Biological Assessment of Iowa's Wadeable Streams

Iowa Department of Natural Resources
Jeffrey R. Vonk, Director

October 2004

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BIOLOGICAL ASSESSMENT OF IOWA'S WADEABLE STREAMS

PROJECT REPORT

Prepared by

Thomas F. Wilton
TMDL and Water Quality Assessment Section
Environmental Services Division

Iowa Department of Natural Resources
Des Moines, Iowa

October 2004

Acknowledgements

This project could not succeed without the sample collection and analysis capabilities of the University of Iowa Hygienic Laboratory (UHL). IDNR is particularly indebted to staff of the UHL Limnology Section for spending long days in the field and countless hours processing samples. The following UHL staff (current and former) are recognized for their contributions: Kyle Ament, Tom Atkinson, Jennifer Baker, Mike Birmingham, Katie Brehm, Brandon Cole, Matt Coleman, Jen Ender, Mary Freitag, Dennis Heimdahl, Todd Hubbard, Jack Kennedy, Melanie Kruse, Julie Leonard, Jim Luzier, Travis Morarend, John Miller, Shannon Murphy, Mark Oglesby, Nathan Ohrt, Heidi Rantala, Mark Schneebeck, Mike Schueller, Lisa Swenson, Ryan Thompson, Jason Veldboom, Pete Wagner, Lee Wagner, Matt Watters, Seth Zimmerman. The following IDNR staff have also made valuable contributions to the project: Maggie Clover, Connie Dou, Chris Ensminger, Janet Gastineau, Greg Gelwicks, Andy Gorn, Ken Krier, Jamie Mootz, John Olson, Adam Schneiders, Greg Simmons, Ralph Turkle, Calvin Wolter. Database development and management by Jamie Mootz and Ken Krier have greatly improved the ability to utilize sampling data. Comments provided by Robert Hughes, Jim Luzier, John Olson, Randy Sarver and Christine Schwake helped improve the final version of this report.

Funding for this project has been provided through various federal and state water quality programs. Federal appropriations were authorized under Sections 104(b)(3), 106, 319, and 604(b) of the Federal Clean Water Act, and through the Regional Environmental Monitoring and Assessment Program (REMAP). Administration of federal grants was provided by the Region VII office of the U.S. Environmental Protection Agency, Kansas City, Kansas. State funding support has been provided through the Ambient Water Monitoring Program with allocations from the Infrastructure (Environment First) Fund.

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1 Executive Summary

The Iowa Department of Natural Resources (IDNR), in cooperation with the University Hygienic Laboratory (UHL), has established procedures for assessing the biological health of Iowa's wadeable rivers and streams. Biological assessment (bioassessment) is a key component of IDNR's water quality monitoring and assessment functions, including: problem investigation, project evaluation, status/trend monitoring, and Total Maximum Daily Load (TMDL) development. Bioassessment results are incorporated in the biennial report of the status of water quality in Iowa and list of impaired waters required by Sections 305(b) and 303(d) of the Federal Clean Water Act. The bioassessment framework described in this document can also serve as a foundation for establishing biological criteria (biocriteria) in Iowa's Water Quality Standards (IAC Chapter 567:61). The framework has four major components: 1) ecoregions, 2) reference stream sites, 3) sampling procedures, and 4) biological indices.

1.1 Bioassessment Components

Ecoregions

Ecological regions (ecoregions) are areas in which there is relative similarity among ecological systems such as lakes, streams, or wetlands. They are a useful geographic framework for water quality management and research because they reduce the amount of natural variability, thereby making it easier to detect environmental changes caused by human activities. IDNR uses ecoregions as a geographic template for defining stream reference conditions and developing biological criteria. Ecoregions are also a major consideration in the development of nutrient criteria for surface waters.

In 1993, U.S. EPA geographic researchers produced a refined map of Iowa's ecoregions. Since then minor changes to Iowa's map have resulted from ecoregion refinement projects in surrounding states. The current map of Iowa's ecoregions consists of ten Level IV Ecoregions (Figure 1-1).

Reference Sites

Reference sites in Iowa represent contemporary stream conditions that are least disturbed by human activities. Representation is also an important consideration. Reference sites strive to represent desirable, natural qualities that are attainable among other streams within the same ecoregion. As they are used in bioassessment, reference sites define biological conditions against which other streams are compared. Therefore, they should not represent stream conditions that are anomalous or unattainable within the ecoregion.

As part of the 1993 ecoregion refinement project, the U.S. EPA and the IDNR established a list of 110 candidate reference stream sites. From 1994-1998, a sampling project was conducted to gather baseline data for biological criteria development. Biological, chemical, and physical stream characteristics of approximately 100 candidate reference sites were sampled and analyzed. Potential impacts from point sources and nonpoint sources of pollution were also evaluated. Candidate sites that were inconsistent with reference quality objectives were eliminated.

Currently, there are 96 reference sites used by IDNR for stream biological assessment purposes (Figure 1-1). Reference site evaluation is an ongoing process. Reference sites and reference conditions for bioassessment are the subject of a significant amount of research and development throughout the U.S. The IDNR is working to improve the reference site evaluation process, and will utilize new methods and technology as they become available.

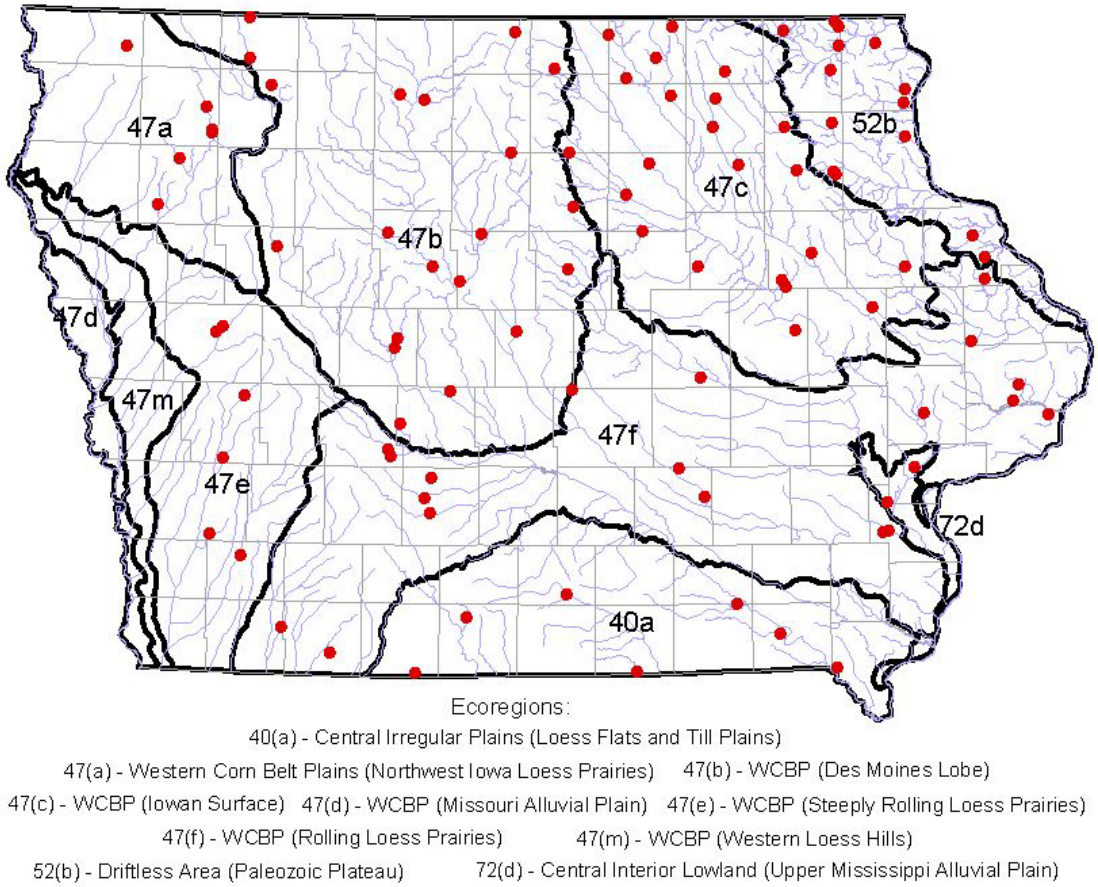

Figure 1-1. Iowa ecoregions and wadeable stream reference sites: 1994–2000.

Sampling Procedures

Standard procedures for sampling stream benthic macroinvertebrates and fish assemblages are used to ensure data consistency between sampling sites and sampling years. Sampling is conducted during a three-month index period (July 15 – October 15) in which stream conditions and the aquatic community are relatively stable. A representative reach of stream ranging from 150-350 meters in length is defined as the sampling area.

Two types of benthic macroinvertebrate samples are collected at each site: 1) Standard-Habitat samples are collected from rock or wood substrates in flowing water; 2) a Multi-

Habitat sample is collected by handpicking organisms from all identifiable and accessible types of benthic habitat in the sampling area. The multi-habitat sample data improve the estimation of taxa richness for the entire sample reach. Benthic macroinvertebrates are identified in the laboratory to the lowest practical taxonomic endpoint.

Fish are sampled using direct current (DC) electrofishing gear. In shallow streams, one or more battery-powered backpack shockers are used, and a tote barge, generator-powered shocker is used in deeper, wadeable streams. Fish are collected in one pass through the sampling reach proceeding downstream to upstream. The number of individuals of each species is recorded, and individual fish are examined for external abnormalities, such as deformities, eroded fins, lesions, parasites, and tumors. Most fish are identified to species in the field; however, small or difficult fish to identify are examined under a dissecting microscope in the laboratory.

Physical habitat is systematically evaluated at each stream sampling site. A series of instream and riparian habitat variables are estimated or measured at ten, stream channel transects that are evenly spaced throughout the sampling reach. A summary of physical habitat characteristics is compiled for the sampling reach, and the summary data are used to complete a habitat assessment form which yields a qualitative stream habitat score and rating (e.g., poor, fair, good, excellent).

Biological Indices

Biological sampling data from reference sites were used to develop a Benthic Macroinvertebrate Index of Biotic Integrity (BMIBI) and a Fish Index of Biotic Integrity (FIBI). The BMIBI and FIBI are described as multi-metric or composite indices because they combine several individual measures or metrics. A metric is an ecologically relevant and quantifiable attribute of the aquatic biological community. A useful metric can be measured cost-effectively and reliably, and will respond predictably to environmental disturbances.

Numerous candidate biological metrics were systematically reviewed, and the best-performing benthic macroinvertebrate and fish data metrics were included in the BMIBI and FIBI, respectively. Each index is comprised of twelve metrics that reflect a broad range of aquatic community attributes (Table 1-1). Reference site sampling data were used to develop metric calculation formulas that transform raw metric values into a normalized scoring range from 0 (poor) –10 (optimum). The normalized metric scores are then combined to obtain the BMIBI and FIBI scores, which both have a possible scoring range from 0 (worst) – 100 (best). Qualitative categories for BMIBI and FIBI scores are listed in Table 1-2. The scoring ranges were developed from an examination of the biological attributes exhibited by stream bioassessment sites encompassing the full range of BMIBI scores from low to high. A more detailed description of the BMIBI and FIBI development and calibration process is provided in Part 5.

Table 1-1. Data metrics of the Benthic Macroinvertebrate Index of Biotic Integrity (BMIBI) and the Fish Index of Biotic Integrity (FIBI).

Benthic Macroinvertebrate Index of Biotic Integrity (BMIBI)	**Fish Index of Biotic Integrity (FIBI)**
1. MH*-taxa richness	1. # native fish species
2. SH*-taxa richness	2. # sucker species
3. MH-EPT richness	3. # sensitive species
4. SH-EPT richness	4. # benthic invertivore species
5. MH-sensitive taxa	5. % 3-dominant fish species
6. % 3-dominant taxa (SH)	6. % benthic invertivores
7. Biotic index (SH)	7. % omnivores
8. % EPT (SH)	8. % top carnivores
9. % Chironomidae (SH)	9. % simple lithophil spawners
10. % Ephemeroptera (SH)	10. fish assemblage tolerance index
11. % Scrapers (SH)	11. adjusted catch per unit effort
12. % Dom. functional feeding group (SH)	12. % fish with DELTs

* MH, Multi-habitat sample; SH, Standard-habitat sample.

Table 1-2. Qualitative scoring guidelines for the BMIBI and FIBI.

Biological Condition Rating	**Benthic Macroinvertebrate Index of Biotic Integrity (BMIBI)**	**Fish Index of Biotic Integrity (FIBI)**
Poor	0 - 30	0 -25
Fair	31 - 55	26 - 50
Good	56 - 75	51 - 70
Excellent	76 - 100	71 - 100

Iowa's rivers and streams have seen significant historical losses of native fish and mussel species caused by long-term physical habitat and water quality degradation. Consequently, biological conditions in Iowa's rivers and streams today are different, and probably significantly lower quality than historic, pre-European settlement conditions. The BMIBI and FIBI are calibrated using contemporary reference sites that define levels of biological condition ranging from poor to excellent. It is important to recognize the range of conditions that are measurable using these indexes probably do not encompass or have the ability to distinguish natural, unaltered biological integrity. Figure 1-2 shows the relationship of the BMIBI and FIBI rating scale in relation to a conceptualized tiered biological condition gradient (Davies 2003; Jackson 2003). The biocondition gradient provides a consistent framework to convey biological information, and can serve as a template for refining aquatic life use designations.

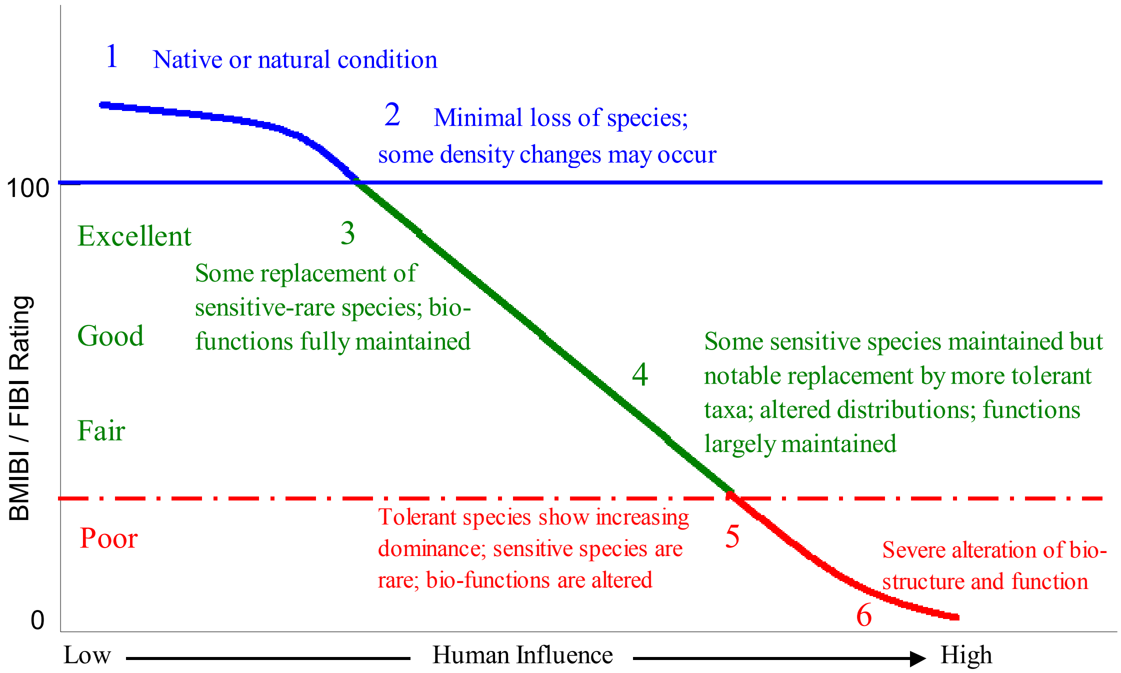

Figure 1-2. Benthic Macroinvertebrate Index of Biotic Integrity (BMIBI) and Fish Index of Biotic Integrity (FIBI) qualitative ratings (excellent, good, fair, poor) in relation to a conceptual tiered biological condition gradient (after Davies 2003).

Biotic Index Performance

For a biological indicator to be useful, it must respond predictably to changes in stream environmental conditions. The BMIBI and FIBI both correlate with a number of physical habitat and water quality variables including bank stability, % fine sediments, riparian buffer condition, total phosphorus, and total suspended solids. Both indices show a uniform response across a gradient of stream environmental quality. For example, Figure 1-3 shows the relationship between FIBI score and the Barbour and Stribling (1991) qualitative physical habitat index. Both habitat quality and ecoregion are important determinants of stream biological condition. Multiple regression analysis found that 56%

of the variance in FIBI scores could be explained by the combination of habitat quality score and ecoregion (r^2=0.56). The BMIBI was also significantly related with habitat quality and ecoregion, but less strongly (r^2=0.32) than the FIBI.

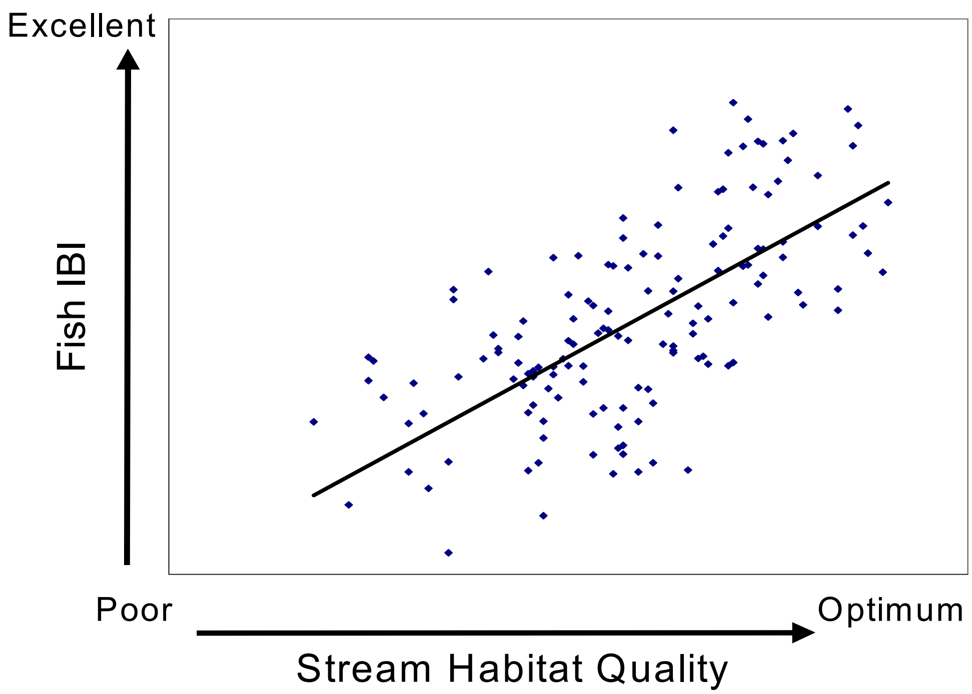

Figure 1-3. Relationship of Fish Index of Biotic Integrity (FIBI) and the Barbour and Stribling (1991) habitat quality index. Sampling data are from 1994-1998 reference sites and test sites.

Another characteristic of a useful biological indicator is an ability to distinguish least-disturbed sites from heavily impacted sites. A statistical analysis of BMIBI and FIBI scores from reference sites and test sites was conducted in two ecoregions where a sufficient number of sites had been sampled. Impacted sites were selected to represent several of Iowa's common stream impacts including channelization, streamside livestock grazing, urban runoff, and wastewater discharges. In both ecoregions, differences between reference site and test site mean scores of the BMIBI and the FIBI were statistically significant ($p<0.05$). Figure 1-4 shows the ranges of BMIBI scores from reference sites and test sites in two ecoregions.

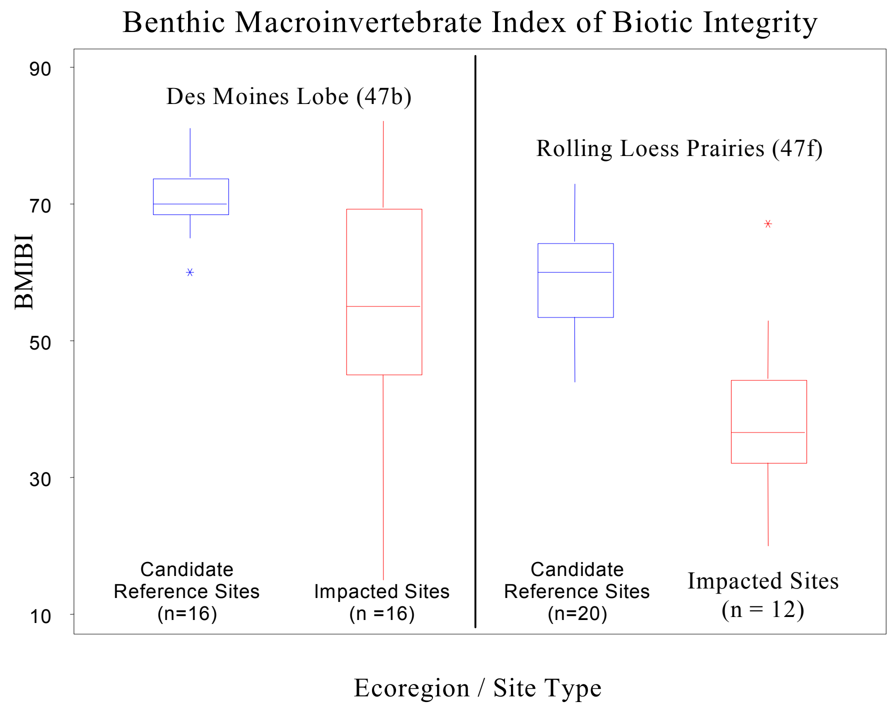

Figure 1-4. Box and whisker plot comparison of candidate reference site and impacted site BMIBI scores from the Des Moines Lobe (47b) and Rolling Loess Prairies (47f) ecoregions.

