent from an oil refinery, and effluent from an agricultural chemicals plant, and habitat modification resulting from several small impoundments. Ohio EPA uses a tiered classification system based on the Iwb to rate sites as exceptional, good, fair, poor, and very poor (Table 3). The exceptional and good ratings reflect full attainment of the Clean Water Act goal of biological integrity. Evaluation of impacted sites on the Ottawa River (Fig. 5) change from good to fair, fair to poor, or poor to very poor when the modified Iwb is used. Although the rating of the relatively unimpacted upstream site and the downstream recovery site appear to change from exceptional to good their original ratings were good because they did not meet all of the criteria for exceptional. In addition the difference between the original and modified Iwb at these two sites was the smallest in the study area.

Modified Iwb

The examples and analyses presented show that the modified Iwb is a consistent and sensitive index to a wide range of environmental stresses. The elimination of any of 14 highly tolerant species from the numbers and biomass components of the Iwb achieves this desired result and resolves a significant shortcoming of the original Iwb. Biological indices are most useful when they score consistently and are sensitive to a wide variety of environmental stresses, both chemical and physical. The modified Iwb achieves these objectives.

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Table 2. Results of electrofishing at selected sits in Ohio that are subjected to different types and levels of environmental degradation showing the different ratings assigned by the original Iwb compared to the modified Iwb.

Stream/River (RM[a])	Sample Type[b]	% No./Wt. Tolerant	Original Iwb	"Old" Rating[c]	Modified Iwb	"New" Rating[c]	Characterization of Degradation
Swan Creek (2.6)	W	45/90	4.10	Poor - V. Poor	2.92	V. Poor	Combined sewers, urban
L. Auglaize R. (17.6)	W	63/73	8.96	Good	7.73	Good - Fair	Channelization
L. Auglaize R. (37.4)	W	80/97	7.21	Fair	4.55	Poor	Sewage, channelization
L. Auglaize R. (41.1)	W	72/83	9.01	Good	7.51	Fair	Channelization
Blue Jacket Cr. (5.4)	2	90/98	7.29	Fair	4.58	Poor	Sewage, heavy metals
E. Br. Nimishillen C. (4.2)	W	95/99+	7.11	Fair	3.77	V. Poor	Toxic wastes, sewage
Mahoning R. (7.1)	B	82/45	1.49	V. Poor	0.88	V. Poor	Toxic wastes
Mahoning R. (46.3)	B	15/56	8.45	Good	7.94	Good	Impounded river
Cuyahoga R. (36.5)	B	90/96	6.05	Poor	3.54	V. Poor	Toxic wastes
Cuyahoga R. (40.4)	B	45/90	8.01	Good	6.58	Fair	Combined sewers, urban
Black R. (9.3)	B	88/98	6.76	Fair	4.34	Poor	Sewage, toxic wastes
L. Darby Cr. (15.2)	W	8/3	9.26	Good - Exceptional	9.20	Good - Exceptional	Unimpacted
Captina Cr. (14.5)	W	17/3	10.53	Exceptional	10.43	Exceptional	Unimpacted
Stillwater R. (16.0)	B	21/26	9.41	Good - Exceptional	9.13	Good - Exceptional	Unimpacted
Ottawa R. (1.2)	B	49/70	9.52	Exceptional	8.54	Good	Recovery site
Ottawa R. (34.7)	B	95/99	5.09	Poor	2.28	V. Poor	Toxic wastes, sewage
Ottawa R. (37.7)	B	80/96	9.12	Good	6.63	Fair-Poor	Combined sewers, urban
Ottawa R. (38.9)	B	85/92	8.49	Good	6.29	Fair-Poor	Com. sewers, impoundment
Gr. Miami R. (98.5)	B	13/24	9.45	Exceptional	9.25	Good - Exceptional	Unimpacted
Gr. Miami R. (77.1)	B	38/81	7.69	Good-Fair	6.54	Fair	Urban, impounded river
Gr. Miami R. (70.4)	B	76/97	6.55	Fair	3.93	V. Poor	Sewage wastes
Gr. Miami R. (65.9)	B	82/98	6.78	Fair	4.04	V. Poor	Sewage, impoundment

a River Mile Index - Ohio EPA PEMSO system.

b W - wading methods; B - boat electrofishing.

c Based on Ohio EPA classification system developed November 1980; revised January 1987.

Table 3. Conceptual response of fish community structural and functional attributes as portrayed by modified Index of Well-Being (I_{wb}). Narrative descriptions of fish community condition for good, fair, poor, and very poor ranges are indicated.

Category	--- MEETS CWA GOALS ---		------ DOES NOT MEET CWA GOALS ------		
	"Exceptional"	"Good"	"Fair"	"Poor"	"Very Poor"
1.[a]	Exceptional, or unusual assemblage of species	Usual association of expected species	Some expected species absent, or in low abundance	Many expected species absent, or in low abundance	Most expected species absent
2.	Sensitive species abundant	Sensitive species present	Sensitive species absent, or in very low abundance	Sensitive species absent,	Only most tolerant species remain
3.	Exceptionally high species richness	High species richness	Declining species richness	Low species richness	Very low species richness
4.[b]	Composite index Greater than 9.5	Composite index Greater than 7.4 - 8.6[b], Less than 9.4	Composite index Greater than 5.3 - 6.3[b], Less than 7.4-8.6[b]	Composite index Greater than 4.5 - 5.0[b], Less than 5.3-6.3[b]	Composite index Less than 4.5 or 5.0[b]
5.	Outstanding recreational fishery		Tolerant species increasing, beginning to predominate	Tolerant species predominate	Community organization lacking
6.	Species with an endangered, threatened, or special concern status are present				

[a] Conditions: Categories 1, 2, 3 and 4 (if data is available) must be met and 5 or 6 must also be met in order to be designated in that particular class.

[b] encompasses range of ecoregional values; area of insignificant departure is –0.5 from ecoregional criterion.