1.2 Sampling Results and Data Analysis

Species Richness

Iowa's surface waters supports a moderate level of fish species diversity compared to states located in other regions of the United States. For example, less fish diversity occurs in states located in the arid Southwest, while greater diversity is found in aquatic habitat-rich states of the Southeast. Of the 139 species thought to be native inhabitants of Iowa's surface waters, 95 fish species were collected during the 1994-1998 wadeable stream reference site and test site sampling phase. In 2001, a single Topeka shiner (*Notropis topeka*) was collected from Buttrick Creek in Greene County; otherwise, no other federally endangered species have been collected. A number of fish species listed as threatened (T) or endangered (E) within Iowa have been documented, including: American brook lamprey (*Lampetra appendix*) (T), black redhorse *(Moxostoma duquesnei*) (T), burbot (*Lota lota*) (T), freckled madtom (*Noturus nocturnus*) (E), grass pickerel (*Esox americanus*) (T), orangethroat darter (*Etheostoma spectabile*) (T), and Topeka shiner (*Notropis topeka*) (T). Several non-native fish species were collected, including: brown trout (*Salmo trutta*); common carp (*Cyprinus carpio*); goldfish (*Carassius auratus);* grass carp (*Ctenopharyngodon idella*); rainbow trout (*Oncorhynchus mykiss*).

During the initial sampling phase, a relatively small number of fish species (9), mostly minnows (Cyprindae), comprised the majority (62%) of fish collected. The total number of fish species sampled from streams in the Mississippi River drainage basin (90) was more than double the total number of species found in streams located in the Missouri River drainage basin (44). Sampling sites located in the Rolling Loess Prairies ecoregion (47f), which includes parts of five major river systems, had the highest total number of fish species (62). The average number of native fish species per sampling site was highest (21) among reference sites in the Iowan Surface (47c) and lowest (8) among reference sites located in the Steeply Rolling Loess Prairies (47e).

The project has helped to fill information gaps pertaining to Iowa's benthic macroinvertebrate populations. Through 2001, approximately 435 distinct benthic macroinvertebrate taxa had been collected. The number of taxa increases each year as sampling continues. The University Hygienic Laboratory (UHL) documents benthic macroinvertebrate collections and maintains a specimen voucher collection. UHL has worked with outside experts to document many new collection records for Iowa.

Aquatic insects are by far the most abundant and diverse group of benthic macroinvertebrates collected. In 1994-1998 standard-habitat samples, 95% of the total number of organisms and 81% of the benthic macroinvertebrate taxa were aquatic insects. Benthic macroinvertebrate diversity varied among Iowa's ecoregions. The average number of benthic macroinvertebrate taxa per multi-habitat sample was highest

(36) for stream sites located in the Iowan Surface (47c) and lowest (22) among sites in the Steeply Rolling Loess Prairies (47e).

Many species of freshwater mussels are included on the state and federal lists of threatened and endangered species. The sampling methods and objectives of this project are not designed to document the occurrence of mussel species in Iowa's streams. Because of the imperiled status of many species, live mussels typically were not disturbed when observed during sampling. Only a small number of mussel species have been collected since the project began, and none of these is listed as threatened or endangered.

Stream Classification

Statistical analyses were conducted to evaluate the usefulness of ecoregions as a stream classification scheme. A modest, but significant amount of the variability in species composition and biotic index scores was explained by ecoregion. Significant differences were found between some, but not all ecoregions. Correspondence to ecoregion was stronger among fish assemblages than benthic macroinvertebrate assemblages. Stream classification strength of ecoregions was stronger than several other landscape classification schemes tested (e.g., landform, hydrologic basins, stream order). All regional classification schemes were relatively weak in terms of the total amount of variation in biological attributes that could be attributed to any given classification scheme. Additional testing found that classification strength could be improved by adding stream size and habitat categories. For example, variability of FIBI scores was reduced when sample sites were placed in habitat categories defined by the amount of rock substrate, cobble-size substrate, and riffle habitat.

Aquatic Biota and Stream Environmental Relationships

Multivariate data analysis was performed to examine relationships between stream biological assemblages and environmental variables. Approximately 45 stream variables were included in the analysis. The stream variables most strongly correlated with differences in benthic macroinvertebrate and fish species composition include: channel slope (gradient), coarse rock substrate, nitrate+nitrite-nitrogen, riffle habitat, and watershed size. The benthic macroinvertebrate and fish assemblages found in Northeast Iowa streams are least similar to assemblages found in other regions of the state. Trout and other aquatic species that require clear, cool water are more likely to occur in Northeast Iowa streams where groundwater inputs are larger than in other regions.

1.3 Aquatic Life Use Support Assessments

One of the primary uses of bioassessment data is to assess the support status of stream aquatic life uses. As required by Section 305(b) of the Federal Clean Water Act, every two years IDNR reports to U.S. EPA and the public on the status of beneficial designated uses. The bioassessment framework described in this report has been utilized for the last two 305(b) cycles (2000, 2002). Bioassessment data from stream segments designated as Limited Resource Warm Water [B(LR)] or Significant Resource Warm Water [B(WW)] were compared to biological impairment thresholds established from reference site sample data. For the 2002 report, impairment thresholds were established for each ecoregion using the 25^{th} percentiles of BMIBI and FIBI scores from 1994-2001 reference site samples (see Table 6-1). Aquatic life impairment thresholds are specified by ecoregion and stream habitat class, and they range from fair to excellent ratings for benthic macroinvertebrate and fish assemblage condition.

Figure 1-5 displays the assessment results from two sampling intervals used in preparing the 2000 and 2002 Section 305(b) reports. 69% of stream sites sampled from 1994-1998 were assessed as supporting aquatic life uses (fully supporting or fully supporting/ threatened) compared to 53% supporting from the 1999-2001 sampling interval.

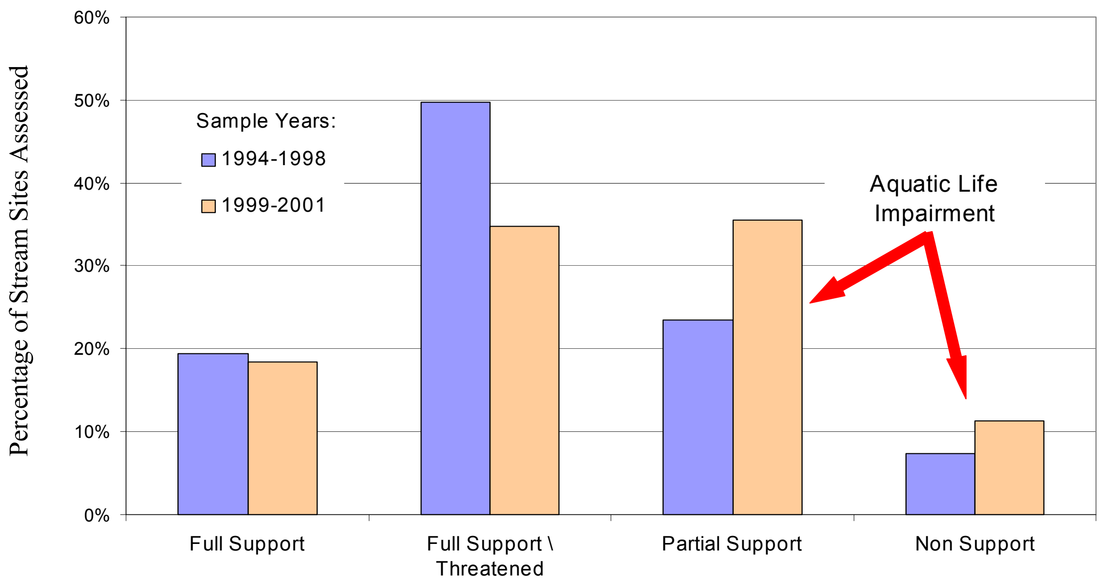

Figure 1-5. Stream aquatic life use support assessments utilizing benthic macroinvertebrate and fish assemblage sample data.

Conversely, 31% of 1994-1998 sample sites were assessed as biologically impaired (partially supporting or not supporting) compared to 47% from 1999-2001. The data set (1994-1998) used for the 2000 305(b) report consisted of approximately two-thirds reference sites and one-third test sites and watershed assessment sites. The 1999-2001 data set used to prepare the 2002 report contained a much greater proportion of test sites reflecting an emphasis toward sampling streams suspected of having water quality problems.

Bioassessment results from the 305(b) report were used to prepare Iowa's 2002 Section 303(d) list of impaired waters. Impaired waters may require the development of a Total Maximum Daily Load (TMDL) or watershed plan to restore designated beneficial water uses to fully supporting status.

The differences in levels of aquatic life use support between the two 305(b) reporting periods shown in Figure 1-5 demonstrate the problem in relying on sample data generated from project biased, non-random sampling. A probabilistic survey design, in which the sample sites are randomly chosen, is preferable for obtaining an unbiased assessment of environmental conditions across a broad geographic area (Paulsen et al. 1998; Hughes et al. 2000). In 2002, IDNR initiated a probabilistic, random stream survey project with funding and technical support provided by the U.S. EPA Environmental Monitoring and Assessment Program (EMAP). The random survey design will provide Iowa with an objective assessment of stream conditions throughout the state and create a benchmark for trend monitoring. The first two years of random sample data suggest that sampling results from non-random stream sites during the previous nine years may have overestimated biological condition levels in Iowa's wadeable streams (Figure 1-6).

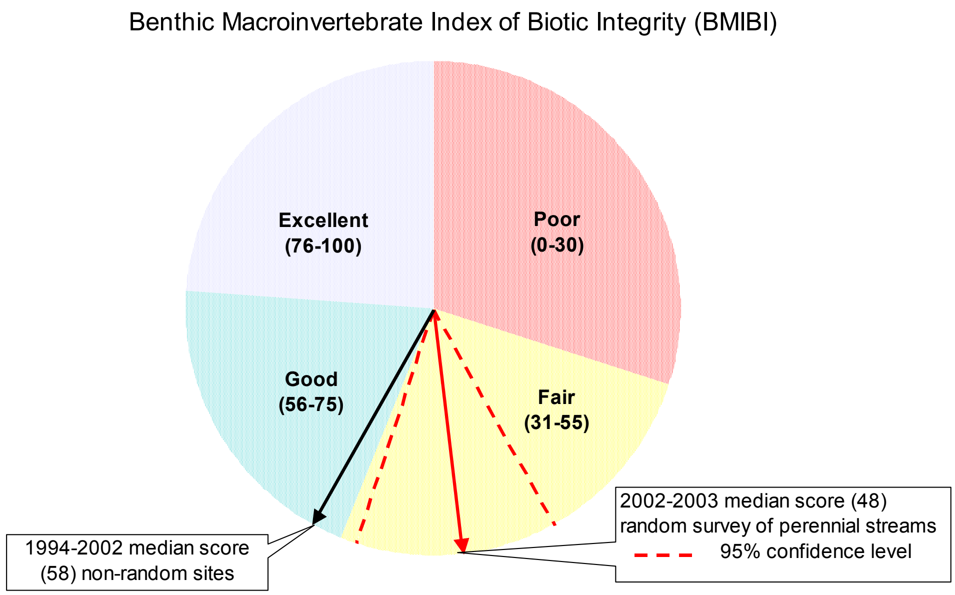

Figure 1-6. Median BMBI scores from 1994-2002 non-random sample sites and the 2002-2003 random survey of perennial streams.

A median (50th percentile) score of 58 was obtained from 1994-2002 non-random sampling. In contrast, 2002-2003 random sampling results indicate that 50% of Iowa's perennial stream miles equal or exceed a BMIBI score of 48. Furthermore, the non-random median score is outside of the 95% confidence limits of the random sampling median score.

1.4 Recommendations

The stream bioassessment framework described in this report can serve as a foundation for establishing biological water quality criteria in Iowa's Water Quality Standards (IAC Chapter 567:61). A continuing process of evaluation and improvement should be pursued to strengthen the existing framework and address deficiencies. Some of the most critical needs and recommendations are listed below:

1. Maintain consistent sampling methods. Sampling methods should remain relatively constant in order to ensure data consistency and continuity over time. Procedural changes may be justified, but should always be carefully evaluated and documented. For example, sampling using both methods simultaneously should be done to establish a statistical relationship between the old and new method.

2. Refine stream classification and reference conditions. Additional refinement and classification of reference conditions are needed. Bioassessment conclusions are reached by comparing test site conditions against reference conditions. Therefore, it is imperative that reference sites and test sites are appropriately classified. Ecoregions are a useful classification tool; however, it is evident that stream classification can be refined and strengthened by incorporating local factors, such as channel morphology and habitat. In order to accurately convey what reference conditions represent, least disturbed reference sites in each ecoregion and stream class should be identified along gradients in biological condition and human disturbance. The multi-tiered biological condition gradient presented by the U.S. EPA (Davies 2003; Jackson 2003) can be used as a conceptual model (see Figures 5-9 and 5-23).

3. Update reference database. A maintenance-sampling program for reference sites is needed to keep reference condition data current and ensure the validity of bioassessment results. Reference sites should be re-sampled with no less frequency than once in five years. Additional reference sites are needed to fill gaps in coverage and address stream classification issues.

A Geographic Information System (GIS) analysis and validation of reference site watersheds is needed. Several improvements in GIS themes and technologies have become available in recent years. For example, the updated coverage of animal feeding operations and manure application fields would provide for a better review of potential animal waste impacts. Land use/cover, soil erosion rates, and watershed morphology characteristics are more easily calculated now. Improved GIS capabilities make it more feasible to complete a quantitative analysis of watershed characteristics and human disturbance factors.

4. <u>Complete random stream survey.</u> The statewide, random (probabilistic) stream survey initiated in 2002 should be completed in 2006 to obtain an unbiased and statistically powerful assessment of Iowa's stream conditions. Similar types of surveys are in progress or have been completed in surrounding states. Iowa's survey design is adapted from methods developed by the U.S. EPA Environmental Monitoring and Assessment Program (EMAP).

5. <u>Adopt biological criteria.</u> To solidify bioassessment within water resource management programs, IDNR needs to formally adopt biological criteria in Iowa's water quality standards. Codification will allow for broader application of bioassessment within the arena of water quality mitigation and regulation programs.

   The process of establishing biocriteria in water quality standards is fraught with potential pitfalls and obviously must be carefully planned and implemented. A logical place to begin is with adoption of narrative biocriteria. Numerous examples from other states show how narrative criteria can establish a framework for bioassessment and numeric biocriteria. Development of narrative biocriteria should also address how biocriteria will link to state water quality standards and Clean Water Act objectives.

   The second major step, one that has not been accomplished in many states, is codification of numeric biocriteria. The biological impairment thresholds listed in Part 6, which are based on the statistical distribution of stream reference site BMIBI and FIBI scores, are an example of the type of quantifiable biological measures that might fit within a numeric biocriteria framework. The Ohio EPA's biocriteria framework, which is based on a tiered aquatic life and biological condition gradient (Yoder and Rankin 1995; Davies 2003), may serve as a useful model for Iowa.

2 Introduction

The ultimate goal of the Federal Clean Water Act (CWA) is to restore the biological, chemical, and physical integrity of the nation's waters. To help measure progress toward achieving this goal, the Iowa Department of Natural Resources (IDNR) is developing a methodology and biological criteria (biocriteria) for Iowa's wadeable rivers and streams. As part of a complete water quality standards program, the CWA requires that states adopt criteria to protect the designated beneficial uses of water bodies within their jurisdiction. Biocriteria serve as a direct measurement endpoint for assessing the status of aquatic life uses.

> *Biocriteria are numerical expressions or narrative expressions that describe the reference biological condition of aquatic communities inhabiting waters of a given designated aquatic life use* (U.S. EPA 1996).

Like other types of water quality criteria, biocriteria can be used to assess water quality status and trends, identify impaired water uses, and support water quality management decisions. Because aquatic biological communities integrate and reflect the cumulative impacts of biological, chemical, and physical environmental disturbances, biocriteria are particularly well suited for uncovering water quality problems that frequently are not detected through application of individual chemical or physical water quality criterion.

The Iowa Department of Natural Resources (IDNR) initiated stream biocriteria development in 1992. IDNR's partner in this project is the University of Iowa Hygienic Laboratory (UHL), which has provided sampling and analytical services throughout the project's life. Funding has been provided through Region VII, U.S. Environmental Protection Agency as authorized by Sections 104(b), 319, and 604(b) of the CWA. Starting in 2000, funding support has also come from Iowa's Ambient Water Monitoring Program.

2.1 Project Objectives

A number of specific objectives were stated at the beginning of the stream biocriteria development project:

- Establish standard biological sampling procedures;
- Select stream reference sites;
- Acquire sampling data for development of biological criteria;
- Develop and evaluate the performance of biological metrics and indices;
- Define reference conditions and recommend biological criteria.

This report summarizes the extent to which project objectives have been achieved, and identifies additional work that is needed to successfully establish and implement stream biocriteria. The report details a framework for stream biological assessment and demonstrates how the framework can be used to assess stream biological integrity and identify aquatic life impairments.

2.2 Historical Perspective

In developing stream biocriteria, a good way to begin is by considering Iowa's rivers and streams from an historical perspective. Understanding what Iowa's streams used to be like and how they have changed can help place biocriteria development in the proper context and lead to appropriate stream rehabilitation goals.

Beginning in the mid-1800's with settlement by European-Americans, large-scale changes to Iowa's landscape and aquatic resources have occurred. The hydrology and water quality of Iowa's streams were drastically altered by prairie conversion and drainage improvement for agricultural purposes. Written accounts before the turn of the century by the ichthyologist, Seth Meek (1892; 1893) described some of the changes to Iowa streams caused by agricultural development. Meek reported streams that at one time were narrow and deep, and which previously flowed cool and clear, had become wide, shallow and muddy. Networks of tile drains and drainage ditches were constructed to facilitate drainage and conversion of wetlands to arable land. In the process, many new miles of stream channel were created in areas occupied by wetlands. In Story County, Iowa, the amount of stream miles in the Bear Creek watershed increased substantially due to this type of hydrologic modification (Anderson 2000).

Other modifications resulted in substantial stream losses. During the first three decades of the 20th century numerous large-scale stream channelization projects were completed throughout Iowa. In excess of 1000 stream miles were lost to channelization, and habitat was permanently damaged in the channelized segments that remained (Buckley 1975). Widespread hydrologic modification of Iowa's watersheds has contributed to stream channel instability and excessive rates of downcutting, bank erosion, and sedimentation.

Many other disturbances have influenced Iowa's rivers and streams. The common carp (*Cyprinus carpio*), first introduced in Iowa around 1880, spread quickly throughout the state's lakes and streams and displaced many native fishes. Before the turn of the century, numerous low-head dams built on Iowa's interior rivers presented barriers to seasonal movements of native Iowa fishes (Menzel 1981). As Iowa's cities and industries grew during the first half of the 20th century, reports of polluted rivers and fish kills from raw or inadequately treated sewage were common. Installation of modern wastewater treatment plants, which was facilitated by the landmark Federal Pollution Control Act of 1972, vastly improved wastewater quality and eliminated severe cases of point source pollution. Beginning in the 1960s, increased inputs of fertilizers and pesticides further contributed to widespread nonpoint source pollution of Iowa's waters. Agricultural and urban runoff containing bacteria, nutrients, organic matter and sediment remain as the largest threats to water quality in Iowa.

Significant losses of native fish and mussel species have resulted from the environmental degradation of Iowa's waters. Of the 139 native fishes of Iowa, twelve (12) are thought to be extirpated from the state (Menzel 1981). As a general trend, northern species that prefer cool, clear streams containing rooted aquatic vegetation were lost or reduced in range, while turbidity-tolerant, warm water species from the south expanded their ranges in Iowa.

Substantial losses of freshwater mussels have also been reported. Nearly one-half of the 55 mussel species thought to occur in Iowa more than 100 years ago were not found in a survey completed in the mid-1980s (Frest 1987). A recent survey documented additional losses. The re-survey of Frest sites in the late 1990s found sharp declines in mussel species richness (Arbuckle and Downing 2000). The reductions were correlated with increased agricultural land use and nutrient levels. The exact causes of the declines are not understood, however, a combination of factors including habitat alterations, over harvesting, and water quality degradation are responsible.

In light of the historic changes and biological losses that have occurred, it is probably safe to assume that biological conditions in Iowa's rivers and streams today are different, and probably significantly lower quality than pre-settlement conditions. Moreover, a return to pre-settlement stream conditions might not be possible considering the irreversible modification of Iowa's stream channels, and may not be realistic if it requires converting most of the state back to a tallgrass prairie ecosystem. Therefore, a valid question to ask is what relevance do pristine historic conditions have for biocriteria development?

The approach to development of Iowa's stream biocriteria described in this report utilizes contemporary reference sites to define wadeable stream reference conditions. Specifically, biological attributes measured at least-disturbed, best-available reference stream sites are used to evaluate other streams of similar type. In using this approach, a certain amount of disturbance and departure from natural or pristine conditions is inherently accepted due to the legacy of historic alterations to Iowa's landscape and stream ecosystems. One concern is that contemporary reference conditions could reflect substantial levels of stream impairment that would lead to establishment of standards that are not consistent with the goals of the Clean Water Act and societal expectations.

Historical information or conceptualizations of biological conditions based on historical records are valuable because they can provide a context for establishing biological criteria and setting stream rehabilitation goals. Reference conditions that reflect the best of what is available today are useful for setting immediate rehabilitation goals; however, these goals should be re-evaluated periodically. Whenever feasible, as conditions improve through better land stewardship and stream management, biocriteria should be adjusted upward toward historical benchmarks. Following this philosophy, incremental progress toward historical biological conditions and integrity should be the long-term goal. Under no circumstances should biologically impaired conditions that fail to meet the "fishable" use interim goal of the CWA (Section 101(a)[2]) be used to establish biocriteria (U.S. EPA 1996).

3 Biological Assessment Framework

A methodological framework has been established to standardize the collection and analysis of stream bioassessment data. The framework is designed to ensure that data are comparable across sampling sites and years, and that a consistent approach is used to evaluate biological condition and the status of aquatic life uses. The framework has four main components: 1) ecoregions, 2) stream reference sites, 3) sampling methods, and 4) biological indices. The first three components are described below. Biological indices are covered in Part 5.

3.1 Ecoregions

Ecological regions (ecoregions) are areas in which there is relative homogeneity in ecological systems and relationships between organisms and their environments (Omernik 1995). They are formed by a complex relationships between natural and human environmental factors such as climate, geology, landform, land cover / use, and soils. Within ecoregions there are recognizable patterns and similarities in the mosaic of environmental resources, ecosystem characteristics, and influence of human activities.

Ecoregions are widely used as a spatial framework for research and management of stream ecosystems (Omernik 1995; U.S.EPA 2002), and the ecoregional approach to biocriteria development is endorsed by the U.S. EPA (1996). The IDNR has incorporated ecoregions in each step of the biocriteria development process including: reference site selection, sample design, data analysis, and establishment of aquatic life impairment thresholds.