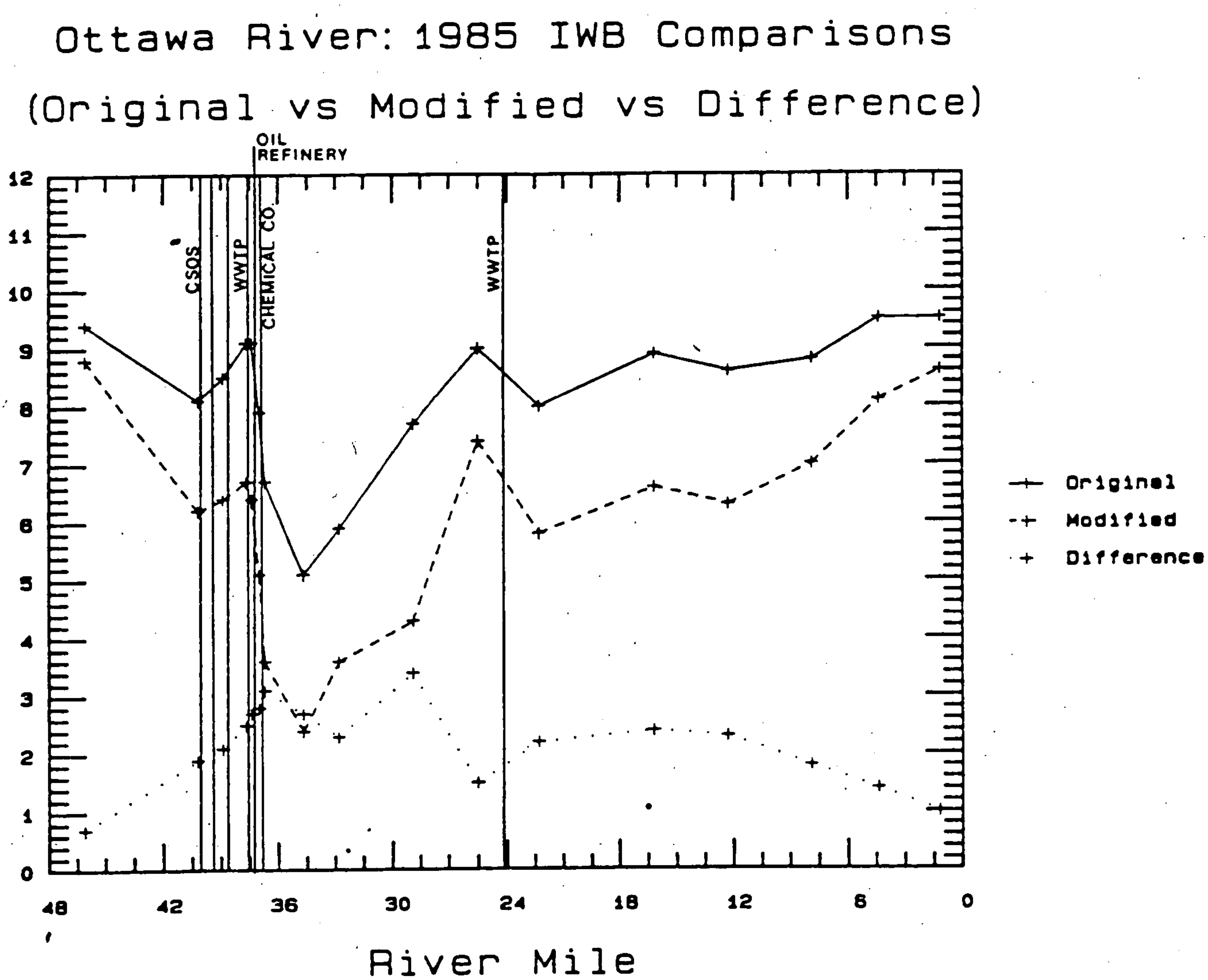

Figure 5. Original Iwb and modified Iwb results based on electrofishing samples from the Ottawa River during July-September 1985. The difference between the original Iwb and modified Iwb is included for comparison. Environmental influences are indicated.

APPENDIX D:

Sampling and Data Variability Analysis

D-1: Background

It is of critical importance in biological monitoring to collect a consistent and reproducible sample. To assess degradation there must be knowledge of the variability of samples to determine the most valid means of detecting significant differences in communities among sites in a study. Variation can be divided into sampling variation (i.e., error) and true variation between sites and sampling times. Ideally, we wish to minimize our sampling error and maximize our ability to detect true differences (in the means and variance of index values) among sampling sites and sampling passes. Further, we need to be able to distinguish between natural variation and "anthropogenic" sources (i.e., pollution) of variation in our data. A prerequisite for determining the precision of an index or method is a demonstration of the accuracy and relevance of the procedures; this was accomplished in the main document and other appendices (especially appendix C).

D-2: Fish

The probability of determining a difference in Iwb or IBI scores is related to changes in the location of means and the variability of the data between sampling passes at a site. The greater the sample size the more confident we are in our estimate of community integrity (i.e., mean index value) at a site. However, it is impractical and unnecessary to sample a location 10-20 times in order to "increase" our confidence in an estimate. Instead we can use past sampling efforts to create an empirical estimate of how large differences between index values need to be for significant differences to be discerned.

Two types of data were examined to estimate normal "background" variation and the magnitude of differences necessary to detect true changes in community integrity: data from a large number of different streams and test zone data that consisted of repeat sampling of the same stream reaches. We examined several hundred sites sampled with wading methods and found that the Iwb from individual samples deviated less that $\pm$0.4 Iwb units from the mean (>9.0, sites with three passes) at a site about 75% of the time. The maximum deviation observed was about 0.75 Iwb units (Fig. D-1; Panel A). For boat methods deviations were 0.5 and about 0.95, respectively (Fig. D-1; Panel B). Only slightly more variability was observed down to an Iwb of 7.0 for wading methods (Fig D-1; Panel A) and 8.0 for boat methods (Fig D-1; Panel B). Below these values the range of variability increased markedly, reflecting the addition of anthropomorphic sources of variability.

Test zone data from a relatively unimpacted site on Little Darby Creek also approximates background variation. Figs. D-2 and D-3 illustrate data from 50m segments plotted by segment and date, respectively. Scores are remarkably consistent, especially considering that the length of sites is only 50m. Slightly greater variability occurs among adjacent stretches than among different dates within a stretch in most cases, variability that would be reduced or "averaged" in longer, normal length zones (i.e., 200m).

When examining integrity of sites with two or three sampling passes the observed variability may be as useful as means for detecting degradation. In fact, variability in Iwb scores is common (but not universal) in stressed communities, especially where the causes of impacts are episodic.

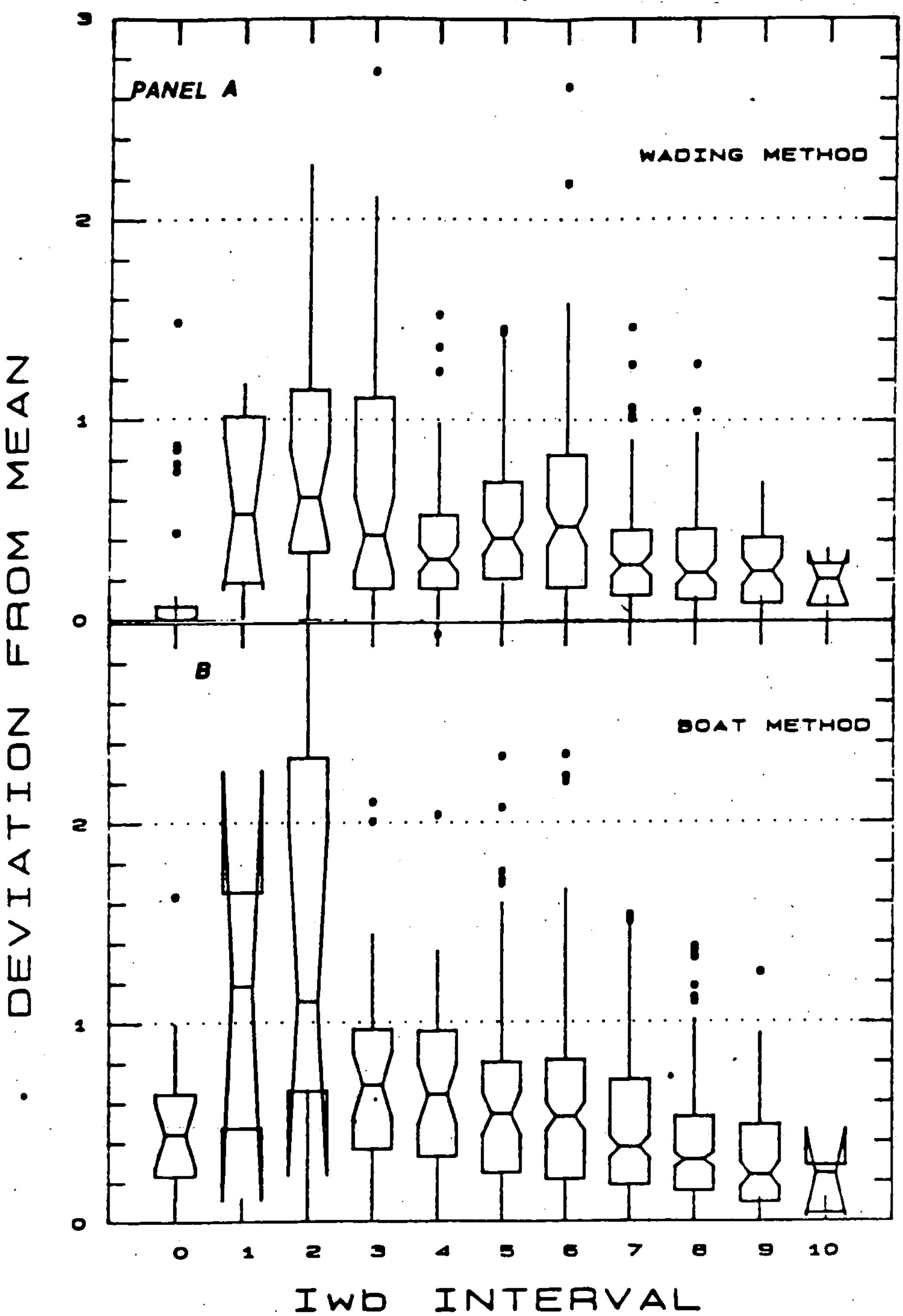

Figure D-1. Deviations of the Iwb for individual sampling passes from mean values of the modified Iwb from sites in Ohio. Means based on three sampling passes. Panel A: wading sites; Panel B: boat sites. Iwb intervals represent integer portion of Iwb ranges.

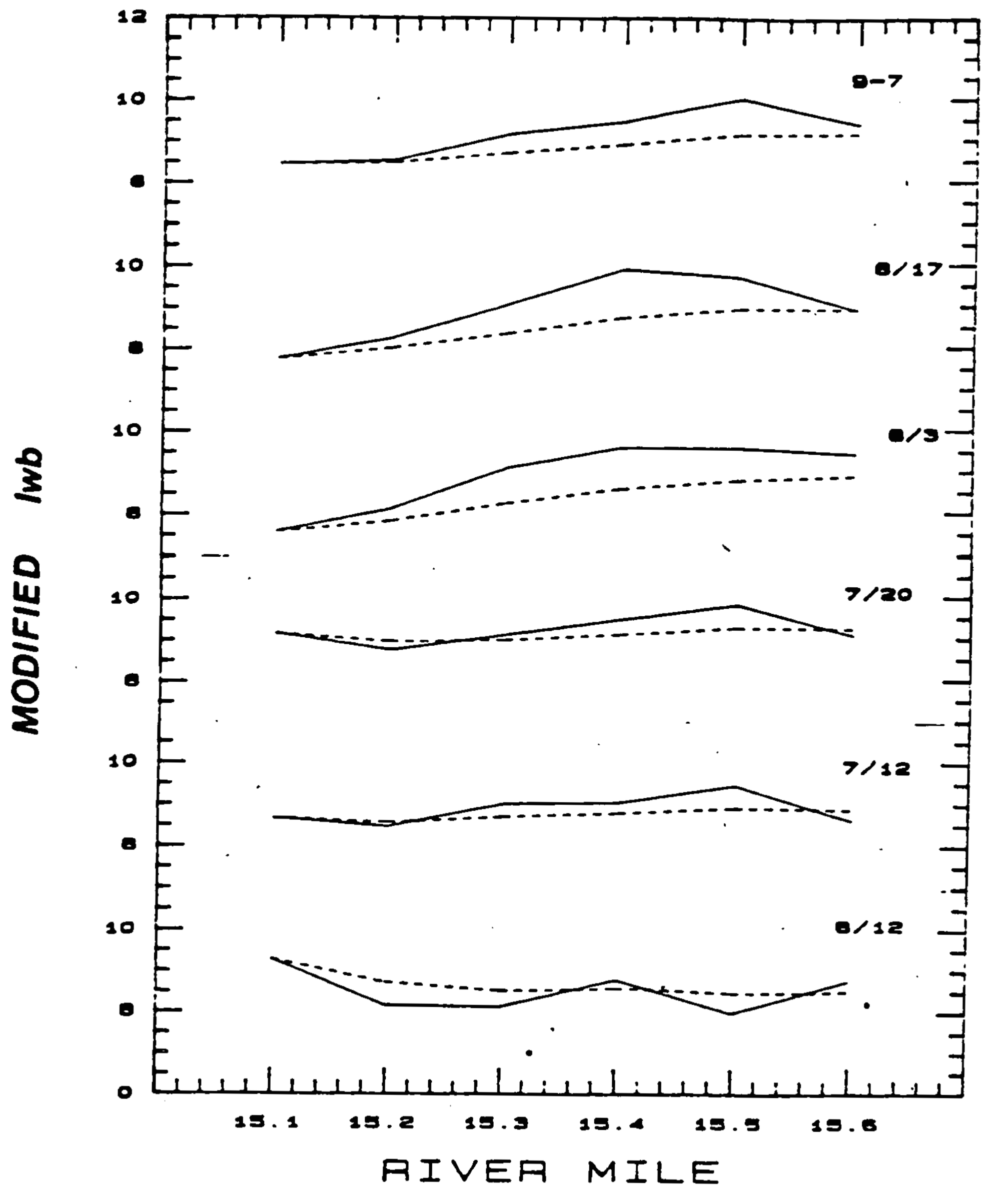

Figure D-2. Plots of the modified Iwb versus river mile for six dates during 1984 in Little Darby Creek. Each point represents a single sample from a 50m long sampling stretch. Dotted lines indicate cumulative IWB values averaged over all stretches for a given date.