Ecoregion Refinement

Ecoregions can be recognized and defined at different scales to suit a variety of purposes (Omernik 1995). In 1993, the U.S. EPA and IDNR completed an ecoregion refinement project to facilitate biocriteria development (U.S. EPA 1993). The project's main goals were to refine Iowa's ecoregion map and identify candidate stream reference sites. Previous studies of Iowa's stream fish communities (Menzel 1987; Paragamian 1990) demonstrated the inadequacy of Level III Ecoregions (Figure 3-1) as a regional framework for biocriteria development. The Western Corn Belt Plains ecoregion (WCBP #47), which covers approximately 83% of Iowa's land surface area, was the main concern. Within the WCBP, substantial differences in stream fish assemblage structure occur among different landform / physiographic regions of the state.

Iowa's portion of the Western Corn Belt Plains ecoregion was subdivided into six Level IV Ecoregions in 1993. Since then, ecoregion refinement projects in adjacent states have also been completed. As a result of subdividing Level III Ecoregions that adjacent states share with Iowa, several minor modifications of the 1993 Iowa ecoregion map have been made. Most of these changes affected nomenclature, not boundary locations. The current map of Iowa's ecoregions consists of ten Level IV Ecoregions (Figure 3-2) (Chapman et al. 2002).

The methods used to define Iowa's ecoregion boundaries are described by Omernik et al. (1993) and Griffith et al. (1994). The project generally involved compiling and reviewing relevant data sources, identifying regional patterns in environmental characteristics, drafting ecoregion boundaries, revising the ecoregion framework based on comments from resource managers and scientists, and producing digitized ecoregion coverages and a final map. Land cover / use, potential natural vegetation, soils and surficial geology (landform) were the most useful landscape variables for defining Iowa's ecoregion and subregions. The map and description of landform regions by Prior (1991) was a particularly useful resource, and many of the ecoregion boundaries align closely with landform boundaries. Most of the important differences between the two regional maps of Iowa have to do with differences in soil types and land cover across the broad landform region referred to as the Southern Iowa Drift Plain. Some general characteristics of Iowa's ecoregions are listed in Table 3-1.

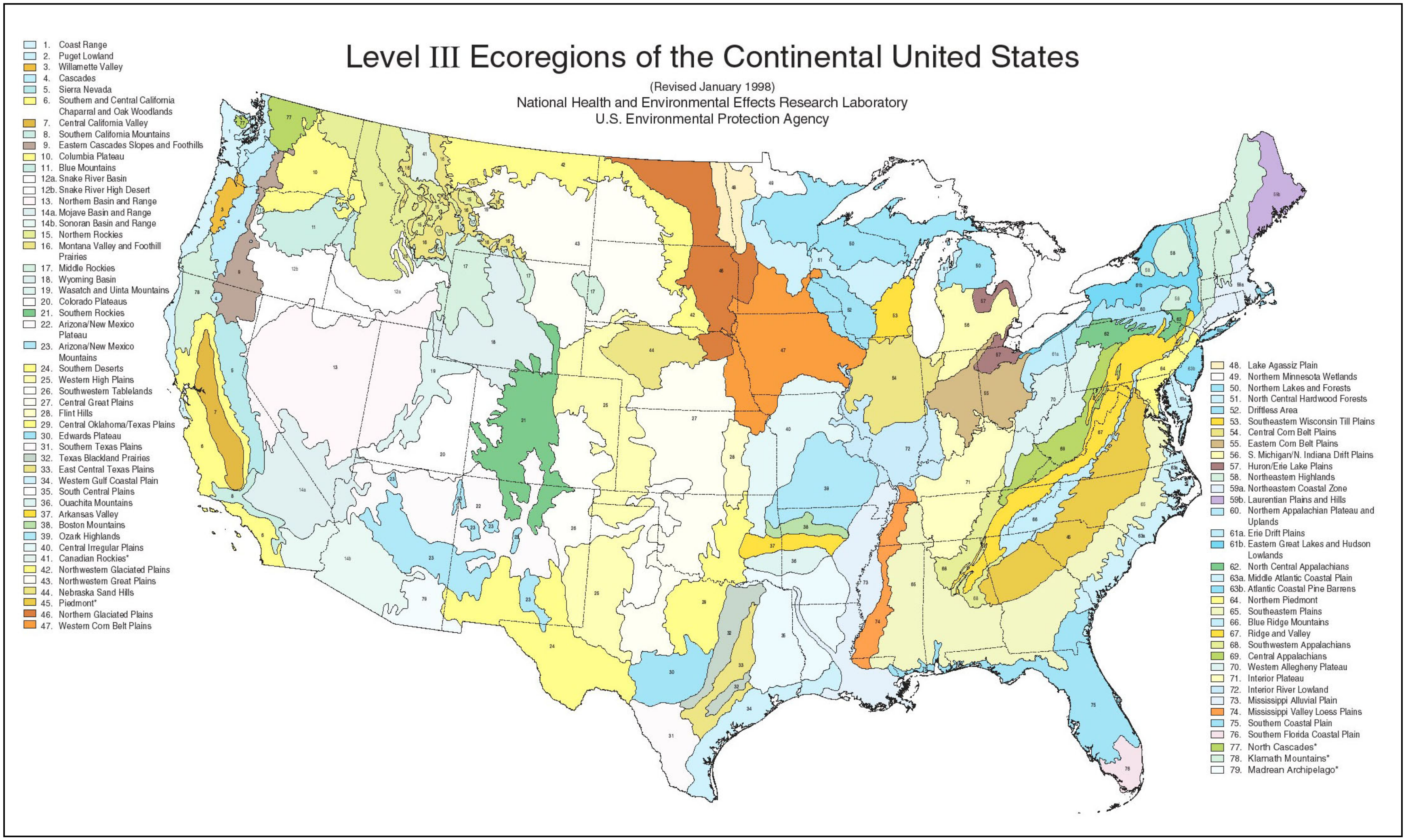

Figure 3-1. Level III Ecoregions of the Continental United States (U.S. EPA 1998a).

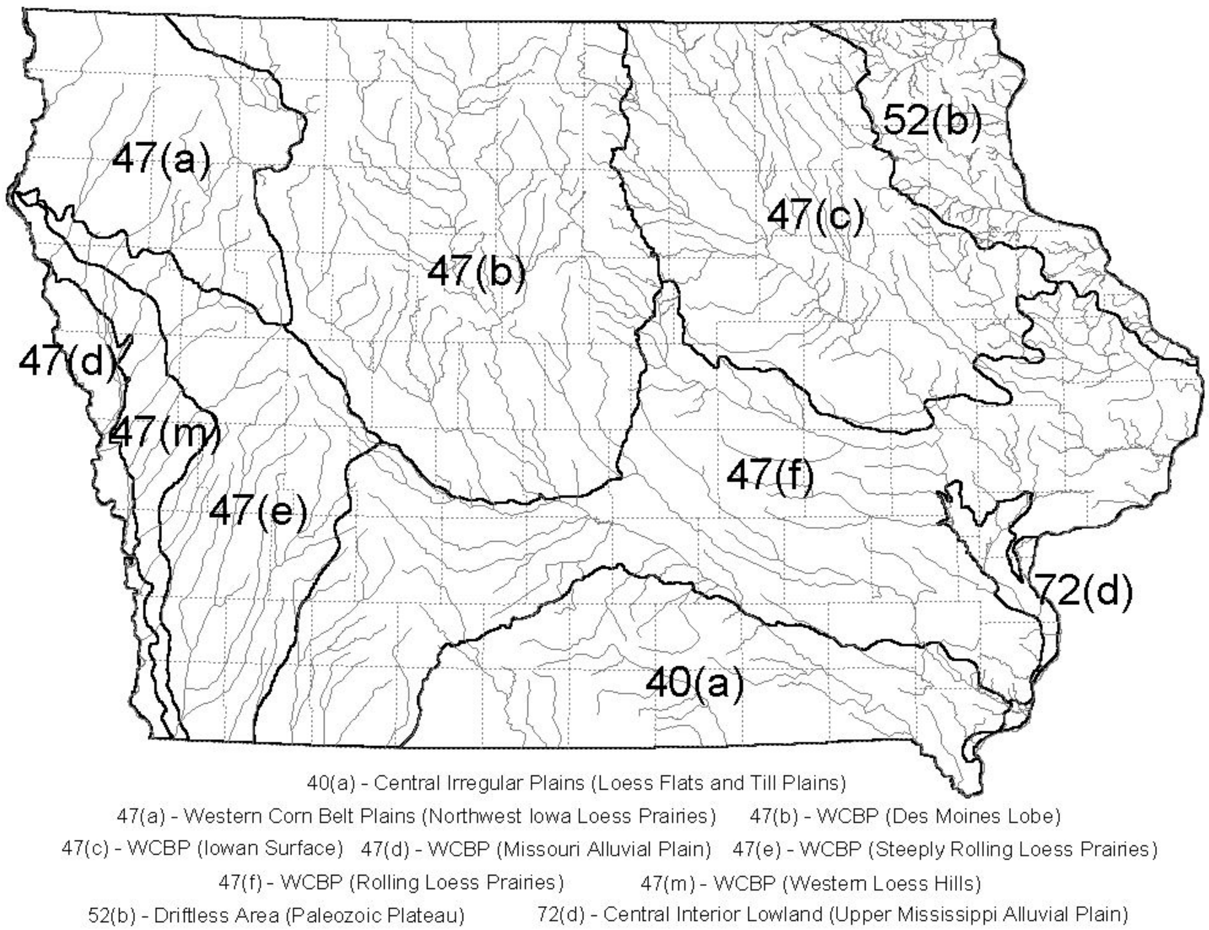

Figure 3-2. Ecoregions of Iowa (after Chapman et al. 2002). Level III Ecoregions are indicated by numeric designators; Level IV Ecoregions are indicated by alpha designators in parentheses.

Table 3-1. Generalized characteristics of Iowa ecoregions (Omernik 1993; Chapman et al. 2002)

Eco-Region #	Ecoregion Name	Landform Description	Surficial Materials	Soils	Climate	Potential Vegetation	Land Use
40(a)	Central Irregular Plains – Loess Flats and Till Plains	Irregular plains, open low hills. Elevation 700-1200 ft.	Moderate loess over loamy till and clay loam till.	Mollisols (Argiudolls){Shelby-Grundy-Haig, Shelby-Seymour-Edina}	Annual precipitation 32-36 in. Freeze free: 170-180 days	Mosaic of bluestem prairie and oak-hickory forest	Cropland and pasture, deciduous forest
47	Western Corn Belt Plains -						
47(a)	Northwest Iowa Loess Prairies	Irregular plains. Elevation 1200-1600 ft.	Moderate to thick loess over clay loam.	Mollisols (Hapludolls) {Galva-Primghar-Sac}	Annual precipitation 27-29 in. Freeze free: 140-150 days.	Bluestem prairie	Cropland
47(b)	Des Moines Lobe	Smooth to irregular plains. Elevation 900-1500 ft.	Loamy till with no loess.	Mollisols (Hapludolls) {Clarion-Nicollet-Webster}	Annual precipitation 28-31 in. Freeze free: 145-160 days.	Bluestem prairie	Cropland
47(c)	Iowan Surface	Irregular to smooth plains. Elevation 900-1200 ft.	Thin loess over loamy till.	Mollisols (Hapludolls, Argiudolls) {Kenyon-Floyd-Clyde}	Annual precipitation 31-33 in. Freeze free: 145-155 days.	Bluestem prairie, oak-hickory forest	Cropland
47(d)	Missouri Alluvial Plain	Smooth to irregular plains. Elevation 900-1100 ft.	Alluvium	Mollisols (Haplaquolls) {Luton-Onawa-Salix}	Annual precipitation 26-28 in. Freeze free: 150-160 days.	Oak-hickory forest, northern floodplain forest	Cropland
47(e)	Steeply Rolling Loess Prairies	Open low hills. Elevation 1000-1500 ft.	Thick loess.	Mollisols (Hapludolls) {Monona-Ida-Hamburg}	Annual precipitation 27-32 in. Freeze free: 150-160 days.	Bluestem prairie, oak-hickory forest	Cropland, some deciduous forest on hills
47(f)	Rolling Loess Prairies	Irregular plains to open low hills. Elevation 700-1300 ft.	Moderate to thick loess.	Mollisols, Alfisols (Argiudolls, Hapludalfs) {Shelby-Sharpsburg-Macksburg, Tama-Muscatine, Otley-Mahaska-Taintor}	Annual precipitation 30-35 in. Freeze free: 160-170 days.	Mosaic of bluestem prairie and oak-hickory forest	Cropland, small areas of deciduous forest

Table 3-1 (continued)

Eco-Region #	Ecoregion Name	Landform Description	Surficial Materials	Soils	Climate	Potential Vegetation	Land Use
47(m)	Loess Hills	Open low hills. Elevation 1000-1500 ft.	Thick loess.	Mollisols (Hapludolls) {Monona-Ida-Hamburg}	Annual precipitation 27-32 in. Freeze free: 150-160 days.	Bluestem prairie, oak-hickory forest	Cropland, some deciduous forest on hills
52(b)	Driftless Area Paleozoic – Plateau	Open hills, irregular plains. Elevation 700-1200 ft.	Thin loess and patches of drift over bedrock.	Alfisols (Hapludalfs) {Fayette-Dubuque-Stonyland}	Annual precipitation 32-34 in. Freeze free: 140-155 days.	Maple-basswood forest	Cropland and pasture, deciduous forest
72(d)	Interior River Lowland – Upper Mississsippi Alluvial Plain	Smooth to irregular plains. Elevation 500-700 ft.	Alluvium	Alfisols, Mollisols (Hapludalfs, Haplaquolls)	Annual precipitation 34-36 in. Freeze free: 165-175 days.	Oak-hickory forest	Cropland, deciduous forest, forested wetlands

3.2 Stream Reference Sites

The IDNR is using stream ecoregion reference sites to establish reference biological conditions for wadeable rivers and streams. Stream locations currently considered as reference sites by the IDNR are listed in Table 3-2. Reference sites play a key role in defining the reference condition, which is the benchmark against which biological conditions of similar types of streams in the same ecoregion are measured. The concept of reference conditions and the process of selecting reference sites are described in various scientific and technical publications (Hughes 1986; Gallant et al. 1989; Yoder and Rankin 1995; Barbour et al. 1996; U.S. EPA 1996).

The two basic requirements of stream reference sites are: 1) minimally disturbed by human activity; 2) representative of streams to which they are compared. They should exhibit biological characteristics that are both natural and regionally attainable. Any single reference site should not be expected to represent all streams in a region. Collectively, however, a set of reference sites should represent the range of minimally impaired biological conditions for streams within a particular ecoregion. In cases where minimally disturbed reference sites are lacking, alternative approaches to establishing reference conditions, such as use of historical data, simulation models, or expert consensus should be considered (U.S. EPA 1996).

3.3 Reference Site Selection

In 1993, the U.S. EPA Corvallis Research Laboratory and the IDNR established a working list of 110 candidate reference sites that represent Iowa's wadeable rivers and streams. The primary goal was to choose reference sites that are regionally representative and that are least disturbed by human activities. IDNR staff developed guidelines that specify the target number of sites for each ecoregion and the range of stream sizes to be considered for reference site nomination (IDNR 1992). The population of candidate streams included wadeable rivers and streams currently designated for protection of warm water or cold water aquatic life uses. Intermittent headwater streams classified as general use waters and large, non-wadeable interior or Border Rivers were excluded.

U.S. EPA researchers provided IDNR staff with photocopied 1:100:000 scale maps showing candidate reference site locations and delineated watershed areas. The IDNR also recommended several candidate sites, which were added to the list after consideration by U.S. EPA researchers. Candidate sites were reviewed using information gathered from field reconnaissance, GIS maps, staff interviews, and stream assessment files. Field reconnaissance was particularly useful for evaluating local instream and riparian habitat conditions. Several candidate sites were eliminated after local inspection found previously unknown habitat alterations or water quality threats.

The reference site review process was generally a subjective, expert-driven analysis conducted by IDNR staff and U.S. EPA researchers (Omernik et al. 1993; Griffith et al. 1994). A quantitative, rule-based approach was not thought to be feasible because of the perceived difficulty in defining meaningful criteria for streams spanning ten ecoregions, and the amount of staff time and other resources needed to apply the criteria. The IDNR considers reference site selection an evolving process that will require ongoing analysis to ensure the population of reference sites meets the basic requirements of quality and representation. Recent advances in GIS capabilities hold promise that a quantitative reference stream watershed validation process can be implemented in the future.

In reviewing candidate reference sites, IDNR staff considered five major factors: 1) animal feeding operations; 2) channel alterations; 3) land cover / land use; 4) riparian and instream habitat characteristics; 5) wastewater discharges. Described below are guidelines used to evaluate each factor.

<u>Animal Feeding Operations</u>

Locations of permitted animal feeding operations were identified from a statewide Geographic Information System (GIS) coverage. Sites were chosen so as to completely avoid if possible or minimize the risk of stream pollution from animal feeding operations. In many cases, reference sites could be found in small watersheds that did not have any large animal feeding operations. As watershed size increased, however, it was very difficult to find reference sites that did not contain at least one animal feeding operation in the watershed. In these cases, the objective was to minimize the risk of pollution impacts from animal feeding operations by considering three factors: a) number and sizes of facilities; b) hydrological proximity and waste management method; c) records of spills and/or fish kills caused by improper waste handling. Candidate reference sites considered vulnerable to livestock waste impacts as a result of one or more of these factors were eliminated.

<u>Channel Alterations</u>

Bridges, channelization, and dams are the major types of channel alterations found in Iowa. Channel alterations occur along every perennial stream in the state; however, the amount varies substantially among different regions. For example, stream channelization is much more extensive in western and southwestern Iowa compared to northeastern Iowa. Therefore, channel alterations first were characterized regionally, and then evaluated at the local level. The ultimate goal was to choose candidate reference sites that were least impacted by channel alterations typical of each ecoregion.

Often, stream habitat is altered for a short distance upstream and downstream from a bridge crossing. The altered habitat might be wider, deeper or unrepresentative in other ways. For this reason, candidate reference sites are located upstream or downstream from the stream reach adjacent to the bridge structure.

Stream channelization is an important issue with respect to stream reference site selection in Iowa. Previous studies in Iowa have documented the adverse impacts of channelization on habitat and fish assemblages (Bulkley 1975; Paragamian 1990). In order to have reference sites located in all of the major ecoregions of Iowa, it was necessary to accept some level of channelization in reference stream watersheds. To minimize the effects of channelization, an effort was made to locate candidate reference sites in stream segments that exhibited a meandering pattern for several miles upstream and downstream from the site. In evaluating channel condition, an effort was made to choose reference sites that did not display evidence of active channel downcutting or excessive levels of bank erosion and sedimentation.

In the headwater areas of Iowa's landscape, thousands of small dams have been built to create farm ponds for erosion control, livestock watering, and recreation. Low head dams built for flood control and hydropower generation are located in numerous segments of Iowa's major interior rivers. A number of reference sites are located in tributary streams of rivers that have one or more low head dams on them. Locating candidate reference sites away from the influence of dams, however, was not a major problem. Streams that flow directly into impoundments created by low head dams were eliminated from consideration as reference sites out of concern that resident fish assemblages would be artificially influenced by species living in the impoundment.

<u>Land Cover / Use</u>

The level of disturbance from land use was considered first at a regional scale and secondly at a local scale. Only very generalized land use coverage was available for the entire state at the time the reference site screening process began in 1992. From this coverage, only coarse patterns in land use could be evaluated at the watershed scale (e.g., distribution of land covered by perennial woody vegetation). Review of satellite imagery combined with field reconnaissance visits were used to make a more detailed local assessment of land cover / use. The general philosophy was to choose reference sites that had as much natural, perennial vegetation along the stream riparian corridor as possible, and had the least amount of disturbance from agricultural practices. Urban areas cover only about 1% of Iowa's surface area, so it was not difficult to avoid urban land use impacts. Livestock grazing in stream riparian areas is commonplace in Iowa. A concerted effort was made to avoid locating reference sites in areas that are actively used for livestock grazing.

Riparian and instream habitat

Physical habitat characteristics of candidate reference sites were evaluated using field reconnaissance and previously gathered stream assessment data. Candidate reference sites judged as having poor riparian and/or instream habitat qualities were eliminated. The types of characteristics evaluated included: channel morphology, grazing impacts, vegetation type, stream dimensions and flow, substrate composition.

Preference was given to stream sites having a wide buffer strip of natural vegetation on each side of the stream. Three general types of buffer strip plant communities were observed: a) predominantly perennial grasses and other herbaceous plants; b) mixed herbaceous vegetation and woody shrub/tree species; c) predominantly trees and/or shrubs. The type of vegetation that occurs along Iowa's streams will vary depending on the region and the position of the stream on the landscape. For example, native vegetation in headwater streams in the Des Moines Lobe ecoregion (47b) consisted of tallgrass prairie, whereas, larger streams flowing through more deeply incised valleys of the region were often bordered by deciduous forest vegetation. In recognition of these types of natural vegetation gradients, an effort was made to choose candidate reference sites having riparian vegetation that was appropriate for the region and landscape setting.

Stream physical habitat variables, such as width, depth, substrate composition, and instream cover are important factors that influence the composition of aquatic species. Stream habitat conditions vary locally and regionally. In choosing reference sites, the goal was to identify sites that represent a range of least-disturbed habitat conditions found in a region. Sites exhibiting a moderate or greater amount of physical habitat complexity, in terms of variability of depth, substrate, and water current velocity, were given preference over stream sites with more monotonous features. In many ecoregions, the difference between streams that have abundant amounts of rock substrate and regular pool-riffle sequences and streams that lack this type of habitat is an important distinction.

In ecoregions where both types of habitat frequently occur, an effort was made to balance the number of candidate reference sites representing each type.

Wastewater Discharges.

Wastewater discharges located in the watersheds of candidate reference sites were identified using a statewide GIS coverage of facilities permitted under the National Pollutant Discharge Elimination System (NPDES). To evaluate the risk of wastewater impacts, the following types of information were considered: a) number and sizes of facilities; b) distance from effluent outfall; c) effluent flow to stream flow ratio; d) stream monitoring or assessment information; e) facility compliance records.