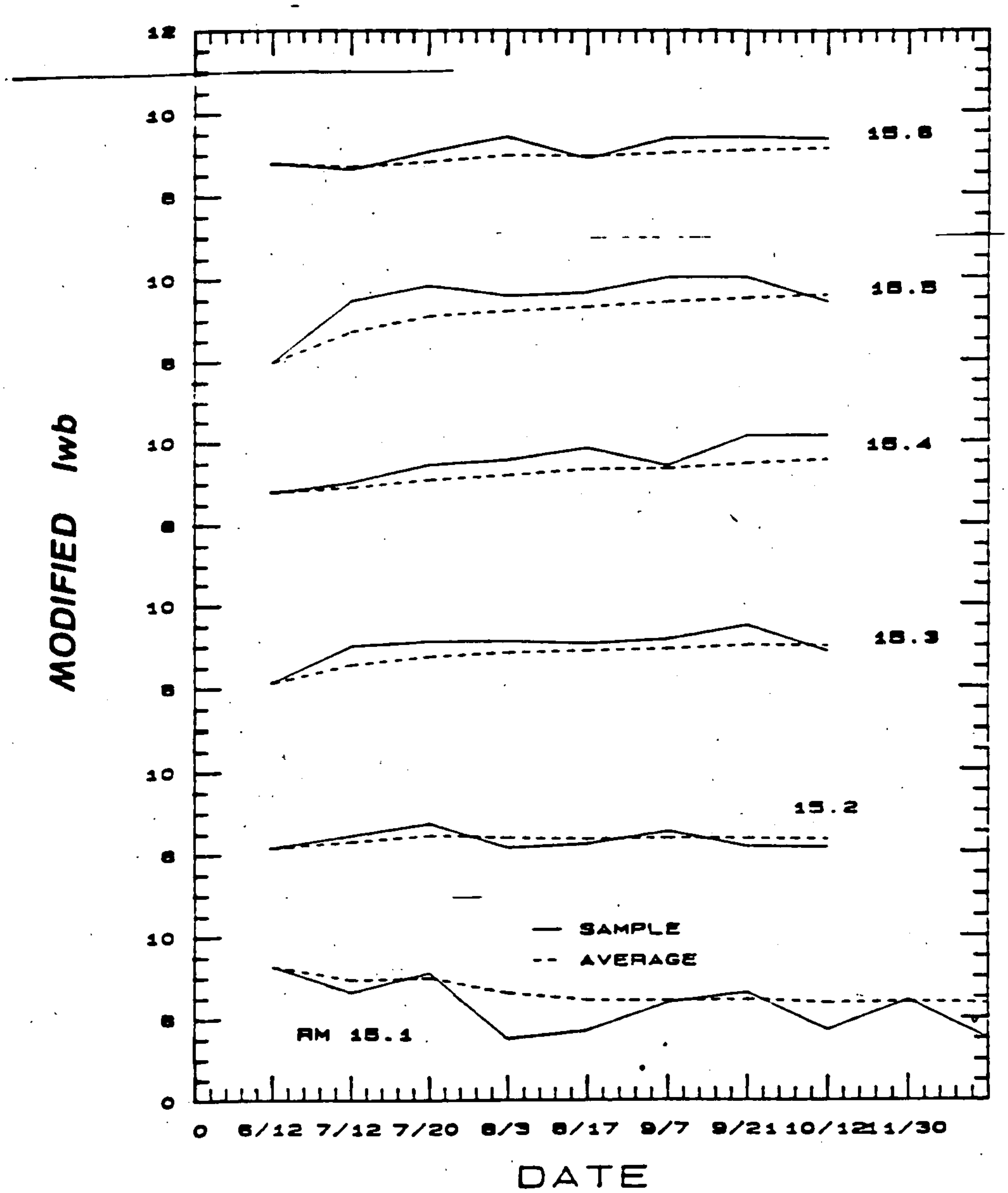

Figure D-3. Plots of the modified Iwb versus date for six adjacent sampling stretches (50m in length) during 1984 in Little Darby Creek. Dotted lines indicate cumulative mean values averaged over all dates for a given stretch.

Karr et al. (1987) found that in Illinois higher-quality sites had less variable IBI scores than sites of lower-quality. Variation, beyond normal background variation may reflect the random timing of pollution events, the ability of fish to avoid pollution, and the ability of fish to quickly recolonize (at least tolerant forms) previously degraded areas from upstream refuges. Cairns (1986) recognizes the importance of examining environmental variation in streams and he chastises approaches that ignore this variation:

"To ecologists, discussions of natural variability would seem platitudinous, since natural variability is one of the commonly accepted phenomena. Yet laboratory toxicologists have almost without exception failed to incorporate this widespread and generally acknowledged ecological phenomena into their investigations. Odum et al. (1979) note that an increase in variability is one of the frequent responses to stress, yet even ecologists have discarded certain field measurements because they are thought to be too highly variable. In fact, differences in variability rather than differences in averages or means might be the best measure of stress in natural systems."

Figure D-4 (Panel A, wading methods; Panel B, boat methods) shows a measure of variation, standard error, plotted versus the Iwb for several hundred sites with three sampling passes. Note the general trend of increasing variation with decreasing Iwb. There is some decrease in variation at the most degraded sites (Iwb < 2) probably because the severity of the impact precludes much recovery of the fish community.

Box and whisker plots of our EWW/WWH reference site data (Fig D-5; wading and boat methods combined, three passes by ecoregion Panel A: Iwb, Panel B: IBI) illustrates background levels of variation as measured by standard errors (SE). Standard errors of greater than about 0.5 for the modified Iwb and 4 for the IBI suggest variability greater than background variability (i.e., possible impacts or poor sampling). The importance of this lies in determining whether a site attains the designated use for an ecoregion.

Ideally, sites should be sampled two to three times to ensure that a site is meeting criteria for an ecoregion. Karr et al. (1987) suggested that one is more likely to overrate poor sites than underrate high-quality sites. Thus a low IBI score is more likely to reflect degraded conditions and less likely to be an "underscoring" high-quality site. As an example, the WWH standard for headwater sites in four of five ecoregions is 40. If a site scores a 32 on a single pass (baring no sampling problems) it is unlikely to reach the standard after more sampling; the low score indicates an impacted community. Further sampling will most likely yield other low scores or produce variable results. For sites with three passes a difference of at least 4 points for the IBI and 0.5 points for the modified Iwb are needed to detect true differences; when comparing data to a standard or unimpacted control site high variability increases the likelihood of a difference (indicating an impact). These criteria are less conservative than parametric ranges tests such as the Student-Newman-Kuels test because increased variation decreases the ability of these parametric tests to detect differences among sites, even though the increase in variability may well indicate increased stress. Figure 6 illustrates the concept behind analyzing use attainment and the confidence of various combinations of scores, variation, and sampling passes. The need to achieve macroinvertebrate criteria (ICI) and both fish criteria (IBI and Iwb) increases the protectiveness of the criteria.

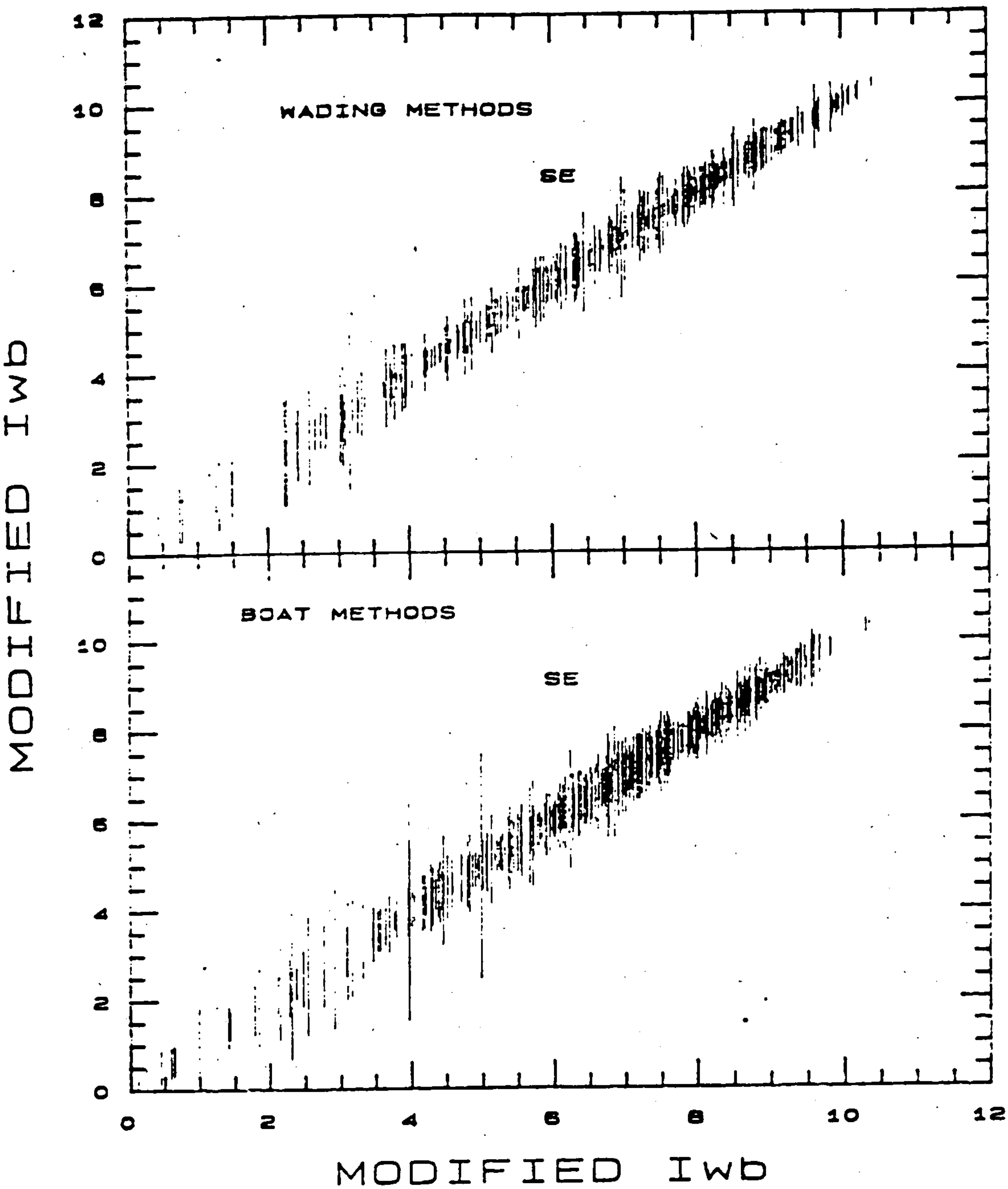

Figure D-4. Standard errors (SE) plotted by increasing magnitude of the modified Iwb. SE is based on three sampling passes for wading sites (Panel A) and boat sites (Panel B).

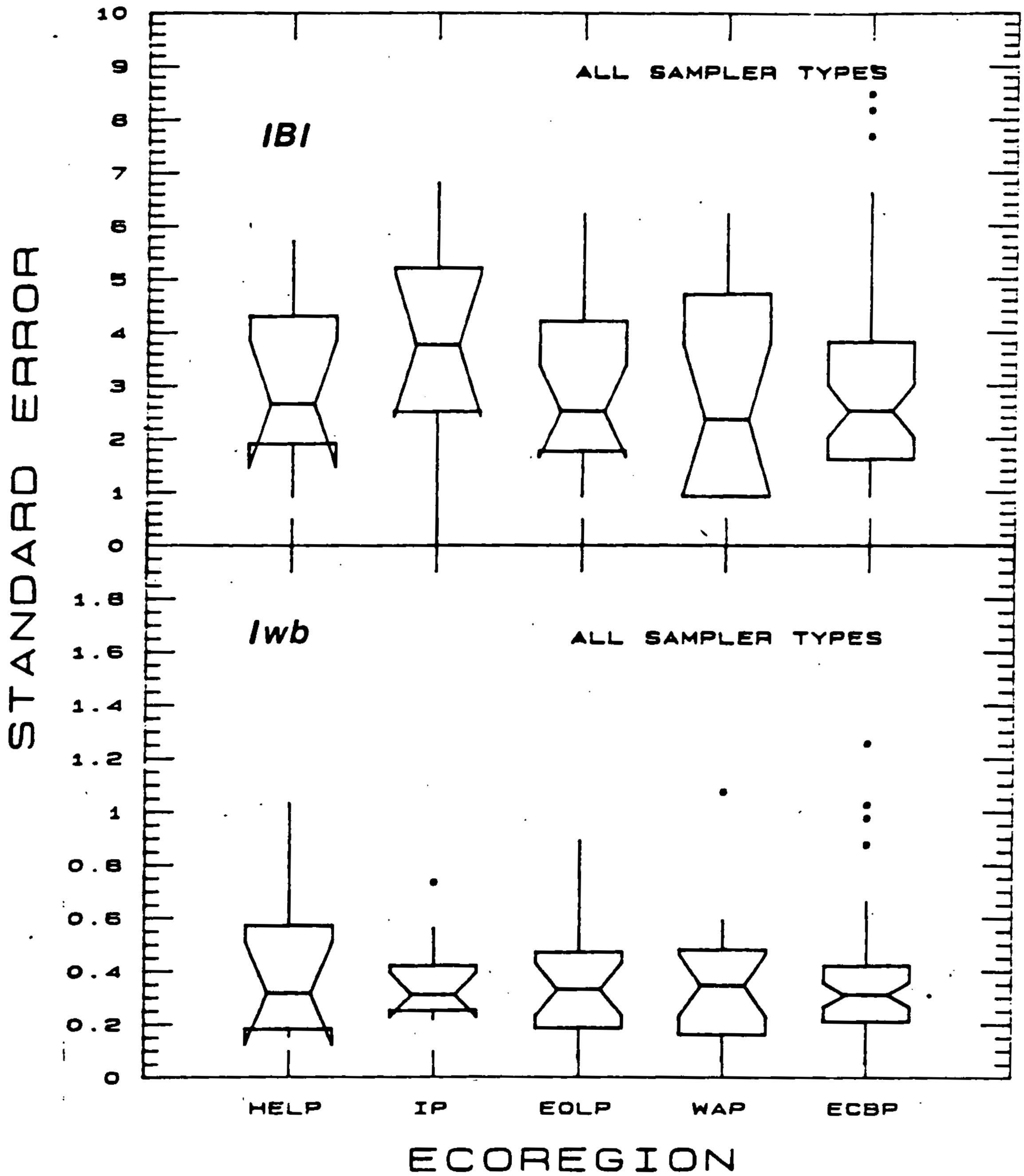

Figure D-5. Box and whisker plots of standard errors for mean Iwb values from Ohio EWH/WWH reference sites (sites with three sampling passes) plotted by ecoregion. Standard errors greater than the 75th percentiles suggest variability that exceeds what is expected in a relatively unimpacted stream (barring known sampling problems).

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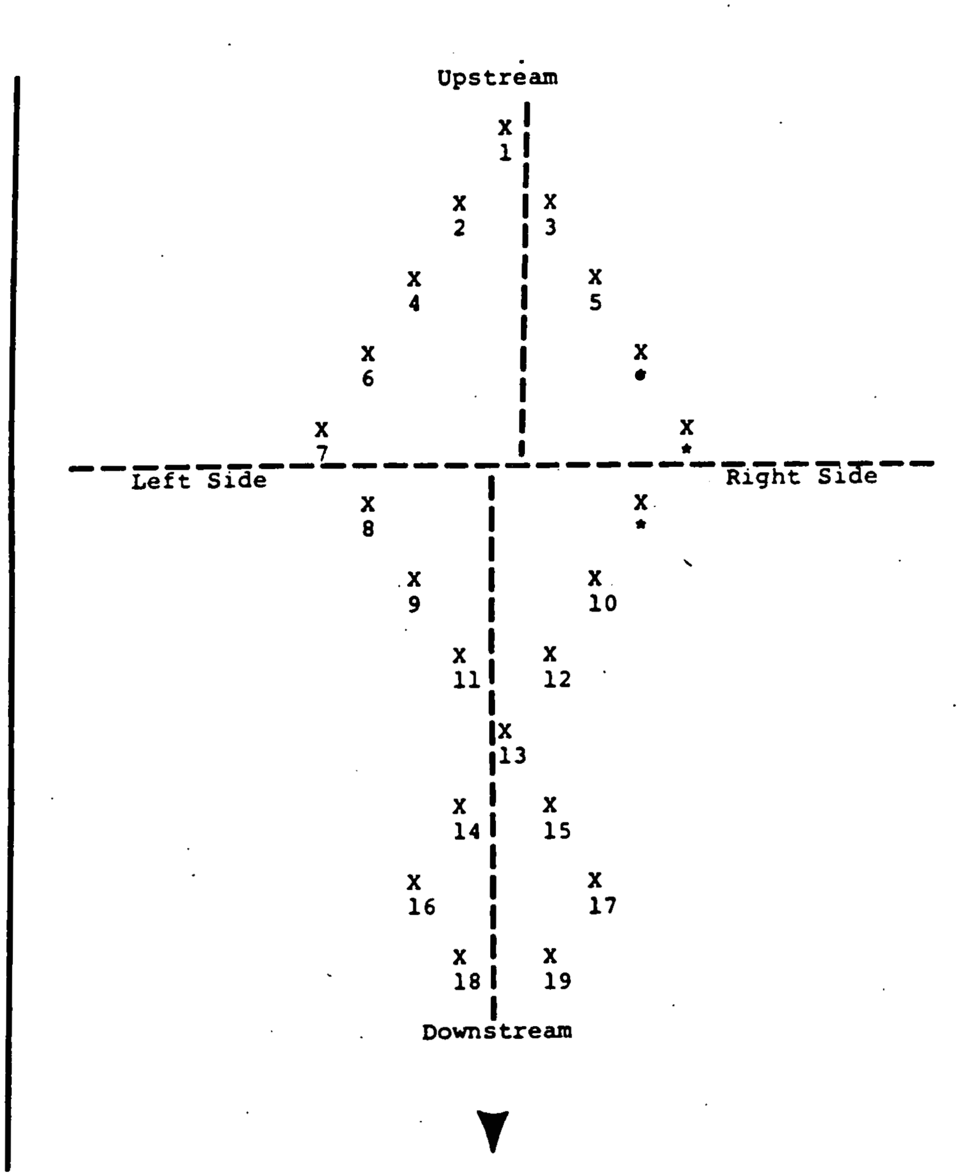
D-3: Macroinvertebrates