Obviously, the ideal situation would be not to have any wastewater discharges located in reference site watersheds. In fact, it was often possible to find reference sites in small watersheds that had no point sources. However, Iowa has more than one thousand permitted wastewater facilities, and as watershed size increases, it becomes nearly impossible to find watersheds that do not have at least one point source upstream from a reference site. Therefore, in order to obtain an adequate number of reference sites for biocriteria development, it was necessary to accept some level of wastewater inputs. In these cases, references sites were located in areas where the risk of pollution from wastewater discharges was minimized by permit compliance and dilution. Candidate reference sites considered likely to be adversely impacted by wastewater discharges were eliminated.

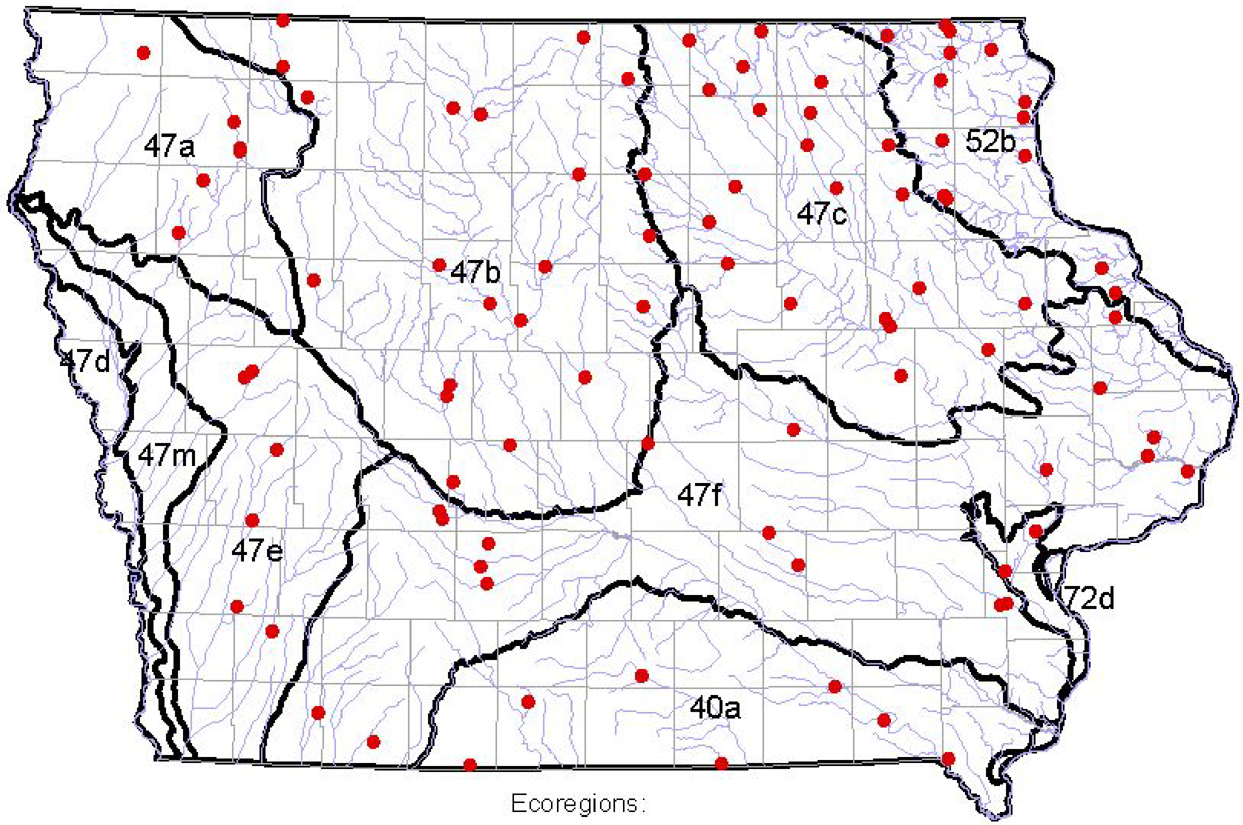

Figure 3-3. Wadeable reference stream sites: 1994–2000.

Table 3-2. Wadeable reference stream sites: 1994–2000.

#	Stream	Location	Legal Description	Eco-region	Drn. Area (mi^2)
1	Chequest Cr.	Approx. 1.5 mi. W. & 1 mi. N. of Pittsburg	SW1/4, S.21,T69N, R10W, Van Buren	40a	120
2	Lick Cr.	Shimek S.F., Lick Creek Unit; S.E. of Farmington	NE1/4, S.17,T67N, R07W, Lee	40a	17
3	Long Cr.	Decatur State Wildlife Area; S.W. of Van Wert	NW1/4, S.28,T70N, R26W, Decatur	40a	99
4	Lotts Cr.	Ringold SWMA; 11 mi. W. of Lamoni	SW1/4, S.24,T67N, R29W, Ringgold	40a	63
5	Shoal Cr.	S.W. of Exline	NE1/4, S.19,T67N, R17W, Appanoose	40a	63
6	Soap Cr.	S.W. of Eldon	NW1/4, S.5,T70N, R12W, Davis	40a	195
7	Wolf Cr.	Near Chariton; S. of Co. Rd. H50	NW1/4, S.22,T71N, R21W, Lucas	40a	65
8	Floyd R.	Sheldon Well Field; approx. 1.5 mi. N.E. of Sheldon	NW1/4, S.29,T97N, R42W, O'brien	47a	64
9	Little Rock Cr.	Little Rock Co. Wildlife Area; approx. 1.5 mi. E. of George	NW1/4, S.5,T98N, R43W, Lyon	47a	181
10	Little Waterman Cr.	Waterman Creek SWMA; approx. 7 mi. S. of Hartley	NW1/4, S.4,T95N, R39W, O'brien	47a	16
11	Mill Cr.	Approx. 3.5 mi. W. & 1/2 mi. S. of Larrabee	NW1/4, S.30,T93N, R40W, Cherokee	47a	260
12	Waterman Cr.	Whitrock Indian Village; approx. 1/2 mi. N. & 3 mi. E. of Sutherland	NW1/4, S.11,T94N, R39W, O'brien	47a	135
13	Willow Cr.	Approx. 5 mi. W. & 1/2 mi. N. from Quimby	NW1/4, S.6,T90N, R41W, Cherokee	47a	32
14	Big Muddy Cr.	Approx. 3 mi. E. & 3 mi. N. of Spencer	SW1/4, S.26,T97N, R36W, Clay	47b	59
15	Black Cat Cr.	Co. Rd. P30; approx. 2 mi. W. & 5 mi. N. of Algona	SE1/4, S.5,T96N, R29W, Kossuth	47b	70
16	Boone R.	Bells Mill Park; approx. 3.5 mi. N. & 1/2 mi. E. of Stratford	NW1/4, S.29,T87N, R26W, Hamilton	47b	900
17	Buttrick Cr.	Waters Co. Wildlife Area; West of Grand Junction	SW1/4, S.1,T83N, R30W, Greene	47b	200
18	East Branch Iowa R.	105th St, Near Belmond	SW1/4, S.6,T93N, R23W, Wright	47b	189
19	Little Beaver Cr.	Approx. 3 mi. S.W. of Woodward	SW1/4, S.11,T81N, R27W, Dallas	47b	34
20	Little Sioux R.	Approx. 1 mi. W. of Diamond Lake; N.E. of Lake Park	NW1/4, S.15,T100N, R37W, Dickinson	47b	103
21	Little Sioux R.	Horshoe Bend Co. Park; S.W. of Milford	SW1/4, S.15,T98N, R37W, Dickinson	47b	330
22	Lizard Cr.	Approx. 3.5 mi. S. of Clare	NE1/4, S.11,T89N, R30W, Webster	47b	240
23	Maynes Cr.	Mallory Co. Park; approx. 5 mi. S. of Hampton	SW1/4, S.29,T91N, R20W, Franklin	47b	36
24	Mosquito Cr.	Upstr. of Highway 44 Bridge; 5 mi. E. of Panora	SW1/4, S.32,T80N, R29W, Dallas	47b	74
25	North Raccoon R.	Raccoon River Greenbelt; approx. 2.75 mi. N. of Sac City	NW1/4, S.2,T88N, R36W, Sac	47b	328
26	Plum Cr.	Approx. 3.5 mi. E. & 3.5 mi. N. of Algona	SW1/4, S.15,T96N, R28W, Kossuth	47b	50
27	Prairie Cr.	Dolliver State Park; approx. 2 mi. W. & 2 mi. N. of Lehigh	SW1/4, S.35,T88N, R28W, Webster	47b	30
28	South Fork Iowa R.	Logsdon Co. Park; approx. 8.5 mi. S. of Iowa Falls	SW1/4, S.35,T88N, R21W, Hardin	47b	120
29	South Skunk R.	Approx. 3 mi. N. & 2 mi. E. of Ames	SE1/4, S.6,T84N, R23W, Story	47b	258
30	West Buttrick Cr.	Adjacent to Spring Lake Park	SE1/4, S.24,T84N, R30W, Greene	47b	105
31	White Fox Cr.	Approx. 5.5 mi. N/N.E. of Webster City	SW1/4, S.10,T89N, R25W, Hamilton	47b	79
32	Willow Cr.	Willow Creek Wildlife Area (Greene Co); approx. 2 mi. E/Se of Hanlontown	SW1/4, S.29,T98N, R21W, Worth	47b	24
33	Winnebago R.	Lande Access; approx. 3 mi. W. & 1.5 mi. N. of Lake Mills	SE1/4, S.31,T100N, R23W, Winnebago	47b	122
34	Bailey Cr.	Ingrebretsen Co. Park; approx. 4 mi. W. & 1.5 mi. N. of Sheffield	NE1/4, S.1,T93N, R21W, Franklin	47c	75

#	Stream	Location	Legal Description	Eco-region	Drn. Area (mi^2)
35	Bear Cr.	Approx. 2 mi. W. & 1 mi. N. of Shellsburg	SW1/4, S.4,T84N, R09W, Benton	47c	52
36	Bear Cr.	Buchanan Co. Park; approx. 2 mi. E. & 1/2 mi. S. of Brandon	SW1/4, S.36,T87N, R10W, Buchanan	47c	46
37	Black Hawk Cr.	Popp Co. Access; approx. 2.5 mi. S.W. of Hudson	NW1/4, S.33,T88N, R14W, Black Hawk	47c	303
38	Buffalo Cr.	Approx. 4 mi. E. of Central City	NE1/4, S.5,T85N, R05W, Linn	47c	187
39	Burr Oak Cr.	Approx. 2 mi. N. & 4 mi. E. of Osage	NE1/4, S.9,T98N, R16W, Mitchell	47c	21
40	Coldwater Cr.	Approx. 3 mi. S. & 1 mi. E. of Greene	SE1/4, S.19,T93N, R16W, Butler	47c	63
41	Crane Cr.	Approx. 1 mi. W. of Lourdes	SW1/4, S.31,T98N, R12W, Howard	47c	71
42	Deer Cr.	Approx. 1 mi. N/N.W. from Carpenter	NW1/4, S.6,T99N, R18W, Mitchell	47c	86
43	E Frk Wapsipinicon R.	Approx. 5 mi. N. & 3 mi. W. of New Hampton	SW1/4, S.10,T96N, R13W, Chickasaw	47c	11
44	E. Br. Wapsipinicon R.	S.W.eet Marsh SWMA; Highway 93; approx. 2 mi. N. & 1 mi. E. of Tripoli	NW1/4, S.26,T93N, R12W, Bremer	47c	145
45	Lime Cr.	Lime Creek Park; approx. 1.5 mi. N.E. of Brandon	SW1/4, S.23,T87N, R10W, Buchanan	47c	30
46	Little Cedar R.	Colwell Co. Park; approx. 2.5 mi. W. of Colwell	NE1/4, S.8,T96N, R15W, Floyd	47c	275
47	Little Turkey R.	Gouldsburg Co. Park; approx. 500' dwnstr. of Confluence With Crane Creek	SW1/4, S.30,T95N, R09W, Fayette	47c	318
48	Pine Cr.	Approx. 3.5 mi. N. & 2 mi. W. of Quasqueton	NW1/4, S.8,T88N, R08W, Buchanan	47c	30
49	Plum Cr.	Approx. 2.5 mi. N. of Hopkinton	SW1/4, S.31,T88N, R03W, Delaware	47c	81
50	Rock Cr.	Approx. 1/4 mi. E. of Rock Creek (Town)	NE1/4, S.12,T97N, R18W, Mitchell	47c	46
51	South Beaver Cr.	Approx. 1 mi. S. & 1.25 mi. W. of Parkersburg	NE1/4, S.2,T89N, R17W, Grundy	47c	114
52	Volga R.	Approx. 3 mi. N. of Maynard; upstr. of Twin Bridges Co. Park	SE1/4, S.34,T93N, R09W, Fayette	47c	50
53	Wapsipinicon R.	Twin Ponds Chickasaw Co. Park; approx. 5 mi. S.E. of Ionia	SW1/4, S.28,T95N, R13W, Chickasaw	47c	155
54	Wapsipinicon R.	Wapsipinicon SWMA; approx. 2 mi. N. & 2 mi. W. of Mcintyre	SW1/4, S.21,T100N, R15W, Mitchell	47c	30
55	West Fork Cedar R.	Lake Considine Co. Park	NE1/4, S.12,T91N, R18W, Butler	47c	554
56	Big Cr.	Approx. 4 mi. N. & 1/2 mi. W. of Denison	SE1/4, S.15,T84N, R39W, Crawford	47e	18
57	East Branch West Nishnabotna R.	Approx. 4.5 mi. N.E. of Avoca	SW1/4, S.26,T78N, R39W, Shelby	47e	200
58	Indian Cr.	Upstr. Highway 6 Bridge; N. W. of Lewis	SW1/4, S.5,T75N, R37W, Cass	47e	180
59	Jordan Cr.	Approx. 1.5 mi. upstr. from Confluence With Farm Creek	NE1/4, S.30,T74N, R39W, Pottawattamie	47e	31
60	Otter Cr.	Approx. 3/4 mi. N.W. of Deloit	SE1/4, S.1,T84N, R39W, Crawford	47e	44
61	Pilot Branch	Approx. 1/2 mi. N.E. of Stennett	SW1/4, S.26,T73N, R38W, Montgomery	47e	6
62	West Nishnabotna R.	Approx. 1 mi. N.E. of Irwin; Upper Nishnabotna Habitat Area	NW1/4, S.29,T81N, R37W, Shelby	47e	85
63	Barber Cr.	Barber Creek SWMA; S.E. of Grand Mound	SE1/4, S.33,T81N, R03E, Clinton	47f	14
64	Bear Cr.	Eden Valley Co. Park; approx. 2 mi. S. & 1/2 mi. W. of Baldwin	NW1/4, S.33,T84N, R01E, Jackson	47f	71
65	Big Slough Cr.	Spring Run Speedway; approx. 4 mi. S. of Columbus City	SW1/4, S.14,T74N, R05W, Louisa	47f	29
66	Buck Cr.	Approx. 8 mi. W. of Barnes City; Poweshiek/Mahaska Co. Line	SW1/4, S.32,T78N, R15W, Mahaska	47f	34
67	Deer Cr.	Approx. 2 mi. N. of Stuart	NW1/4, S.21,T78N, R30W, Guthrie	47f	11
68	East Nodaway R.	Hawleyville; approx. 3 mi. N. & 2 mi. W. of New Market	SW1/4, S.13,T69N, R36W, Page	47f	299

#	Stream	Location	Legal Description	Eco-region	Drn. Area (mi^2)
69	Honey Cr.	Approx. 3 mi. E. of Bedford	SE1/4, S.21,T68N, R33W, Taylor	47f	29
70	Howerdon Cr.	Approx. 4 mi. W. And 2 mi. N. of Winterset	SE1/4, S.19,T76N, R28W, Madison	47f	12
71	Long Cr.	Approx. 3 mi. S. of Columbus Junction	SE1/4, S.13,T74N, R05W, Louisa	47f	132
72	Lost Cr.	Approx. 2.5 mi. N. & 3.5 mi. W. of Princeton	NW1/4, S.29,T80N, R05E, Scott	47f	33
73	Lytle Cr.	Approx. 1.5 mi. N. & 4 mi. W. of Zwingle	NE1/4, S.30,T87N, R02E, Dubuque	47f	57
74	Middle R.	Pammel State Park; approx. 2 mi. S. & 2.5 mi. W. of Winterset	NE1/4, S.16,T75N, R28W, Madison	47f	228
75	Mud Cr.	Approx. 4.5 mi. W. & 1.5 mi. N. of Baxter	SW1/4, S.1,T81N, R21W, Jasper	47f	10
76	North Branch North R.	Next to Goeldner Wood Co. Park; S.E. of Earlham	NE1/4, S.21,T77N, R28W, Madison	47f	39
77	North Skunk R.	Approx. 3.5 mi. N. & 1/2 mi. E. of Rose Hill	NE1/4, S.22,T76N, R14W, Mahaska	47f	529
78	Richland Cr.	Approx. 1/2 mi. N. of Haven	NE1/4, S.21,T82N, R14W, Tama	47f	56
79	Rock Cr.	Approx. 2 mi. S. And 1 mi. W. of Tipton	SW1/4, S.13,T80N, R03W, Cedar	47f	55
80	Silver Cr.	Approx. 1.25 mi. N. & 1.5 mi. W. of Dewitt	SW1/4, S.2,T81N, R03E, Clinton	47f	41
81	South Raccoon R.	Nation's Bridge Co. Park; N. of Stuart	SW1/4, S.5,T78N, R30W, Guthrie	47f	332
82	Brush Cr.	W51 Bridge S. of Wadena	SW1/4, S.4,T92N, R07W, Fayette	52b	33
83	Canoe Cr.	Canoe Creek SWMA; N.E. of Decorah	NE1/4, S.25,T99N, R07W, Winneshiek	52b	67
84	Catfish Cr.	Swiss Valley Dubuque Co. Park	SE1/4, S.19,T88N, R02E, Dubuque	52b	11
85	Coldwater Cr.	Coldwater Spring SWMA N. W. of Bluffton	NE1/4, S.31,T100N, R09W, Winneshiek	52b	18
86	Deep Cr.	Near Wadena	NE1/4, S.10,T92N, R07W, Fayette	52b	3
87	Dibble Cr.	Approx. 1.5 mi. N.W. of Clermont	SE1/4, S.21,T95N, R07W, Fayette	52b	12
88	French Cr.	French Creek SWMA; approx. 7 mi. N. & 4 mi. E. of Waukon	SE1/4, S.23,T99N, R05W, Allamakee	52b	10
89	Little Maquoketa R.	Downstr. Twin Springs Rd. Crossing; 6 mi. W. of Dubuque	SW1/4, S.15,T89N, R01E, Dubuque	52b	47
90	Middle Bear Cr.	Approx. 2.5 mi. N. & 1.5 mi. E. of Highlandville	SW1/4, S.14,T100N, R07W, Winneshiek	52b	5
91	North Bear Cr.	N. Bear Creek Public Access Near Highlandville	NE1/4, S.25,T100N, R07W, Winneshiek	52b	28
92	North Cedar Cr.	SWMA upstr. of Co. Rd X60 Bridge	NW1/4, S.17,T94N, R03W, Clayton	52b	6
93	Paint Cr.	Yellow River S.F. dwnstr. of Little Paint Creek confluence	SE1/4, S.32,T97N, R03W, Allamakee	52b	74
94	Trout R.	Trout River Public Area; approx. 7 mi. S. & E. of Decorah	SE1/4, S.33,T98N, R07W, Winneshiek	52b	7
95	Yellow R.	Yellow River Unit/Yrsf; approx. 1.5 mi. E. of Ion	SE1/4, S.19,T96N, R03W, Allamakee	52b	225
96	Honey Cr.	Approx. 3 mi. S. & 1/4 mi. W. of Conesville	NE1/4, S.1,T75N, R05W, Louisa	72d	20
97	Pike Run	Approx. 5 mi. E. & 1/2 mi. N. of Nichols	NE1/4, S.8,T77N, R03W, Muscatine	72d	9

3.4 Data Collection

Sampling Design

Once candidate reference sites were identified, a sampling plan (IDNR 1993) was prepared. The plan called for sampling 110 reference sites and 40 test (impacted) sites over a five-year period from 1993-1997. Because of statewide record levels of rain and flooding in 1993, the project's start was postponed until 1994. Between 1994 and 1998 101 candidate reference sites, 15 test sites, and 46 watershed assessment sites were sampled. Most sites were sampled just once during the initial five-year period. With limited project resources, the decision was made to sample as many streams as possible in order to better define the range of biological conditions within each ecoregion. Three reference sites were sampled repeatedly during a four-year period to examine temporal, within-site variability. Each year, sampling sites have been widely distributed across five or more ecoregions (Figure 3-4).

Sampling priorities have shifted since the initial 1994-1998 sampling period, which emphasized candidate reference sites (Figure 3-5). Sampling from 1999 through 2001 emphasized follow-up sampling in streams reported as having physical habitat or water quality problems. In 2000, the IDNR established a 5-year rotational schedule for re-sampling reference sites originally sampled from 1994-1998. Since 2001, stream bioassessment has been incorporated in several TMDL monitoring projects. The latest project to utilize bioassessment sampling is the probabilistic (random) stream survey initiated in 2002. This unique project is designed to provide an unbiased, statistically powerful assessment of Iowa's perennial rivers and streams (IDNR 2001a).

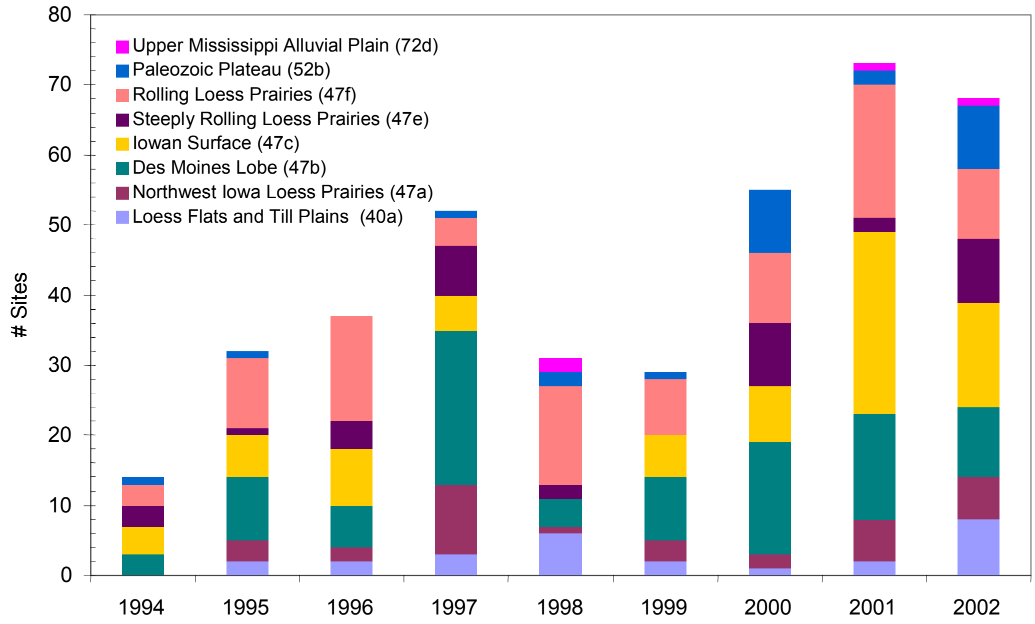

Figure 3-4. Distribution of stream bioassessment sample sites by ecoregion: 1994-2002.