Variation in evaluating parameters at a given site must be kept at a minimum in order to make accurate biological assessments based on developed criteria. To this end, a study was conducted at a site in Big Darby Creek in central Ohio in the summer of 1981. The original intent of the study was to evaluate the effectiveness of the sampling unit consisting of five artificial substrate samplers. Parameters generated from the data (composition, number of taxa, density, and diversity index) were subjected to a number of statistical analyses to evaluate sampling unit reliability. Results of this study are reported elsewhere (Ohio EPA 1984). The next logical progression was to analyze the degree of variation in ICI values generated by the data.

The study location was a section of Big Darby Creek at river mile 36.5. Big Darby Creek is a documented high quality aquatic system composed of a very diverse benthic fauna many taxa of which are quite rare in abundance (Ohio EPA 1983a). Thus it would seem that the potential for variation under these conditions is significant. Twenty-two sampling units of five artificial substrates each were placed in a run in the general configuration depicted in Figure D-6. An attempt was made to minimize differences in current velocity and depth over the samplers. Colonization occurred between June 30 and August 11, 1981. Methods of retrieval and sample processing were consistent with the procedures outlined in Ohio EPA (1987a). Nineteen of the sampling units were subsequently analyzed and ICI summary statistics are listed in Table D-1. The box-and-whisker plot of the ICI values is depicted in Figure D-7.

Previous examination of the data (Ohio EPA 1984) indicated that the physical factors measured (depth and current velocity) were kept relatively constant and had no significant effect on the biological parameters measured. Similar results were found when the physical factors were compared to the ICI values. Assuming that the same water quality conditions were affecting all the sampling units, it was inferred that any variability in ICI was due to natural biological processes (e.g., predation, emigration, immigration, mortality, natality) influencing the community colonizing the sampling unit.

ICI values were reasonably consistent. The median value was 34 and the 25th and 75th percentiles were 32 and 36, respectively. This suggests that the four point "gray" zone of insignificant violation is an accurate range and would allow for the effect of natural variation on the ICI value. More tests of this kind in other high quality Ohio stream locations are planned to further substantiate and test the consistency and reproducibility of the ICI.



* Not collected.

Figure D-6. Sampling configuration of the artificial substrate units at the 1981 Big Darby Creek test location.

Table D-1. ICI summary statistics generated from data collected at the 1981 Big Darby Creek test location.

Sample Size:	19
Average:	34
Median:	34
Standard Error:	0.8
Minimum Value:	28
Maximum Value:	44
Quartile	
lower (25%):	32
upper (75%):	36

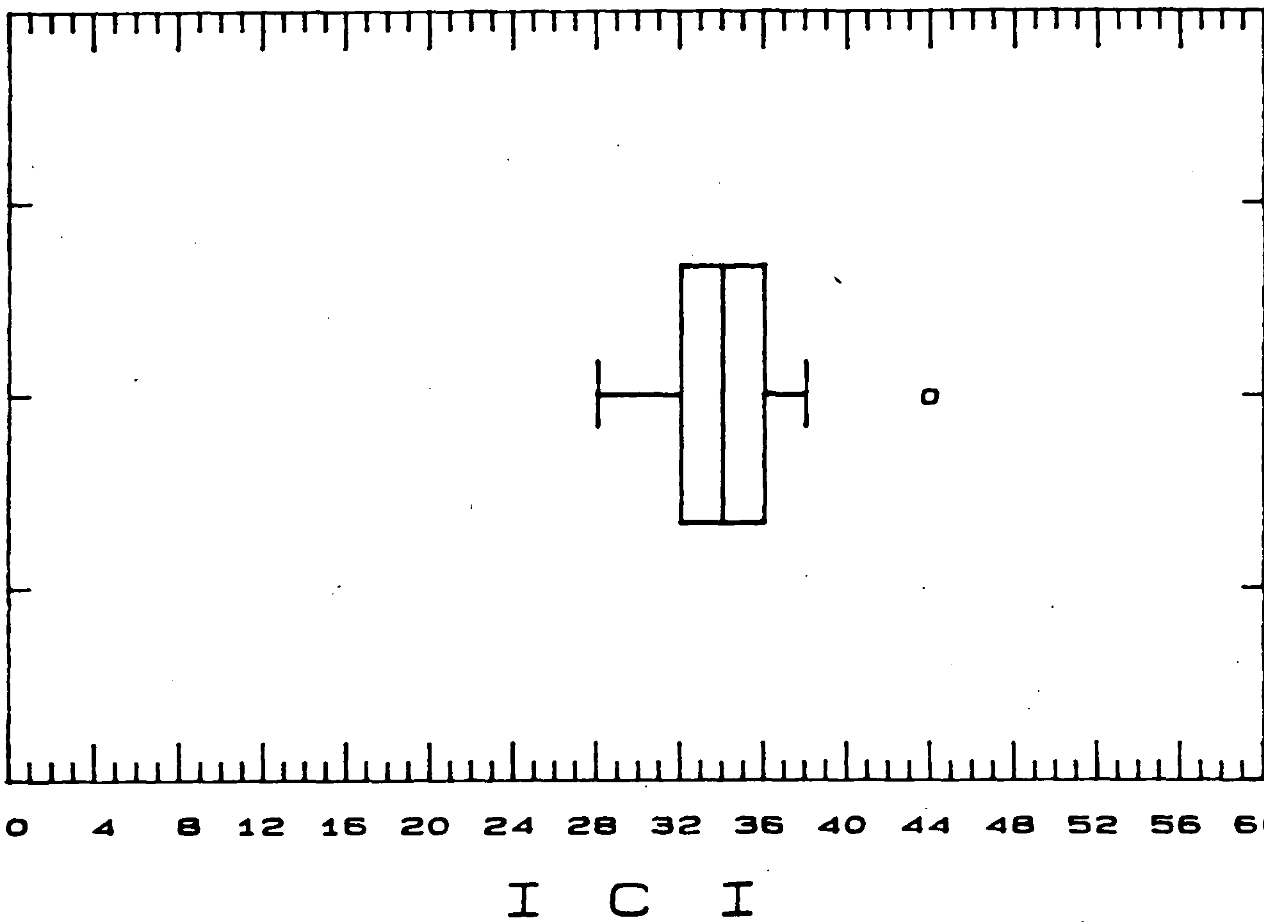


Figure D-7. Box-and-whisker plot of ICI values generated from data collected at the 1981 Big Darby Creek test location.

APPENDIX E:

Ohio EPA Stream/River Size Measuring
and Sampling Location Methods

E-1: Methods for Calculating Drainage Areas

Three methods may be used for calculating drainage areas (square miles) which lie upstream from sampling locations. They may be used individually or combined as the need dictates. The method(s) used is dependent on three variables, 1) accessibility of drainage area information, 2) whether or not data are computerized, and 3) time constraints. Time constraints are often the most important factor, resulting in the consistent use of one method over another.

Precision of drainage area calculations in areas of 20 square miles or less is especially important when they are used as factors in various biological indices (e.g. Headwaters IBI). Calculation of larger drainage areas allows for a greater margin of error, so relative precision in such areas is not as critical. An acceptable error margin is 10% (this can be determined through a more detailed process of using a digitizer).

The first and easiest method used for calculating drainage areas is to use drainage areas listed in the Gazetteer of Ohio Streams (Ohio Dept. Nat. Res. 1960) and the Supplement to the Gazetteer of Ohio Streams (Ohio Dept. Nat. Res. 1967). Sampling locations which are located within one mile of the mouth of a listed stream or river are assigned the value which corresponds to the drainage area of that watershed. Drainage areas of sampling locations which fall between two listed streams are calculated by interpolation. This method is used most often and requires a relatively small effort.

A second method is a "hands-on" procedure in which a clear sheet of plastic marked with one square mile grids is over-laid on a USGS 7 1/2 minute topographical map. Mapped contour lines are carefully observed and watershed boundaries are outlined. Any portion of the watershed which lies within any portion of a block of the overlay is used in the calculation. For sections of a watershed which cover only a portion of a grid, the percentage of the grid which is filled is estimated. All full grids and partial grids are then added together, resulting in the total drainage area. This method is used for small streams and the headwaters portions of larger streams where the Supplement to the Gazetteer of Ohio Streams does not include the information necessary for calculating drainage areas. This method is also used in conjunction with the Supplement to the Gazetteer. Grids are used to calculate small drainage areas between sampling locations and Gazetteer reference points.

The third method, and the most complex, is that of creating a plot of the sampling locations. Data must be in a computerized information base to use this method. An electronic data file is created which contains the stream code, river mile and latitude/longitude coordinates of the sampling locations. This file is then merged with a PEMSO plotting program called PEMLST. PEMLST will produce a plot of the state of Ohio with all sampling locations labeled with an "x" and a river mile index number. When a plot has been produced, a mylar map containing the boundaries of Ohio watersheds is over-laid on the plot. To accomplish the alignment of sampling points within the watershed boundaries, the map of Ohio watershed boundaries is first over-laid on the map of Principle Streams of Ohio (Ohio Dept. Nat. Res. 1984). Stream courses are drawn in using a pencil. When the watershed map is over-laid on the plot of sampling locations, points should fall along the stream courses. This procedure aids in determining the drainage pattern of a stream basin. When all of these preliminary steps have been completed, a digitizer is used to outline the estimated watershed boundaries upstream from the selected sampling point. Drainage areas of watersheds are listed in two computer printouts labeled PEMSO Watershed Characteristics. All drainage areas are listed in acres. The scale of the digitizer is set to acres to correspond to drainage areas listed in the PEMSO Watershed Characteristics printouts. All numbers derived from the digitizer calculations must then be converted to square miles (this is done by dividing the number of acres by 640). This method is the most time consuming, but has the capability of being the most accurate for determining drainage areas. However, since all tributaries are not shown on the Principle Streams of Ohio map, precise boundary lines are not always known.

E-2: FINS Basin-River/Stream Codes

Basin-river/stream codes were developed for use with the Fish Information System (FINS). This is composed of a two digit prefix or basin code and a three digit river/stream code. The two digit basin code conforms to the major basin codes used with the Ohio EPA PEMSO system (Ohio EPA 1983[b]). Twenty-three major basins are designated across the state.

The three digit river/stream code was developed by using the Gazetteer of Ohio Streams (Ohio DNR 1960). Each major mainstem stream or river within each of the 23 major basins is designated 001. Major tributaries of the mainstem stream or river are assigned codes 100, 200, 300, etc. Smaller streams and tributaries are given numbers in between. Thus the code for the Hocking River is 01-001 reflecting its location in major basin 01 and its prominence as the mainstem river.

FINS basin-stream/river codes are stored at Ohio EPA for each major basin according to a numerical sort for all rivers and streams listed in Ohio DNR (1960). Codes and names are assigned to streams not listed in the gazetteer and stored at Ohio EPA. Interested persons should contact Ohio EPA, Division of Water Quality Monitoring and Assessment, Surface Water Section for numerical listings and other information.

E-3: Ohio EPA PEMSO River Mile Index

The Ohio EPA REMSO River Mile Index (RMI) system is used to locate and designate biological sampling locations. The RMI itself is comprised of a string of distinct river mile numbers arranged in the order of stream tributation from the largest tributary to the smallest (Ohio EPA 1983b). For the purposes of the biological sampling locations we use the last number in the RMI string along with the FINS basin-river/stream code. Together these are equivalent to a given RMI string. River miles are ordered from downstream to upstream beginning with river mile (RM) 0 at the confluence or mouth of each stream. Thus RM 52.1 is positioned 52.1 miles upstream from the mouth.

River miles for specific locations are determined from maps located in the Office of Planning. Copies of these maps are located in each District Office and at the Water Quality Laboratory. More information about the RMI is given in Ohio EPA (1983b).

APPENDIX F

List of Ohio EPA Study Areas, 1977-1986

Appendix F: Availability of Reports

This appendix lists river and stream basins, subbasins, and mainstem segments which have been evaluated using the standardized biological field evaluation methods detailed in this document. Readers should note that all reports completed prior to 1986 and some completed in 1986 may rely on biological data evaluation techniques which have since been superceded by those presented in this document. The Ohio EPA biological data base back to and including at least 1982 data will be re-analyzed based on the methods contained in this manual for the 1988 305b report which is scheduled for completion in April 1988.

In addition to the major study areas listed in Table F-1 Ohio EPA conducts a number of site evaluations and "mini-surveys" each year. These are generally conducted on small streams and include 3-5 sampling locations. These efforts usually include biological data collection, but are not listed in Table F-1. Please contact the Division of Water Quality Monitoring and Assessment for further information.

Table F-1. Biological and water quality studies conducted between 1977 and 1985 by the Ohio EPA, Division of Water Quality Monitoring and Assessment.[a]

Year	Survey Area	Scope	Report Availability[b]
1977	Ottawa River	Upstream of Lima to Auglaize River	BWQR
1978	Mill Creek	Upstream of Marysville to Scioto River	BWQR
1978	Scotts Creek	Upper section (Hocking County)	BWQR
1979	Brush Creek	Headwaters to Ludlow Creek	BWQR
1979	Scioto River	Prospect to Ohio River	BWQR
1979	Sandusky River	Upstream of Bucyrus to Tymochtee Creek	BWQR
1979	Gilroy Ditch	Headwaters to Little Miami River	BWQR
1979	Rocky Fork	Mansfield to Black Fork	CWQR(*)
1980, 1981, and 1983	Mahoning River	Leavittsburg to Beaver River (Pa.), Mill Creek (Boardman to mouth), and Mosquito Creek downstream reservoir.	TSD
1981	Great Miami River	Mainstem from Taylorsville Reserve to the mouth, lower Mad, Stillwater R.	CWQR(*)
1981	Bear Creek	New Lebanon to Great Miami River	CWQR(*)
1981	Big Darby Creek	Entire Mainstem, lower Little Darby	CWQR(*)
1981	Bokes Creek	Upper watershed (West Mansfield)	CWQR(*)
1981	Cowles Creek	Geneva to Lake Erie	CWQR(*)

Table F-1. Continued.

Year	Survey Area	Scope	Report Availability[b]
1981	Eagle & Silver Creeks	Headwaters to downstream from Garrettsville	CWQR(*)
1981	Elk Fork	MacArthur to Raccoon Creek	CWQR(*)
1981	Four Mile Creek	Acton Lake to Great Miami River	CWQR(*)
1981	Kopp Creek	New Bremen to St. Marys River, includes Wierth Ditch	CWQR(*)
1981	Little Chippewa Creek	Upstream Orrville to Chippewa Creek	CWQR(*)
1981	Nettle Creek	Entire Mainstem	CWQR(*)
1981	Rocky River	Entire Subbasin	CWQR(*)
1981	Sandusky River	Tiffin to Fremont (Ballville Dam)	CWQR(*)
1981	Scioto River (Central)	Upstream of Columbus to Chillicothe	CWQR(*)
1981	Yellow, Little Yellow and Brush Creeks	Leipsic to Cutoff Ditch	CWQR(*)
1982	Big Walnut Creek	Headwaters to Hoover Reservoir	CWQR(*)
1982	Black River	Mainstem and estuary, lower E. and W. Branches	CWQR(*)
1982	East Branch Vermilion River	Mainstem and Skellinger Creek	CWQR(*)
1982	East Fork Little Miami River	Mainstem and tributaries upstream and downstream from Harsha Reservoir	CWQR(*)

Table F-1. Continued.