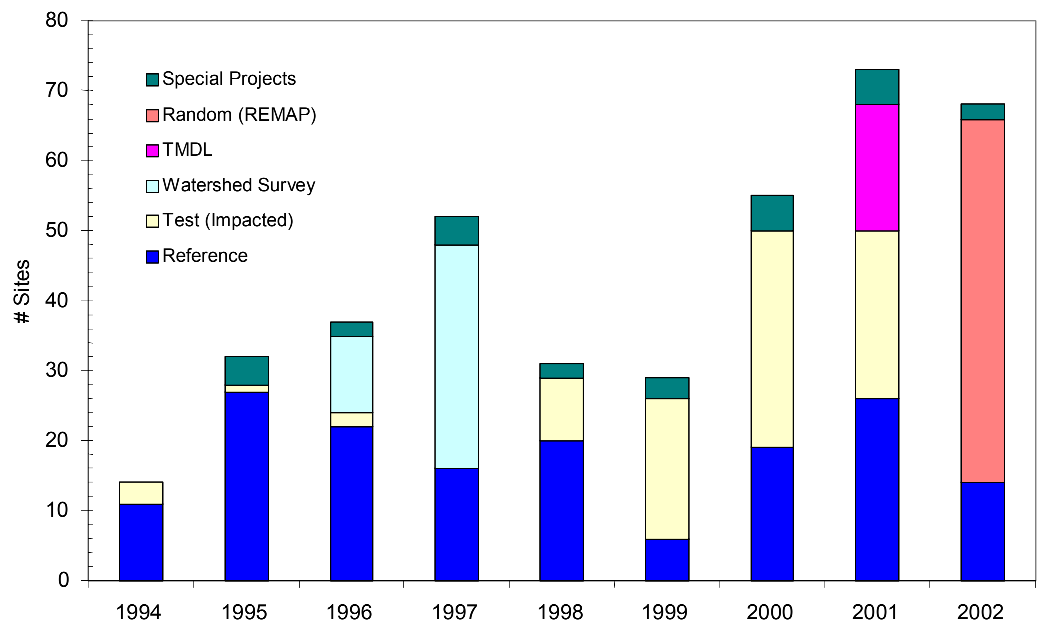

Figure 3-5. Types of stream bioassessment sample sites: 1994-2002.

Sampling Procedures

In 1994, wadeable stream sampling procedures were established for biological sampling and physical habitat evaluation. Standard procedures ensure that sample data are consistent across sampling sites and years. The procedures were updated in 2001 to provide additional clarification (IDNR 2001b; 2001c). The biological sampling procedures describe methods for collecting and processing stream benthic macroinvertebrates and fish. The habitat evaluation procedures describe the collection and compilation of quantitative and qualitative habitat data. Biological sampling and habitat evaluation are conducted in a pre-defined stream reach ranging in length from 150-350 meters, depending on stream size and habitat repetition frequency. Following is a synopsis of the stream bioassessment sampling procedures:

Benthic Macroinvertebrate Assemblage

Two types of stream benthic macroinvertebrate samples are collected: 1) standard-habitat and 2) multi-habitat.

Triplicate standard-habitat samples are collected from either rock or wood substrates in riffle/run habitat. A modified-Hess sampler or Surber sampler is used in naturally occurring riffle/run habitats that are comprised of large gravel and cobble substrates. An array of four Hester-Dendy style artificial substrates is used in streams that lack riffles with coarse rock substrates. Each artificial substrate consists of 8, 4"x4"wood plates mounted on a steel rod, which is pushed into the stream bottom. The artificial substrates are allowed a 4-6 week colonization period before they are retrieved and processed. Three replicate standard-habitat samples are collected from each site. In the laboratory, a 100-organism subsample is randomly obtained from each replicate sample.

A multi-habitat sample is collected from a pre-defined stream reach from 150-350 meters in length, which usually encompasses at least two pool/riffle sequences or two major channel bends. Benthic macroinvertebrates are handpicked from all types of benthic habitat that are accessible. Common types of benthic substrates sampled include: silt, sand, muck, rock, detritus, wood, root wad, and vegetation. Organisms are collected both from depositional and erosional zones of the stream.

The objective of multi-habitat sampling is to maximize the number of taxa collected. Several (3-10) individuals of each visually distinct taxon are collected to facilitate identification and differentiation of similar taxa. A combined sampling time of 90 minutes is divided among two or three collectors who cover the entire sampling reach. All of the organisms are combined in one sample for the stream reach.

Macroinvertebrate sample contents are preserved in 10% Formalin and transported to the University of Iowa Hygienic Laboratory (UHL) for analysis. Organisms are identified to the lowest-practical taxonomic level. In most cases, the analysis endpoint is genus or species. Some problematic organisms (e.g., Chironomidae) are identified to family level. Factors that determine the taxonomic endpoint include: 1) life stage and maturity of the organism; 2) availability of dichotomous taxonomic keys; 3) time/cost required to make an accurate determination. An outside expert confirms taxonomic determinations of a subset of organisms.

Fish Assemblage

Fish are sampled by direct current (DC) electrofishing. One battery-powered, backpack shocker is used in small streams of average width less than 15 feet. In wide and shallow streams, two or three backpack shockers are operated side-by-side. A tow-barge electrofishing unit consisting of fiberglass boat with live well, generator, DC control box, and two reel-mounted electrodes is used in deeper, wadeable streams that require more power for efficient sampling.

The sampling area (i.e., stream reach) is selected based on the average width of the stream and repetition of major stream features, such as riffles or channel bends. The minimum length of stream sampled is 150 meters and the maximum length is 350 meters. Block nets are set across the stream at the downstream and upstream sampling boundaries when needed to prevent large, mobile fish (e.g. Catostomidae species) from leaving the sampling area. Block net dimensions are 0.75-inch mesh-diameter x 4 ft. height x 30 ft. or 60 ft. length. Block nets are not needed in streams having shallow riffles that serve as obstacles to fish movement.

Fish are collected in a single pass through the sampling reach. The direction of sampling is from downstream to upstream. An effort is made to sample all accessible habitats in the sampling area and collect all stunned fish. Fish are captured using 3/16 inch mesh-diameter landing nets and transferred to plastic buckets or a live well for processing on-site. Fish are identified, counted, and examined for external physical abnormalities before being released to the stream. Fish that can't be identified to species in the field are preserved in 10% Formalin and brought back to the laboratory. Fish voucher specimens are routinely collected. An outside expert in fish taxonomy is periodically used to verify fish identifications. IDNR and UHL staff maintain a reference collection of Iowa stream fishes.

Physical Habitat Evaluation

Habitat data are systematically gathered from ten channel cross-section transects that are evenly spaced in the designated sampling area. Measurements or visual observations of several instream and riparian habitat variables are obtained at each transect. Examples include: riparian buffer width and vegetation type, stream shading, stream bank condition, stream width and depth, substrate type, amount and type of instream cover.

A map of the sample reach and major stream channel features is sketched during the transect data gathering process. A tally of different types of macro habitat that occur (e.g., pools, riffles, runs) and the thalweg line of stream maximum depth is recorded. The physical habitat data are compiled and a number of summary statistics are generated.

The data are also used to complete a habitat quality assessment form (Barbour and Stribling 1991). Benchmark photographs are taken at the downstream and upstream sample reach boundaries.

Water Quality Parameters

Depending on sampling objectives, a series of water quality parameters are sampled at each stream bioassessment site. Typically, in-situ measurements of dissolved oxygen, pH, and temperature are obtained. A grab sample is usually collected for analysis of conventional water quality parameters including: total ammonia, nitrate+nitrite-nitrogen, Kjeldahl nitrogen, total phosphorus, specific conductance, total dissolved solids, total suspended solids, and turbidity. Other water quality parameters including toxics (e.g., metals, pesticides) may be included to address site-specific needs. Water sample data are used to characterize water quality conditions at the time of biological sampling. Because the sample data are very limited, the data are mostly intended for identifying potential water quality concerns and relationships to biological assemblage data, and less as a means of evaluating water quality at any particular site.

Watershed Characteristics

A series of stream watershed variables are calculated by IDNR GIS staff. Watershed characteristics are calculated using the ArcView Spatial Analyst software (ESRI) and data sources maintained in the IDNR GIS Library. GIS analysis is essential for identifying patterns in watershed characteristics that help explain stream biological and physical habitat conditions. In conjunction with stream biological sampling results, GIS analysis results are used in the diagnosis of causes and sources of stream use impairment. The types of GIS information gathered and analyses conducted are listed in Tables 3-3 and 3-4. Calculations for most of the reference sites and some impacted (test) sites have been completed. These data have not been fully compiled or analyzed; therefore, results are not included in this report.

Table 3-3. Watershed characteristics calculated for stream bioassessment sites.

WATERSHED CHARACTERISTIC	DEFINITION
Total Drainage Area (TDA) (sq mi)	Area inside the drainage divide contributing to surface runoff at the watershed outlet.
Basin Length (BL) (mi)	Measured along a line areally centered through the drainage divide from watershed outlet to where main channel meets the drainage divide.
Basin Perimeter (BP) (mi)	Measurement of length around watershed drainage divide.
Average Basin Slope (BS) (%)	Average percent slope measured by "contour band" method
Basin Relief (BR) (ft)	The difference between elevation of highest grid cell within the drainage divide and elevation of grid cell at watershed outlet.
Effective Basin Width (BW) (mi)	Measured in miles is equal to the total drainage area (TDA) divided by the basin length (BL).
Shape Factor (SF)	Dimensionless ratio of basin length (BL) to effective basin width (BW)
Elongation Ratio (ER)	Dimensionless ratio equal to the diameter of a circle of equal area to watershed divided by basin length (BL).
Rotundity of Basin (RB)	Dimensionless ratio of basin length (BL) to total drainage area (TDA).
Compactness Ratio (CR)	Dimensionless ratio of perimeter of watershed drainage divide to the circumference of a circle of equal area.
Relative Relief (RR) (ft/mi)	Measured in feet per mile is equal to the basin relief (BR) divided by basin perimeter (BP).
Main Channel Length (MCL) (mi)	The length of the main channel from the watershed outlet to the point where the main channel would meet the drainage divide if the channel were extended.
Total Stream Length (TSL) (mi)	Sum of lengths of all channel segments in the watershed.
Main Channel Slope (MCS) (ft/mi)	Measured in feet per mile using elevation difference and distance between points at 10% and 85% of the main channel distance
Main Channel Sinuosity Ratio (MCSR)	Dimensionless ratio of main channel length (MCL) divided by basin length (BL).
Stream Density (SD) (mi/sq mi)	Measurement of miles of stream per square mile of watershed area.
Main Channel Slope Proportion (MCSP)	Dimensionless $MCSP = MCL / (MCLS)^{0.5}$
Ruggedness Number (RN) (ft/mi)	$RN = (TSL)(BR)/(TDA)$
Slope Ratio (SR)	Dimensionless ratio of main channel slope (MCL) to average basin slope (BS).
Number of First Order Streams (FOS)	Total number of Strahler first order streams (FOS) in watershed
Basin Stream Order (BSO)	Strahler order of main stream channel at the watershed outlet.
Drainage Frequency (DF) (#/sq mi)	The number of first order streams per square mile of watershed area.
Relative Stream Density (RSD)	Dimensionless $RSD=DF/(SD)^2$

Table 3-4. Land cover / use and soil loss variables included in GIS watershed analysis.

Land Cover / Use	Description
Artificial	% Watershed area as artificial surfaces (e.g., roads, parking lots, buildings).
Barren	% Watershed area as barren ground (e.g., quarries, construction sites)
Grass	% Watershed area as grass cover (e.g., golf courses, lawns, meadow, pasture, prairie, other herbaceous cover)
Row Crop	% Watershed area as row crop (e.g., corn, soybeans)
Water	% Watershed area as water (i.e., lakes, ponds, rivers, streams, inundated wetlands)
Forest	% Watershed area as forest (e.g., tree plantations, farm woodlots, state forest, other areas of dense woody vegetation cover)
Soil Loss and Delivery	Description
Potential Soil Loss (T/A/Y)	Potential sheet and rill erosion rate calculated by Revised Universal Soil Loss Equation (RUSLE) in tons/acre/year
Potential Sediment Delivery (T/A/Y)	Potential rate of sediment delivery to stream network (tons/acre/year)

4 Sample Results and Data Analysis

4.1 Stream Environmental Characteristics

Stream physical habitat and water quality are important determinants of aquatic community structure and biological condition. To set appropriate standards or restoration goals for streams, it is first important to characterize the environmental conditions encompassed by healthy, minimally disturbed streams. To be able to distinguish the effects of human impacts from natural variation, it is equally important to understand the relationships between environmental conditions and stream biological communities.

This part of the report is devoted to stream sampling data and analysis. Section 4.1 displays the statistical ranges of physical habitat and water quality parameters sampled from 98 candidate reference sites during the (1994-1998) initial biocriteria data-gathering phase. The data are limited from the standpoint that most sites were sampled only once. Collectively, however, the sites do represent a reasonable cross-section of Iowa's perennial wadeable rivers and streams. Section 4.2 describes the types of benthic macroinvertebrates and fish found in Iowa's wadeable streams. Statistical analysis of relationships between stream biota and environmental variables are discussed in Section 4.3.

<u>Box and Whisker Plots</u>

Box and whisker plots (see Figure 4 -1) are an easy way of displaying the range of water quality values from a group of samples. Box and whisker plots displayed in this report consist of the following: 1) the box represents the interquartile range encompassing all the values between and including the 25^{th} percentile and 75^{th} percentile values; 2) the horizontal line through the box represents the median (50^{th} percentile) value; 3) the vertical lines (whiskers) extending above and below the box represent values that are within a distance 1.5 times greater or lesser than the interquartile range, respectively; 4) asterisks indicate high and/or low outlier values that are a distance beyond 1.5 times the interquartile range.

Physical Habitat

Those who are not familiar with Iowa are sometimes surprised by the diversity of landscapes that occur within the state. As reflected by the ranges of physical habitat variables measured at 98 candidate reference sites (Table 4-1), Iowa's stream environments might also be considered surprisingly diverse. Types range from warm and sluggish, soft-bottomed prairie streams to cold and swift, rocky-bottomed forest streams.

Figure 4-1 shows the ranges of various habitat characteristics of candidate reference stream sites grouped by ecoregion. Within ecoregion groupings, there is a substantial amount of variability in physical habitat characteristics. Despite this variability, the ecoregion effect was statistically significant for 75% of the physical habitat variables tested (Analysis of Variance; $p<0.05$). Testing for ecoregion mean differences in physical habitat variables was not done because the number of samples was small and unevenly distributed among the ecoregions. Iowa's probabilistic (random) stream survey to be completed in 2006 will provide a much better data set from which to examine ecoregion differences.

Among ecoregions, candidate reference sites of the Paleozoic Plateau (52b) in Northeast Iowa ranked highest in levels of coarse rock substrate, riffle habitat amount, stream gradient and habitat quality. Candidate reference sites of the Steeply Rolling Loess Prairies (47e) in Southwest Iowa ranked highest in fine sediment amounts, while channel sinuosity and stream habitat quality ranked lowest. Stream shading and large woody debris amounts were lowest among candidate reference sites representing the Northwest Iowa Rolling Prairies (47a).

Table 4-1. Statistical ranges of stream physical habitat parameters sampled at 98 candidate reference sites: 1994-1998.

Stream Physical Habitat Parameters	Minimum	25th Percentile	50th % (Median)	75th Percentile	Maximum
Instantaneous Flow (cfs)	0.1	4	10	26	98
Gradient (ft./mi.)	0.7	3.6	5.9	11.1	40.5
Surface Watershed Area (sq.mi.)	5	30	64	144	900
Segment Sinuosity (x straight line)	1.0	1.3	1.4	1.7	5.3
Avg. Stream Width (ft.)	7.1	19.8	30.7	41.6	114.3
Avg. Water Depth (ft.)	0.15	0.56	0.80	1.05	2.36
Avg. Thalweg Depth (ft.)	0.42	1.07	1.51	1.92	4.18
Stream Width:Thalweg Depth	4.4	14.7	20.2	30.5	69.0
% Stream Bottom Area as Clay	0	0	0	4	45
% Stream Bottom Area as Silt	0	6	10	18	80
% Stream Bottom Area as Sand	0	18	38	66	92
% Stream Bottom Area as Fines (clay + silt + sand + soil)	6	30	64	84	98
% Stream Bottom Area as Gravel	0	6	16	30	60
% Stream Bottom Area as Cobble	0	0	10	24	62
% Stream Bottom Area as Boulder	0	0	0	2	40
% Stream Bottom Area as Coarse Substrate (gravel + cobble + boulder)	0	8	36	61	89
% Stream Area as Pools	0	13	25	45	100
% Stream Area as Runs	0	40	59	77	100
% Stream Area as Riffles	0	0	9	18	36
% Stream Area Providing Instream Cover for Large, Adult Fish	0	2	6	12	60
% Bare Lower Stream Bank Area	1	41	61	71	96
Stream Bank Condition Rating (0-20)	2	7	10	12	19
Riparian Buffer Rating (0-20)	6	13	16	17	19
Average % Stream Shaded	3	25	44	64	90
Habitat Quality Index Score (0-180)	51	88	105	118	144

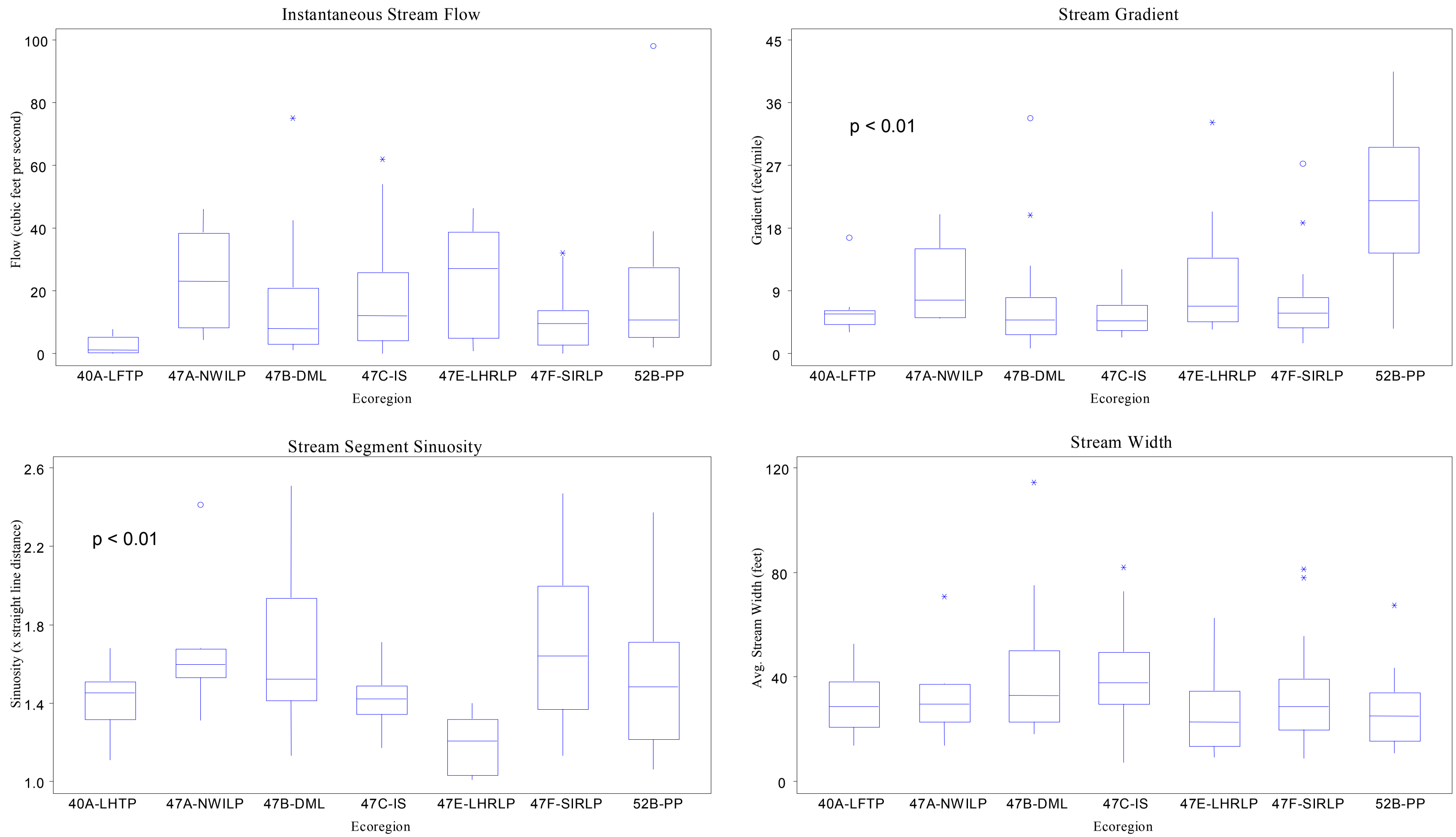

Figure 4-1. Stream physical habitat parameters sampled at 98 candidate reference sites grouped by ecoregion (Figure 3-2*). P-values are given for parameters in which the ecoregion effect was significant (ANOVA; p<0.05).*

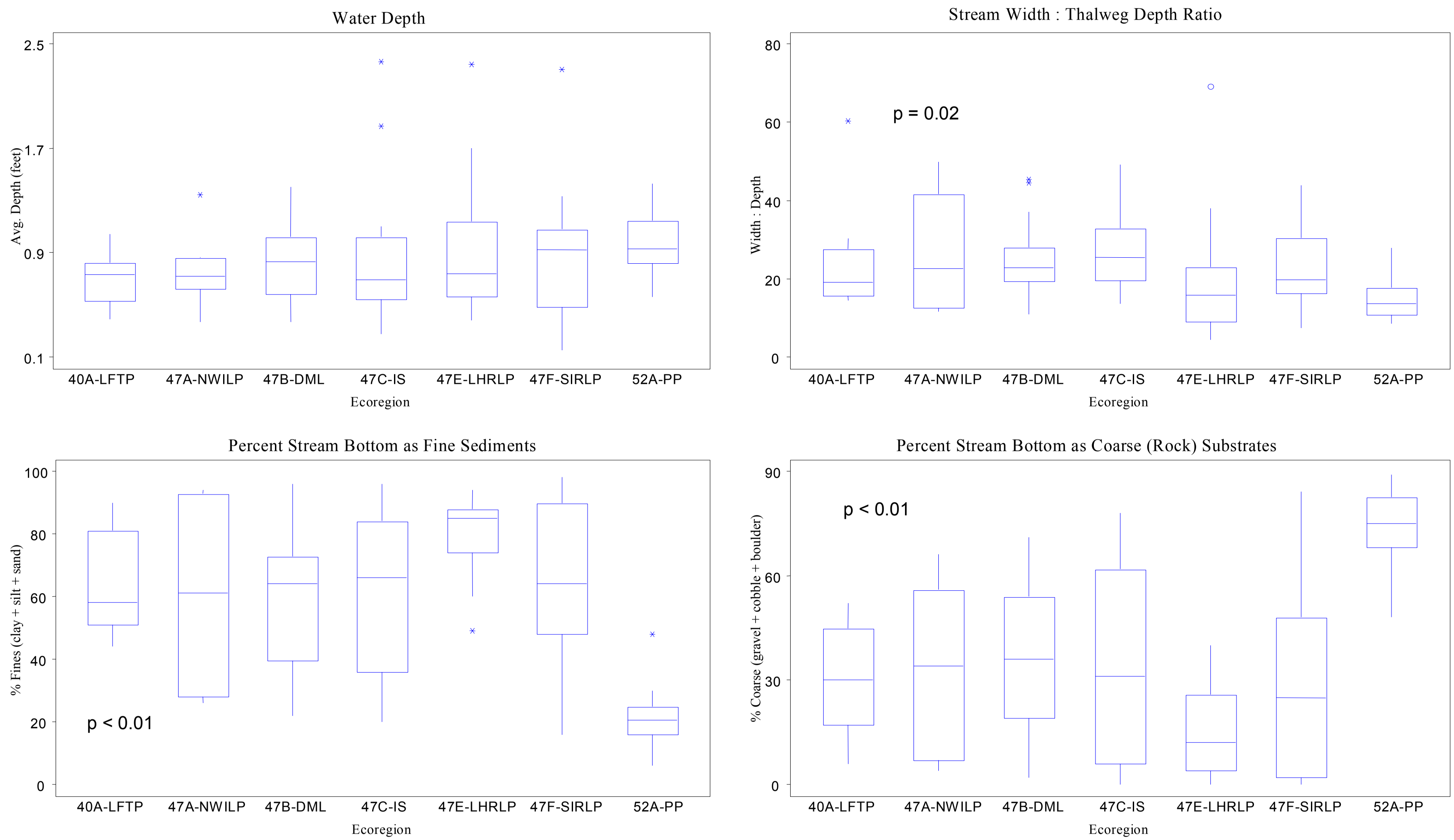

Figure 4-1 (continued). Stream physical habitat parameters sampled at 98 candidate reference sites grouped by ecoregion (Figure 3-2). *P-values are given for parameters in which the ecoregion effect was significant (ANOVA; p<0.05).*

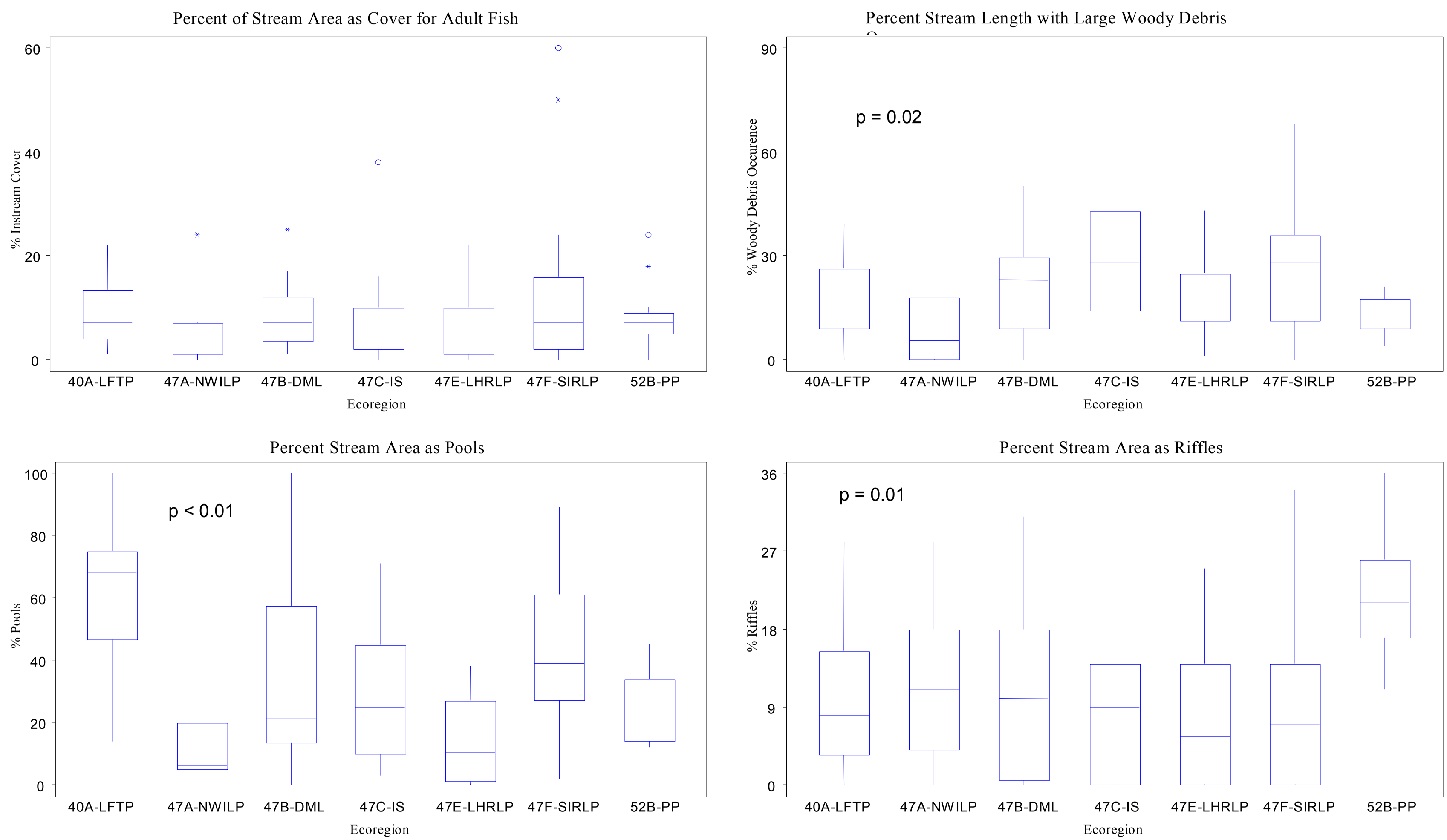

Figure 4-1 (continued). Stream physical habitat parameters sampled at 98 candidate reference sites grouped by ecoregion (Figure 3-2). *P-values are given for parameters in which the ecoregion effect was significant (ANOVA; $p<0.05$).*

Water Quality

Statistical ranges of water quality parameters sampled at 98 candidate reference sites in Iowa are summarized in Table 4-2. As might be expected from a cross-section sampling of Iowa's streams, the ranges of water quality characteristics vary substantially between and within ecoregions. The ranges of water quality variables are displayed in Figures 4-2. Analysis of Variance (AOV) was used to examine for ecoregion effects among water quality variables. The effect of ecoregion was significant ($p<0.05$) for all water quality parameters except stream temperature, which is strongly affected by sample date and time.

A few regional patterns are noteworthy. Dissolved oxygen levels ranked highest among candidate reference sites located in the Paleozoic Plateau ecoregion (52) of northeastern Iowa. Most of these streams are spring-fed to some degree. Streams of the Paleozoic Plateau also tended to rank low in levels of phosphorus, suspended solids, and turbidity. Candidate reference sites in the Loess Flats and Till Plains (40a) of south central Iowa ranked lowest in pH, dissolved solids, hardness, and nitrite+nitrate-nitrogen, while atrazine levels tended to rank higher than streams in other ecoregions. Candidate reference sites located in the Northwest Iowa Loess Prairies (47a) ecoregion ranked highest in dissolved solids, nitrite+nitrate-nitrogen, specific conductance, and total hardness levels.

Table 4-2. Statistical ranges of water quality parameters sampled at 98 candidate reference sites: 1994-1998.

Water Quality Parameter	Minimum	25th Percentile	50th Percentile (Median)	75th Percentile	Maximum
Temperature (C)	8	14.6	18.6	21	26.8
Diss. Oxygen (mg/L)	4.7	7.7	8.4	9.5	12.6
pH (std.units)	6.5	7.4	7.7	8	8.6
Total Hardness (mg/L)	160	260	310	380	470
Conductivity (umhos/cm)	340	518	625	733	1200
Dissolved Solids (mg/L)	210	280	340	400	610
Suspended Solids (mg/L)	1	11	24	41	210
Turbidity (ntu)	1	8	16	26	80
NO2+NO3-N (mg/L)	<0.1	1.4	4.4	7.3	13
Total Phosphorus (mg/L)	<0.1	<0.1	0.1	0.2	0.7
Atrazine (ug/L)	<0.10	<0.10	0.14	0.21	1.8

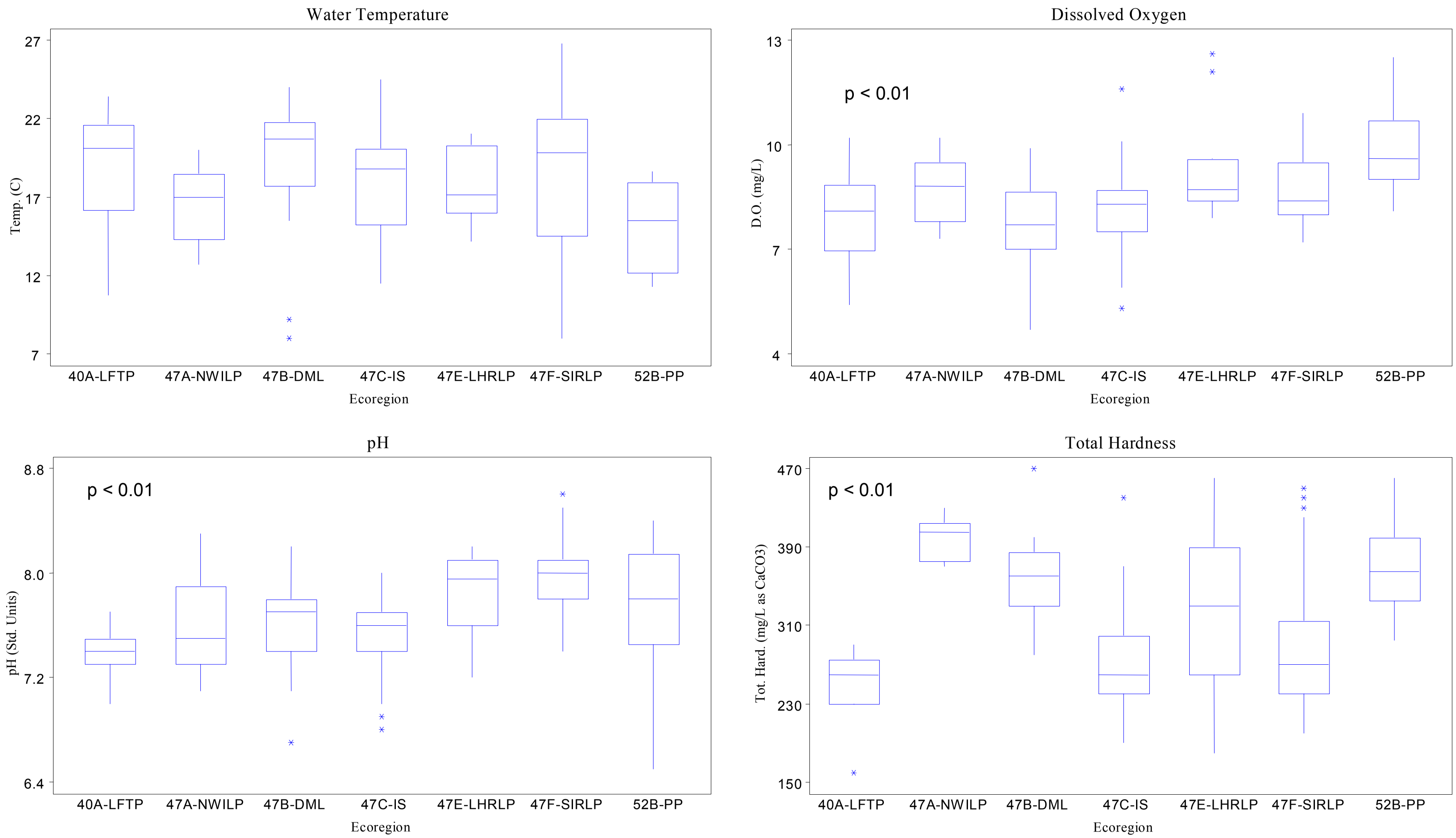

Figure 4-2. Stream water quality parameters sampled at 98 candidate reference sites grouped by ecoregion (Figure 3-2*). P-values are given for parameters in which the ecoregion effect was significant (ANOVA; p<0.05).*

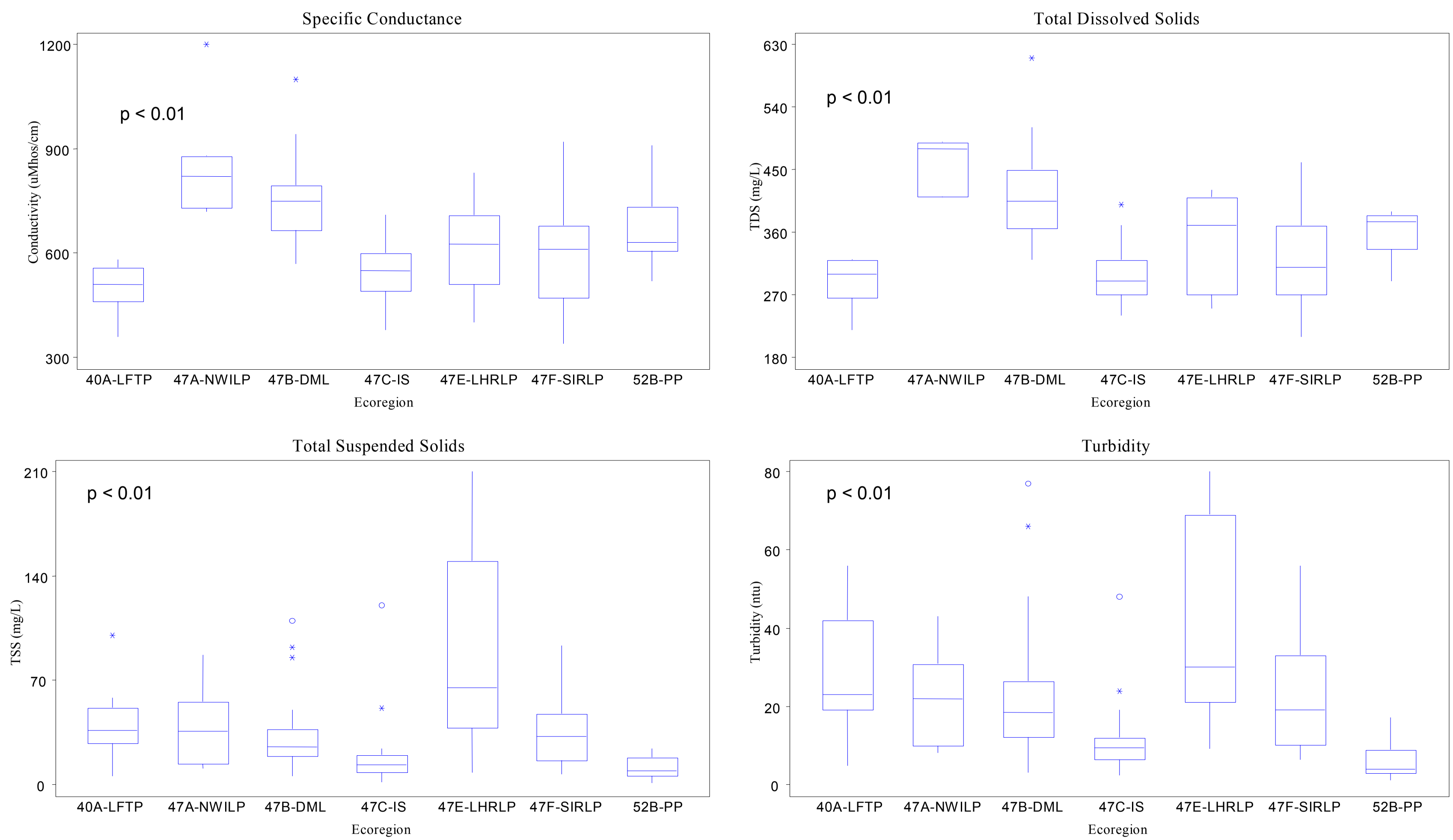

Figure 4-2 (continued). Stream water quality parameters sampled at 98 candidate reference sites grouped by ecoregion (Figure 3-2). *P-values are given for parameters in which the ecoregion effect was significant (ANOVA; p<0.05).*

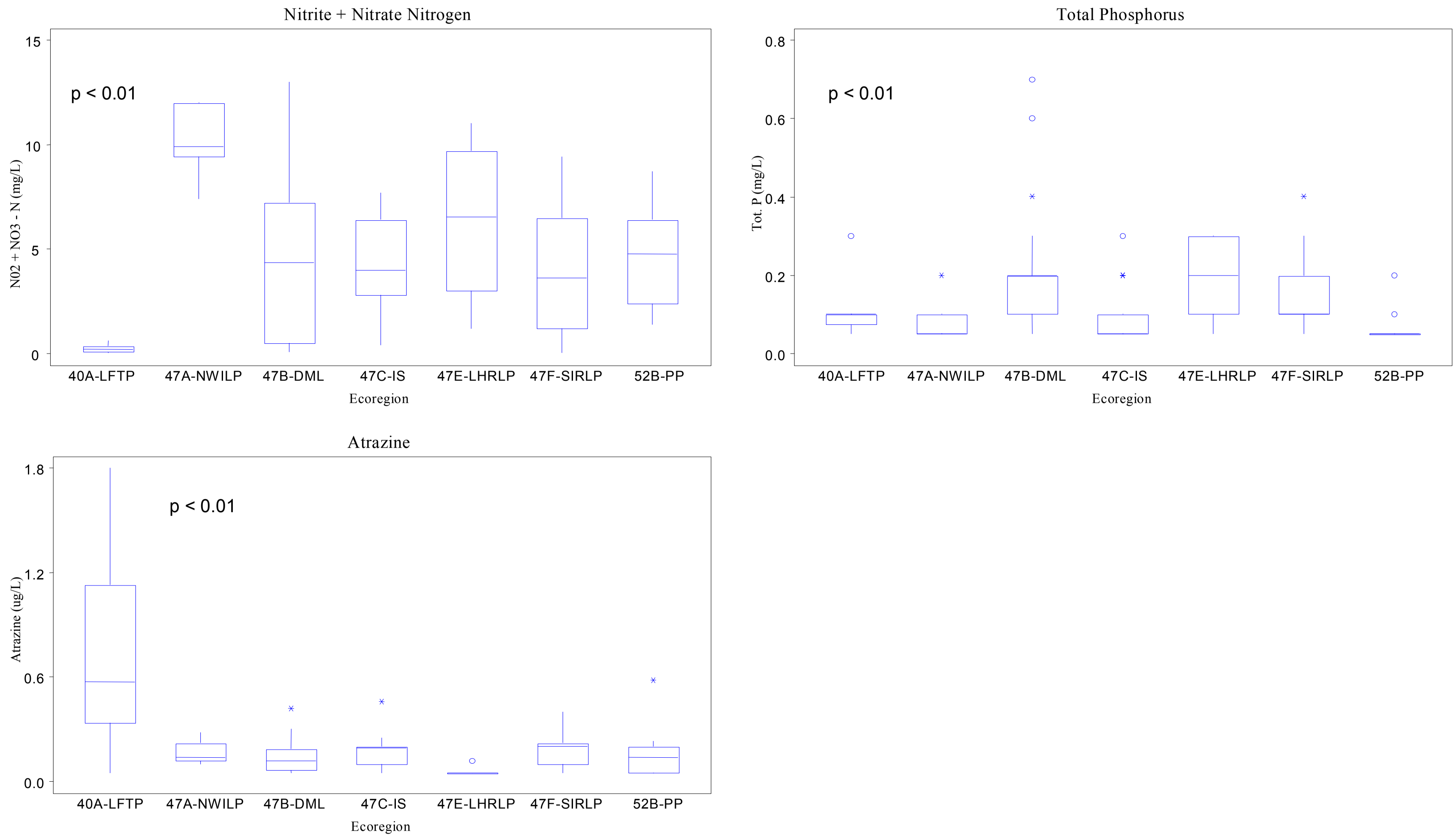

Figure 4-2 (continued). Stream water quality parameters sampled at 98 candidate reference sites grouped by ecoregion (Figure 3-2). *P-values are given for parameters in which the ecoregion effect was significant (ANOVA; $p<0.05$).*

4.2 Stream Biota and Environmental Relationships

Fish Assemblage

Despite significant historical losses, Iowa's streams still support a substantial number of fish species. One hundred thirty nine (139) native species of fish and at least nine introduced species are thought to reside in Iowa's waters (Menzel 1981; Harlan and Speaker 1987). Through 2002, the stream bioassessment project has sampled a total of 102 fish species. Iowa's wadeable rivers and streams are dominated by minnows (Cyprinidae), which represented 32% of the species and 70% of all fish collected between 1994-1998 (Figure 4-3). Nine species were present in 71% - 95% samples and comprised 62.5% of the total number of fish sampled (Table 4-3).