Year	Survey Area	Scope	Report Availability[b]
1982	East Fork Whitewater River	Headwaters to Ohio-Ind. state line	CWQR(*)
1982	Great Miami River	Mainstem from Indian Lake to Taylorsville Reserve	CWQR(*)
1982	Hocking River	Mainstem to Enterprise Rush Creek, Clear Creek	CWQR(*)
1982	Kyger Creek	Entire Subbasin	1986 305b
1982	Licking River	Newark to Dillon Reservoir, lower North and South Forks	CWQR(*)
1982	Little Beaver Creek	Headwaters to Beaver Creek (Greene County)	CWQR(*)
1982	Muddy Creek	Headwaters to estuary	CWQR(*)
1982	N. Turkeyfoot Cr., Bad Cr.	Mainstem - ust. & dst. of Wauseon and Delta	CWQR(*)
1982	Southfork Great Miami River	Headwaters to Belle Center	CWQR(*)
1982	Stillwater River	Mainstem, Swamp Cr. to mouth; Painter Creek, entire length; Greenville Creek, State line to Greenville; Harris Run, entire length; Swamp Creek, entire subbasin; N. Fork Stillwater R., headwaters to downstream of Ansonia.	CWQR(*)
1982	Walnut Creek	Entire mainstem, Paw Paw Creek, Sycamore, George Creeks	CWQR(*)
1983	Blanchard River	Entire Mainstem, minor tributaries	TSD(1984)

Table F-1. Continued.

Year	Survey Area	Scope	Report Availability[b]
1983	Cross & Yellow Creeks	Entire subbasins	TSD(1985)
1983	Killbuck Creek	Mainstem and major tributaries from Wooster to Walhonding R.	TSD(1985)
1983	Little Auglaize River	Entire subbasin	TSD(1985)
1983	Little Miami River	Mainstem and major tributaries	TSD(1986)
1983	McMahon, Sunfish, & Captina Creeks	Entire subbasins	TSD(1985)
1983	Tuscarawas River	Mainstem, Wolf Creek, Chippewa Creek, lower Sugar Creek, minor tributaries	File
1984	Cuyahoga River	Mainstem from Lake Rockwell to mouth, Tinkers Creek, Brandywine Creek, Mud Brook, Breakneck Creek	File
1984	Maumee River	State line to Napoleon, lower Auglaize River, Gordon Creek	TSD (1986)
1984	Tiffin River	Lower mainstem and major tributaries	TSD (1986)
1984	Mad River	Urbana to mouth, lower Buck Creek	TSD (1986)
1984	Lytle Creek	Entire length	TSD (1986)
1984	Upper Scioto River	Upstream McGuffey to dst. Kenton	TSD (1986)
1984	Little Raccoon Creek	Lake Rupert to mouth, includes tributaries	TSD (1985)
1984	Wills Creek	Seneca Fork to Wills Cr. Reservoir, Leatherwood Creek	TSD (1986)

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Table F-1. Continued.

Year	Survey Area	Scope	Report Availability[b]
1984	Yankee Creek	Mainstem and Little Yankee Creek	TSD (1986)
1984	Huron River	Mainstem from Norwalk to mouth, lower East and West Branches, Rattlesnake Cr.	TSD (1986)
1984	Mills Creek	Upper Mills Creek and Snyders Ditch	TSD (1985)
1984	Beaver Creek	Grand Lake outlet to Wabash River	TSD (1985)
1984	Whetstone Creek	Mt. Gilead to Delaware Reservoir	TSD (1985)
1984	Jerome Fork	Upstream Ashland to mouth, includes Lang Creek and tributaries	TSD (1986)
1984	Black Fork	Upstream and downstream Shelby	TSD (1985)
1985	Paramour Creek	Entire Subbasin	TSD (1987)
1985	Portage River	Downstream Brush-Wellman to Oak Harbor	TSD (1986)
1985	Mills Creek	Lower section in Sandusky to L. Erie	TSD (1986)
1985	Ottawa River	Upstream Lima to mouth	File
1985	Sixmile Creek	Near Spencerville; includes Auglaize River downstream to Ottawa River	TSD (1986)
1985	Wabash River	Upstream and downstream Ft. Recovery	TSD (1986)
1985	Disher Ditch	Upstream and downstream Whitehouse	TSD (1986)
1985	Sugar Creek	Dst. Ford Motor-Lima Engine Plant	TSD (1986)
1985	Rocky Ford Cr.	Upstream and downstream North Baltimore	TSD (1986)
1985	Nimishillen Creek	Entire basin, includes Sandy Creek downstream confluence	File
1985	Deer Creek	Oak Run and upper mainstem	TSD (1986)

Table F-1. Continued.

1985	Little Beaver Creek	Entire subbasin except minor tribs.	TSD (1986)
1985	Fulton Creek	Upstream and downstream Richwood	TSD (1986)
1985	Clear Creek	Near Hillsboro into Rocky Fork Lake	TSD (1986)
1985	Indian Creek	Near Millville to mouth	TSD (1986)
1986	Mill Creek	Ust. Marysville to mouth	TSD (1987)
1986	Big Darby Creek	Ust./dst. Plain City area	TSD (1987)
1986	Raccoon Creek	Dst. Clyde to Sandusky Bay	TSD (1987)
1986	Chagrin River	Ust. Chagrin Falls to RM 4.0	TSD (1987)
1986	L. Cuyahoga River	Subbasin, Ohio Canal, and Summit Lake	TSD (1987)
1986	Lower Maumee River	Napoleon to Toledo including Maumee Bay, major tribs.	TSD (1987)
1986	L. Salt Creek	Ust. Jackson to RM 13.0	TSD (1987)
1986	Upper Mad River	Selected sites ust. Kings Cr., inc. tribs.	TSD (1986)
1986	Rocky Fk. Licking R.	Selected sites in subbasin inc. tribs.	TSD (1986)
1986	Twin Creek	Mainstem and selected tribs.	TSD (1987)
1986	Alum & Blacklick Creeks	Mainstems to Big Walnut	TSD (1987)
1986	Scioto River	Columbus to Circleville	File
1986	Ohio River	Cincinnati area	File
1987	Cuyahoga River	L. Cuyahoga to Lake Erie	IP
1987	Dicks Creek	Entire basin	IP

Table F-1. continued.

1987	Ohio Brush Creek	Mainstem and tributaries	IP
1987	Buffalo Creek	Entire subbasin	IP
1987	Raccoon Creek	Upper mainstem near Johns-town	IP
1987	Kokosing River	Mainstem and tributaries	IP
1987	Little Scioto River	Mainstem and tributaries	IP
1987	Grand River	Lower mainstem and estuary	IP
1987	Olentangy River	Lower mainstem in Columbus	IP
1987	Cemetary Creek	Near Jeffereson	IP

a For further information contact Division of Water Quality Monitoring & Assessment, Surface Water Section, Box 1049, Columbus, Ohio 43266-0149

b Letter codes denote the following: CWQR(*) - Certified Comprehensive Water Quality Report; CWQR(D) - draft CWQR; BWQR - Biological and Water Quality Report (before 1981); TSD - Water Quality Technical Support Document (after 1984); File - file information: no report; IP - in progress..

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