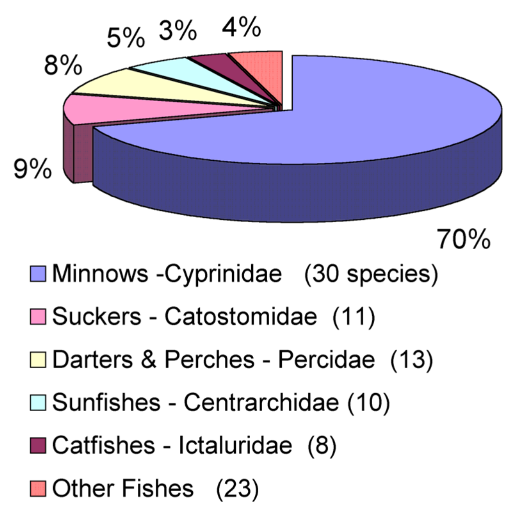

Figure 4-3. Proportional abundance within groups of fish sampled from wadeable rivers and streams: 1994-1998. *Numbers of species within each group are listed in parentheses.*

In 2001, a single Topeka shiner (*Notropis topeka*) was collected from Buttrick Creek in Greene County; otherwise, no other federally endangered species have been collected. A number of fish species listed as threatened (T) or endangered (E) within Iowa have been documented, including: American brook lamprey (*Lampetra appendix*) (T), black redhorse (*Moxostoma duquesnei*) (T), burbot (*Lota lota*) (T), freckled madtom (*Noturus nocturnus*) (E), grass pickerel (*Esox americanus*) (T), orangethroat darter (*Etheostoma spectabile*) (T), Topeka shiner (*Notropis topeka*) (T). Exotic fish species collected in the project sampling include: brown trout (*Salmo trutta*), common carp (*Cyprinus carpio*), goldfish (*Carassius auratus),* grass carp (*Ctenopharyngodon idella*), and rainbow trout (*Oncorhynchus mykiss*),

Table 4-3. Nine most-commonly sampled fishes from Iowa's wadeable rivers and streams: 1994-1998.

Common Name	*Scientific Name*	% Samples Containing	% Total Fish Catch
Creek Chub	*Semotilus atromaculatus*	95%	9.9%
Sand Shiner	*Notropis stramineus*	84%	9.7%
White Sucker	*Catostomus commersoni*	83%	5.4%
Bigmouth Shiner	*Notropis dorsalis*	82%	5.7%
Bluntnose Minnow	*Pimephales notatus*	76%	11.3%
Green Sunfish	*Lepomis cyanellus*	75%	2.4%
Johnny Darter	*Etheostoma nigrum*	74%	3.0%
Central Stoneroller	*Campostoma anomalum*	71%	8.3%
Common Shiner	*Luxilus cornutus*	71%	6.8%
			62.5%

The number of fish species residing in Iowa's wadeable rivers and streams varies across major drainage basins. During 1994-1998, 90 fish species were sampled from tributary streams of the Mississippi River compared to just 44 species collected from tributaries of the Missouri River. Stream fish species richness also varies by ecoregion. The largest number of species (62) was found in the Rolling Loess Prairies (47f), a large and heterogeneous ecoregion that straddles several large rivers. The smallest number of species (25) was found in the Steeply Rolling Loess Prairies (47e). Streams in this ecoregion are greatly altered by channelization and carry high sediment loads. Severe downcutting and channel instability has led to installation of numerous grade stabilization structures, which further alter stream habitats and act as barriers to fish movements.

Fish species ranges of distribution can expand or contract in response to anthropogenic disturbances and natural factors. The historical ranges of Iowa's native fish have been documented in periodic statewide fisheries surveys dating back to the late 19th century. The last major statewide fish survey was completed in the 1980s. One of the benefits of the stream biological criteria development project is that it is providing new information to document the current distribution of Iowa's stream fishes. This data along with other current and historic fish survey records from Iowa are being entered in the Integrated River Information System (IRIS) a database under development by the Iowa Cooperative Fish and Wildlife Research Unit, Iowa State University GIS Facility and IDNR (ICFWRU 2003). Among many other useful features and functions, the web-based database will allow all documented fish survey records to be accessed simultaneously, which will make it much easier to analyze trends in fish distribution.

Regional Patterns

In order to use fish as indicators of stream biological integrity, it is important to understand how the structure of fish assemblages varies in response to environmental gradients. With this goal in mind, a multivariate statistical analysis was conducted using the 1994-1998 candidate reference site data. The analysis was performed using CANOCO 4© (terBraak and Smilauer 1998), a statistical analysis program that features canonical ordination and regression methods for investigating relationships between species assemblages and the environment.

Two primary data analysis methods were used to analyze the data set: 1) Detrended Correspondence Analysis (DCA) and 2) Canonical Correspondence Analysis (CCA). A brief description of each method precedes the discussion of analysis results.

1) Detrended Correspondence Analysis (DCA)

DCA is a multivariate analysis technique that uses iterative steps of reciprocal averaging to arrange sample entities (e.g., fish species) in multi-dimensional space. Entities that are the most similar are placed near each other and dissimilar entities are placed far apart (Gauch 1982). Using fish assemblage data as an example, DCA constructs unimodal distribution curves that represent the abundance and distribution of each species within a set of sample sites. Along each ordination axis, a species distribution curve will appear, rise to its peak, and disappear over a span of approximately 4 standard deviation (S.D.) units.

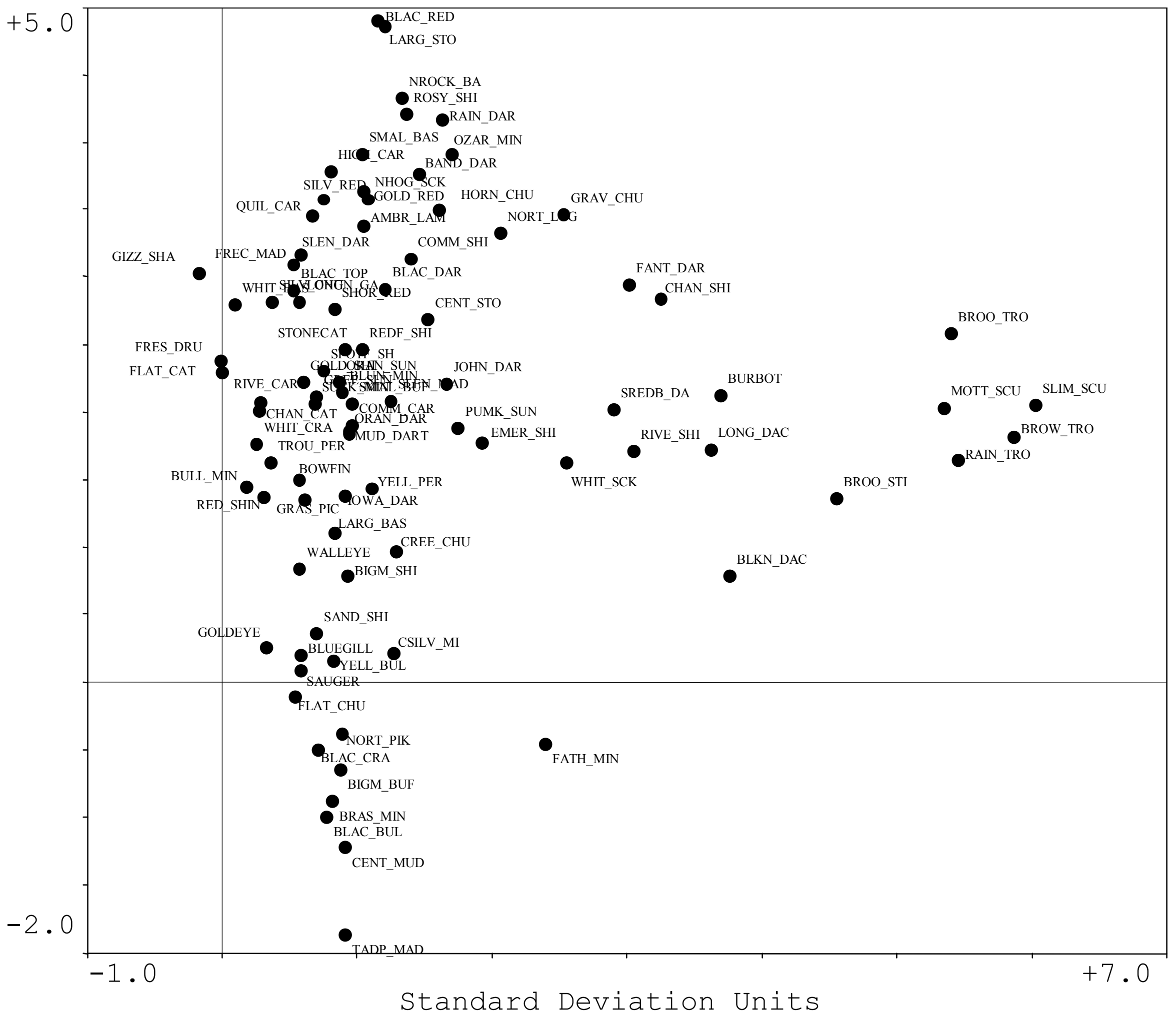

Figure 4-4. Detrended Correspondence Analysis (DCA) of 1994-1998 fish species abundance data from candidate reference stream sites.

(x,y coordinates of plot symbols represent the fish species distribution centroid values for the 1st (x) and 2nd (y) ordination axes. Species that are placed close together are more likely to co-occur at sample sites than species that are placed far apart.)

Figure 4-4 shows a DCA ordination of fish species sampled from 1994-1998 candidate reference stream sites. Table 4-4 lists the fish species and abbreviations appearing in Figure 4-4. The dot

Table 4-4. Fish species abbreviations used in DCA and CCA ordination.

Abbreviation	Common Name	*Scientific Name*	Abbreviation.	Common Name	*Scientific Name*
AMBR_LAMP	Am. brook lamprey	*Lampetra appendix*	LARG_STON	largescale stoneroller	*Campostoma oligolepsis*
BAND_DART	banded darter	*Etheostoma zonale*	LONG_DACE	longnose dace	*Rhinichthys cataractae*
BIGM_BUFF	bigmouth buffalo	*Ictiobus cyprinellus*	LONGN_GAR	longnose gar	*Lepisosteus osseus*
BIGM_SHIN	bigmouth shiner	*Notropis dorsalis*	MOTT_SCUL	mottled sculpin	*Cottus bairdi*
BLAC_BULL	black bullhead	*Ameiurus melas*	MUD_DARTR	mud darter	*Etheostoma asprigene*
BLAC_CRAP	black crappie	*Poxomis nigromaculatus*	NHOG_SCKR	northern hog sucker	*Hypentelium nigricans*
BLAC_DART	blackside darter	*Percina maculata*	NORT_LOGP	northern logperch	*Percina caprodes*
BLAC_REDH	black redhorse	*Moxostoma duquesnei*	NORT_PIKE	northern pike	*Esox lucius*
BLAC_TOPM	blackstripe topminnow	*Fundulus notatus*	NROCK_BAS	northern rock bass	*Ambloplites rupestris*
BLKN_DACE	blacknose dace	*Rhinichthys atratulus*	ORAN_DART	orangethroat darter	*Etheostoma spectabile*
BLUEGILL	bluegill	*Lepomis macrochirus*	ORAN_SUNF	orangespotted sunfish	*Lepomis humilus*
BLUN_MINN	bluntnose minnow	*Pimephales notatus*	OZAR_MINN	ozark minnow	*Notropis nubilus*
BOWFIN	bowfin	*Amia calva*	PUMK_SUNF	pumkinseed	*Lepomis gibbosus*
BRAS_MINN	brassy minnow	*Hybognathus hankinsoni*	QUIL_CARP	quillback carpsucker	*Carpiodes cyprinus*
BROO_SILV	brook silverside	*Labidesthes sicculus*	RAIN_DART	rainbow darter	*Etheostoma caeruleum*
BROO_STIC	brook stickleback	*Culaea inconstans*	RAIN_TROU	rainbow trout	*Oncorhynchus mykiss*
BROO_TROU	brook trout	*Salvelinus fontinalis*	RED_SHINE	red shiner	*Cyprinella lutrensis*
BROW_TROU	brown trout	*Salmo trutta*	REDF_SHIN	redfin shiner	*Lythrurus umbratilis*
BULL_MINN	bullhead minnow	*Pimephales vigilax*	RIVE_CARP	river carpsucker	*Carpiodes carpio*
BURBOT	burbot	*Lota lota*	RIVE_SHIN	river shiner	*Notropis blennius*
CENT_MUDM	central mudminnow	*Umbra limi*	ROSY_SHIN	rosyface shiner	*Notropis rubellus*
CENT_STON	cental stoneroller	*Campostoma anomalum*	SAND_SHIN	sand shiner	*Notropis stramineus*
CHAN_CATF	channel catfish	*Ictalurus punctatus*	SAUGER	sauger	*Stizostedion canadense*
COMM_CARP	common carp	*Cyprinus carpio*	SHOR_REDH	shorthead redhorse	*Moxostoma macrolepidotum*
COMM_SHIN	common shiner	*Luxilus cornutus*	SHORT_GAR	shortnose gar	*Lepisosteus platostomus*
CREE_CHUB	creek chub	*Semotilus atromaculatus*	SILV_CHUB	silver chub	*Macrhybopsis storeriana*
EMER_SHIN	emerald shiner	*Notropis atherinoides*	SILV_REDH	silver redhorse	*Moxostoma anisurum*
FANT_DART	fantail darter	*Etheostoma flabellare*	SLEN_DART	slenderhead darter	*Percina phoxocephala*
FATH_MINN	fathead minnow	*Pimephales promelas*	SLEN_MADT	slender madtom	*Noturus exilis*
FLAT_CATF	flathead catfish	*Pylodictus olivaris*	SLIM_SCUL	slimy sculpin	*Cottus cognatus*
FLAT_CHUB	flathead chub	*Platygobio gracilis*	SMAL_BASS	smallmouth bass	*Micropterus dolomieu*
FREC_MADT	freckled madtom	*Noturus nocturnus*	SMAL_BUFF	smallmouth buffalo	*Ictiobus bubalus*
FRES_DRUM	freshwater drum	*Aplodinotus grunniens*	SPOTF_SHI	spotfin shiner	*Cyprinella spilopterus*
GIZZ_SHAD	gizzard shad	*Dorosoma cepedianum*	SREDB_DAC	s. redbelly dace	*Phoxinus erythrogaster*
GOLD_REDH	golden redhorse	*Moxostoma erythrurum*	STONECAT	stonecat	*Noturus flavus*
GOLD_SHIN	golden shiner	*Notemigonus crysoleucas*	SUCK_MINN	suckermouth minnow	*Phenacobius mirabilis*
GOLDEYE	goldeye	*Hiodon alosoides*	TADP_MADT	tadpole madtom	*Noturus gyrinus*
GRAS_PICK	grass pickerel	*Esox americanus*	TROU_PERC	trout-perch	*Percopsis omiscomaycus*
GRAV_CHUB	gravel chub	*Erimystax x-punctata*	WALLEYE	walleye	*Stizostedion vitreum*
GREE_SUNF	green sunfish	*Lepomis cyanellus*	WHIT_BASS	white bass	*Morone chrysops*
HIGH_CARP	highfin carpsucker	*Carpiodes velifer*	WHIT_CRAP	white crappie	*Poxomis annularis*
HORN_CHUB	hornyhead chub	*Nocomis biguttatus*	WHIT_SCKR	white sucker	*Catostomus commersoni*
IOWA_DART	iowa darter	*Etheostoma exile*	YELL_BULL	yellow bullhead	*Ameiurus natalis*
JOHN_DART	johnny darter	*Etheostoma nigrum*	YELL_PERC	yellow perch	*Perca flavescens*
LARG_BASS	largemouth bass	*Micropterus salmoides*			

associated with a fish species represents its centroid value of distribution and coordinates along the first (x) and second (y) DCA ordination axes. Distance along the axes is expressed in terms of standard deviation units. Generally, species that are positioned close together tend to overlap in their occurrence among sampling sites. Species that are placed farther apart are less likely to co-occur. In Figure 4-4, some species positioned at the edges of the plot are separated by a distance of 4 S.D. or more, thus indicating very little overlap in their occurrence among sampling sites. Most species are within 4 S.D. units of each other, thereby indicating significant distributional overlap.

An understanding of fish habitat preferences is helpful for interpretation of Figure 4-4. Generally, the first (x) ordination axis is stretched to the right by species that occur in Iowa's small, high-gradient, cold-water streams (e.g., [SLIM_SCU] *Cottus cognatus*; [BROW_TRO] *Salmo trutta*). In contrast, species positioned to the far left tend to occur in larger, low gradient, turbid rivers and streams (e.g., [FLA_CATF] *Pylodictus olivaris*). The second (y) axis is stretched at the top by fish species that are primarily found in northcentral and northeastern Iowa in relatively clear, cool streams that have some amount of rock substrate and pool-riffle sequences (e.g., [NROCK_BA] *Ambloplites rupestris*). Fish species positioned toward the bottom of the plot are more likely to occur in turbid, low gradient, soft-bottom streams (e.g., [CENT_MUD] *Umbra limi*). The ordination of fish species data hints at some of the important environmental variables, such as stream gradient and size that influence aquatic community structure. Many of these relationships are examined in more detail later in the chapter.

Ecoregions

Detrended Correspondence Analysis (DCA) was also used to examine the degree of correspondence between fish assemblages and ecoregions. For the analysis, each of the 1994-1998 candidate reference sites was assigned a level IV ecoregion designation and all of the fish species abundance data was included. Figure 4-19 shows the boundaries of level IV ecoregions as well as landform regions and drainage basin units referred to in the report.

The results of the analysis are shown in Figure 4-5. Each symbol corresponds to a sample site, and the type of symbol indicates the ecoregion in which that site is located. More specifically, a symbol represents the centroid value of all the individual species distribution curves for that site. Sites that are close together have similar species composition and abundance. Sites that are far apart share relatively little similarity in fish composition. Along the ordination axes, a complete turnover in species composition occurs at a distance of 4 S.D. whereas a 50% turnover in species composition occurs in the range of 1.0 – 1.39 S.D. units (Gauch 1982).

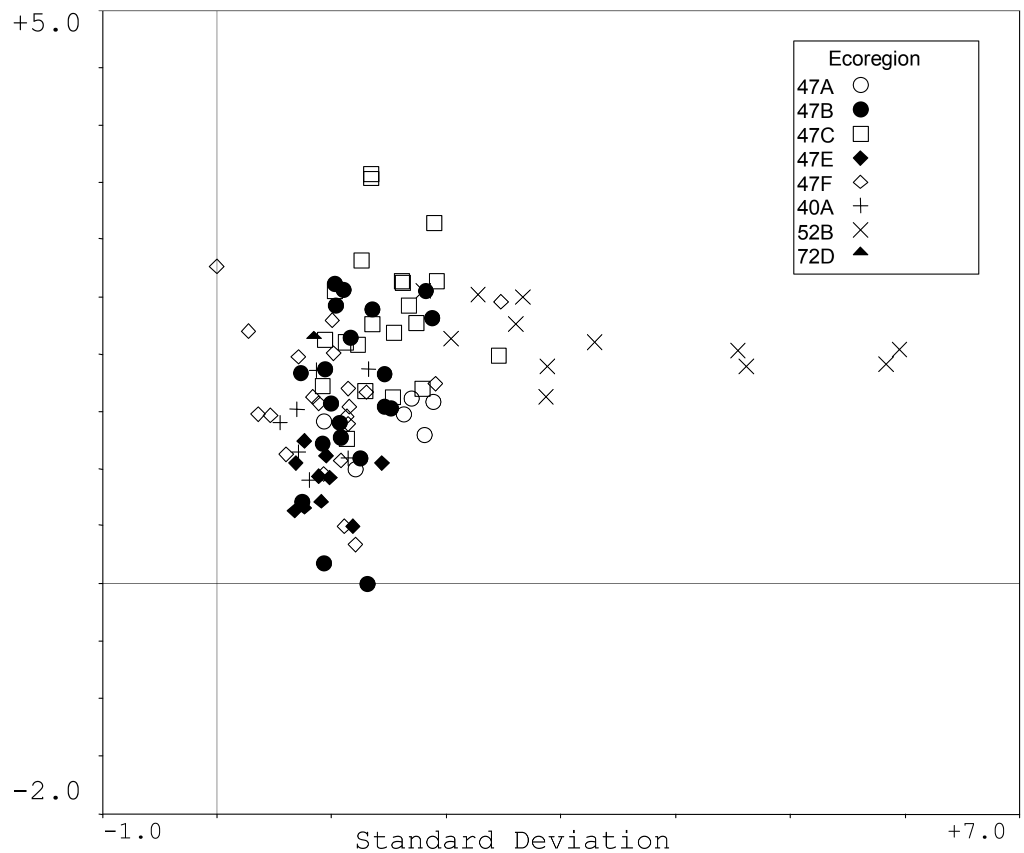

Figure 4-5. DCA of fish assemblage 1994-1998 sampling data from stream candidate reference sites classified by Level IV ecoregion.

(x,y coordinates of plot symbols represent the sample site fish assemblage centroid values for 1st (x) and 2nd (y) ordination axes. Sites that are placed close together have more similarity in fish species composition than sites that are placed far apart).

The most noticeable feature of Figure 4-5 is the way the 1st ordination (x) axis is stretched to the right by sites in the Paleozoic Plateau ecoregion (52b). These sites are coldwater streams comprised of trout and other stenothermic fish species such as sculpins (*Cottus* sp.). Because the fish assemblages of these sites are vastly different from most of Iowa's stream fish assemblages, the ordination results are strongly skewed by their presence in the data set. Therefore, to more easily examine patterns in fish species composition among the majority of candidate reference sites, the analysis was repeated after excluding sites from the Paleozoic Plateau (52b).

The DCA plot of candidate reference sites excluding the Paleozoic Plateau sites (Figure 4-6) shows a lot of interspersion and no clear groupings of sites by ecoregion. Perhaps the strongest pattern is a lack of overlap in sites representing the Iowan Surface (47c) (solid-black diamond) and sites from the Rolling Loess Prairies (47e) (open diamond) of Southwest Iowa. The Iowan Surface fish fauna include many that prefer relatively cool, clear streams having rock substrates. The Rolling Loess Prairies streams are part of the Missouri Drainage system of Iowa, which contains species that are tolerant of fine sediments and turbidity.

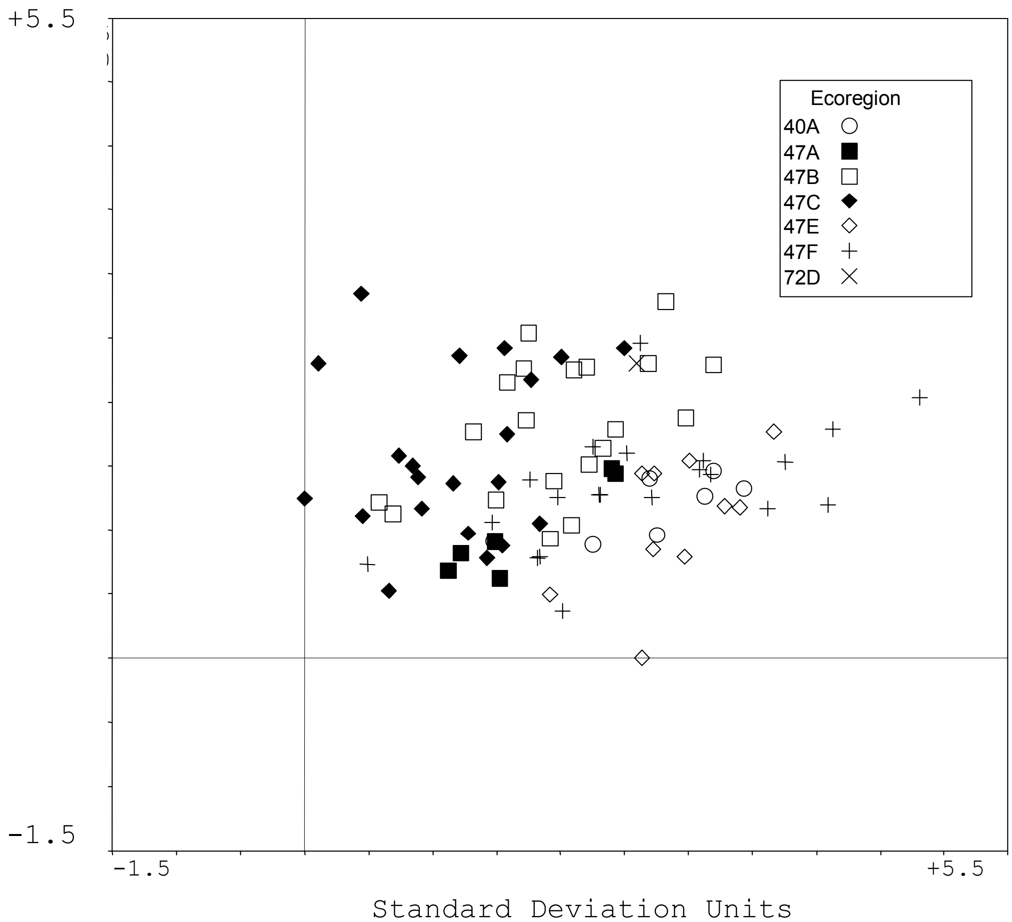

Figure 4-6. DCA of fish assemblage 1994-1998 sampling data from stream candidate reference sites classified by Level IV ecoregion (excluding Paleozoic Plateau (52b) sites).

(x,y coordinates of plot symbols represent the sample site fish assemblage centroid values for 1st (x) and 2nd (y) ordination axes. Sites that are placed close together have greater similarity in fish species composition than sites that are placed far apart).

Great River Basins

Approximately 70% of Iowa's land surface drains to the Mississippi River and 30% drains to the Missouri River before eventually flowing into the Mississippi River (Larimer 1974). As noted earlier, the combined total fish species richness of stream sites located in the Mississippi River basin was 204% of the sites in the Missouri River basin. The relative strength of correspondence between candidate reference site fish assemblages and great river basins was examined using DCA (Figure 4-7).

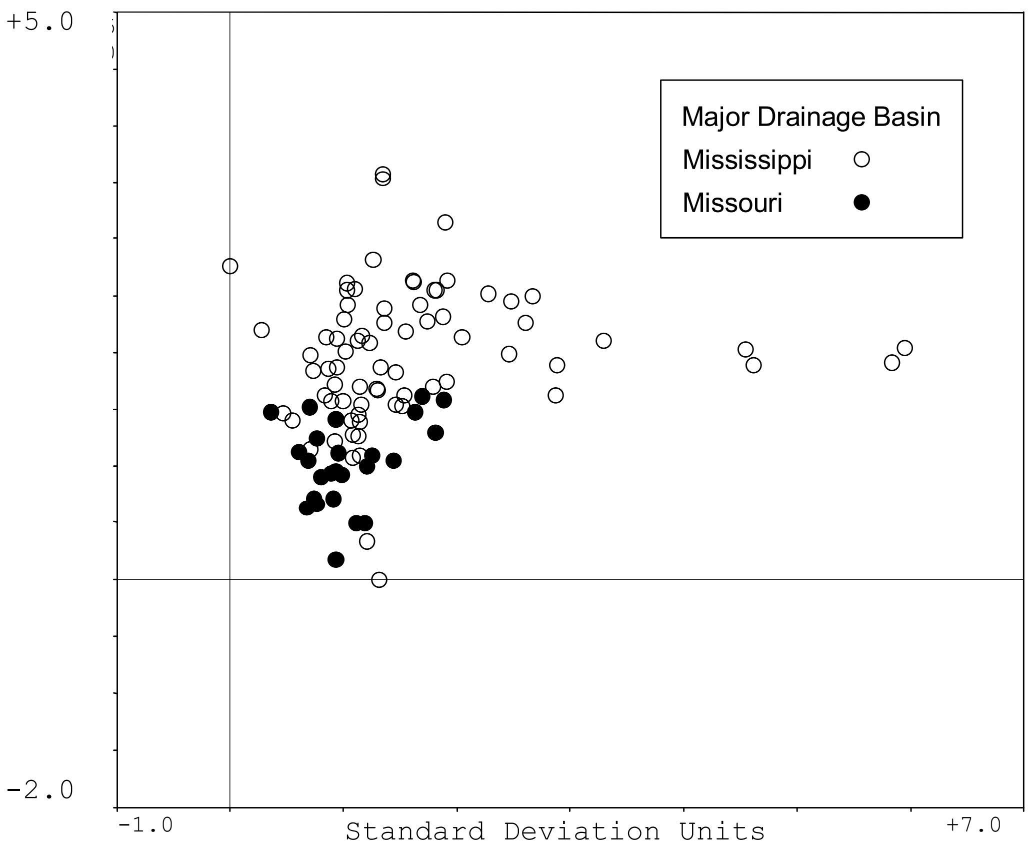

Figure 4-7. DCA of fish assemblage sampling data from 1994-1998 stream candidate reference sites classified by major drainage basin.

(x,y coordinates of plot symbols represent the sample site fish assemblage centroid values for 1st (x) and 2nd (y) ordination axes. Sites that are placed close together have greater similarity in fish species composition than sites that are placed far apart).

As shown in Figure 4-7, sample sites in the Missouri River basin are clustered fairly-tightly, but also are interspersed with some of the Mississippi River basin sites. The fish assemblages of the Mississippi River basin sites are much more variable as indicated by the greater spread of sites along both ordination axes. The influence of cold-water stream sites located in the Paleozoic Plateau (52b) ecoregion can be seen again in the spread of sites along the 1st ordination (x) axis.

The interspersion of Mississippi and Missouri basin sites was further explored by analyzing data from the Southern Iowa Drift Plain (SIDP) landform region. The SIDP spans most of southern and western Iowa, and is considered relatively homogeneous from the standpoint of geologic morphology (Prior 1991). By analyzing data exclusively from sample sites in the SIDP, differences in stream fish assemblages that might be attributable to major drainage basin can be examined more directly.

DCA was performed on the SIDP data set after classifying sites by ecoregion and major drainage basin (Figure 4-8). The ecoregion units overlapped by the SIDP are represented by different symbol shapes (circle, square, and diamond). Open symbols represent sites from the Mississippi drainage basin, while closed symbols represent Missouri drainage basin sites. Although the separation of sites among ecoregion or drainage basin classes is not strong, the DCA plot generally shows there is as much site affiliation with drainage basins as ecoregions. Mississippi drainage sites tend to group in the upper-left area of the plot, while Missouri drainage basin sites group in the lower-right area. The results of this analysis affirm that major drainage divides can contribute to differences in stream fish assemblages, and therefore, should be considered in the development of biological criteria.

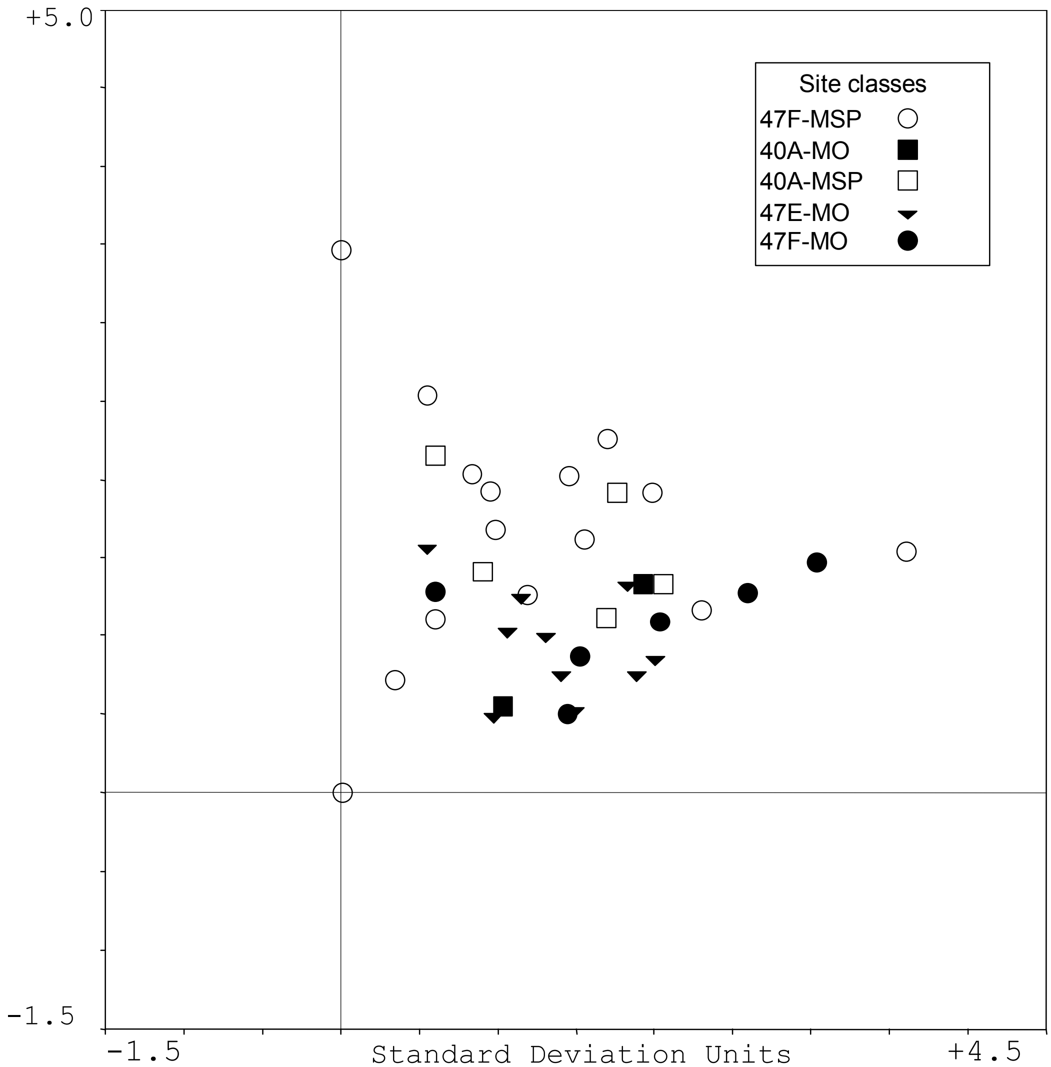

Figure 4-8. DCA of fish assemblage sampling data from 1994-1998 stream candidate reference sites classified by ecoregion and major drainage basin (MSP=Mississippi [open symbols]; MO=Missouri [filled symbols]). The analysis includes only sample sites located in the Southern Iowa Drift Plain landform region.

(x,y coordinates of plot symbols represent the sample site fish assemblage centroid values for 1st (x) and 2nd (y) ordination axes. Sites that are placed close together have greater similarity in fish species composition than sites that are placed far apart).

2) <u>Canonical Correspondence Analysis (CCA)</u>

A second multivariate statistical analysis method, Canonical Correspondence Analysis (CCA), was used to examine the strength of correspondence between fish assemblages and stream environmental variables. CCA is a type of direct gradient analysis in which the data ordination is constrained by the environmental variables included in the analysis. By constraining the analysis, the association of variables can be observed more easily. In the analysis described below, CCA was used to test the strength of correspondence between stream fish assemblages and various geographic classification schemes, specifically drainage basins, ecoregions, and landform regions.

The simplest geographic classification scheme examined using CCA was great river basins (i.e., Mississippi River, Missouri River). A second drainage basin framework was also tested. The framework consists of six drainage basin areas that are referenced in Iowa's Water Quality Standards (IAC. Chapter 567:61) and the biennial Section 305(b) report on Iowa's water quality. Each drainage basin area is an aggregate of several individual USGS HUC-8 drainage basins. The names of the six drainage basin areas are: 1) Western; 2) Southern; 3) Des Moines River; 4) Skunk River; 5) Iowa-Cedar River; 6) Northeastern.

In addition to drainage basins, the association between fish assemblages and Level III and IV ecoregions was also examined. Ecoregions are hierarchical (Figures 3-1, 3-2). Iowa is covered by parts of 4 Level III ecoregions and 10 Level IV ecoregions. Sample sites were assigned to the ecoregion in which the site was located. In a small number of cases, a portion of the sample site's watershed was located in a different ecoregion than the actual sample site.

Table 4-5 lists the statistical output from the CCA analysis. The first column in the table identifies the classification scheme. The analysis started with the simplest classification scheme and proceeded to more complex classification schemes. The second column gives the ordination eigenvalue score, which is a measure of importance or strength. Eigenvalues range from 0 and 1, the larger the value, the greater the correspondence between the fish assemblages and classification units. The eigenvalues reported in Table 4-5 are for the first ordination axis, which typically encompasses the largest proportion of the combined total variance explained by all the axes. The third column reports the p-value of the significance test, which indicates the probability that the variance explained by the first ordination axis is equal to zero. A very small p-value (e.g., <0.05) is strong evidence that the ordination axis does explain a significant amount of the variance in the fish assemblage data. The forth column lists the amount of variance in fish assemblage data that is explained by the first ordination axis.

All of the classification schemes tested were statistically significant; however, none explained a large amount of the variability in fish assemblages (Table 4-5). The lack of strong correspondence is probably attributable to several factors including the broad distribution of many Iowa stream fishes, relatively subtle gradients in landscape and stream characteristics, and the masking effect of other environmental variables such as stream size.

Table 4-5. Canonical Correspondence Analysis (CCA) results using various classification schemes as explanatory variables of fish assemblage composition.

Classification Scheme	1st Axis Eigenvalue	P-Value	Total % Species Variance Explained By First Two Canonical Axes
Mississippi / Missouri	0.19	.01	2.9
6 WQ Drainage Basin Units	0.37	.005	7.3
Level III Ecoregions	0.41	.005	7.9
Level IV Ecoregions	0.46	.005	10.9
Level IV Ecoregions (Southern Iowa Drift Plain Ecoregions Aggregated by Msp./ Mo. Basins	0.46	.005	10.9
Level IV Ecoregions & Major Drainage Basins Combined	0.52	.01	12.2

Level IV ecoregion classes explained 10.9% of the species variance (1st and 2nd canonical axes combined). The eigenvalue of the first canonical axis was 0.46. In contrast, the six major drainage basin units explained 7.3% of the variance in fish assemblage data, and the first eigenvalue was 0.37. By combining ecoregions and drainage basin units, there was a slight increase in the amount of variance explained (12.2%) and the length of the 1st axis eigenvalue (0.52).

Figure 4-9 shows in a graphical format the CCA results using drainage basin units and ecoregions as explanatory variables of fish assemblage data. The lengths of the arrows indicate the relative strengths of association, while the directions of the arrows indicate the amount of correlation between variables and the ordination axes. The longest arrows represent variables that explain the most variation in fish assemblage composition. Variables represented by arrows that are closely aligned in the same plane are more strongly correlated than variables that are far apart and oriented in different planes.

Among the drainage basins and ecoregions, the Paleozoic Plateau (PP-52b) is the strongest explanatory variable of fish assemblage composition. The next strongest explanatory variables are the Iowan Surface ecoregion (IS-47c), Northeast drainage basin unit, and the Rolling Loess Prairies ecoregion (RLP-47f), respectively. Not surprisingly, drainage basins and ecoregions that geographically-overlap have arrows that are closely aligned and pointing in the same direction (e.g., Iowa-Cedar drainage basin and Iowan Surface ecoregion [IS-47c]).

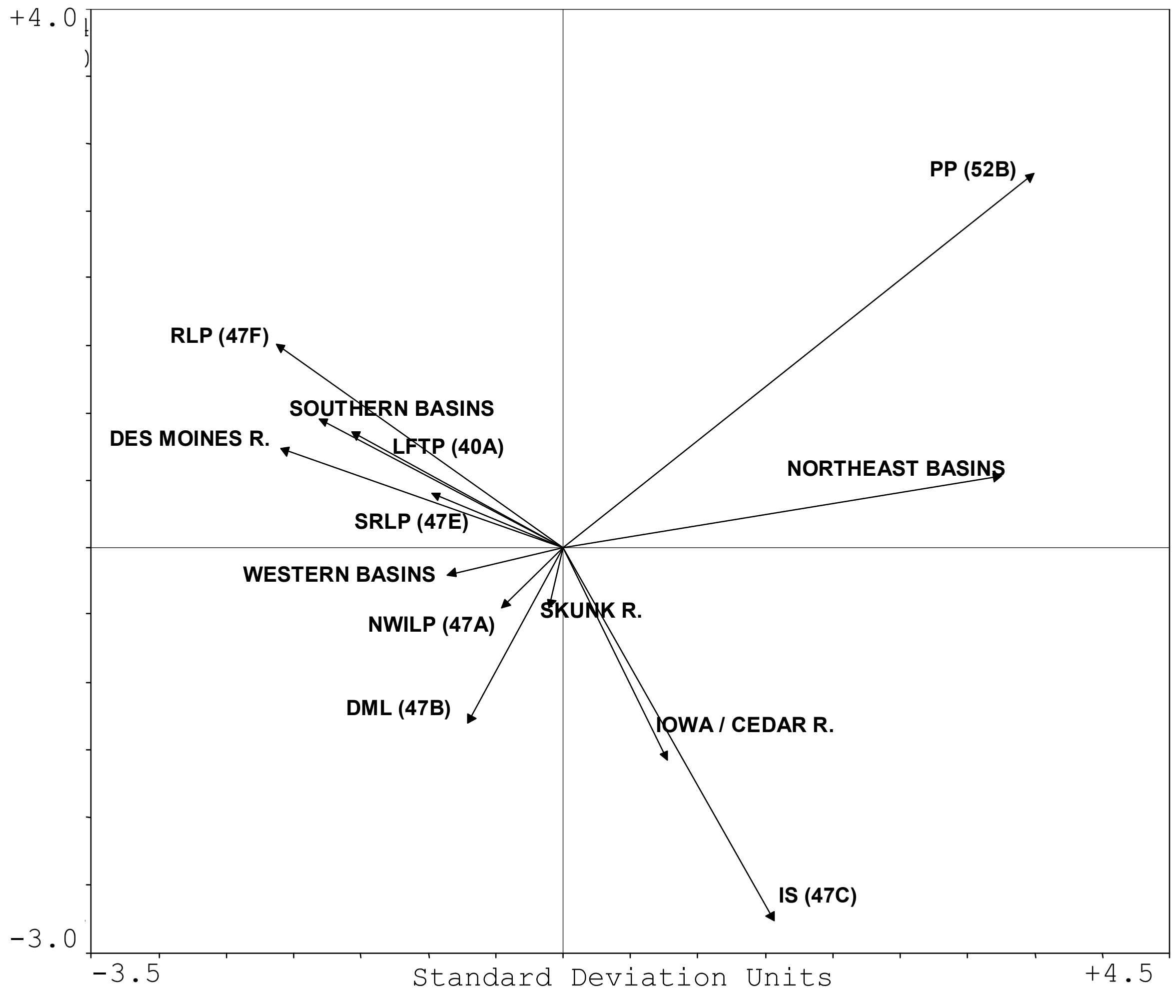

Figure 4-9. Results of Canonical Correspondence Analysis (CCA) of 1994-1998 fish assemblage sampling data showing relative strength of association with major drainage basin units and ecoregions.

The length and direction of the arrows indicate the relative strength of association with fish assemblage composition and the amount of correlation of each variable in relation to other variables and to the 1st (x) and 2nd (y) ordination axes. The longest arrows represent variables that explain the most variation in fish assemblage composition. Variables represented by arrows that are closely aligned in the same plane are more strongly correlated than variables that are far apart and oriented in different planes.

Environmental Relationships

A series of multivariate statistical analyses were performed to examine relationships between stream environmental variables and fish assemblage data obtained from 98 stream candidate reference sites sampled from 1994-1998. In the first step, Detrended Correspondence Analysis (DCA) was used to quantify the total amount variance in fish assemblage that could be explained by the unconstrained ordination of fish assemblage samples. This amount would later be compared to amounts of fish assemblage variation explained by combinations of environmental variables.

Table 4-6. Stream environmental variables included in direct gradient analysis of fish species composition in candidate reference stream sites from 1994-1998.

Stream Dimensions	Substrate / Instream Habitat	Stream Bank / Riparian	Water Quality
Surface Drainage Area	% Clay	Bank Condition Rating	Water Temperature
Stream Gradient	% Silt	% Bare Stream Bank	Dissolved Oxygen
Stream Sinuosity	% Sand	% Stream Shading	pH
Wetted Channel Width	% Soil/Bank	Shade Variability	Dissolved Solids
Maximum Water Depth	Total % Fine Sediment	Buffer Strip Condition Rating	Suspended Solids
Average Thalweg Depth	% Gravel	Herbaceous Riparian Veg.*	Nitrite+Nitrate- Nitrogen
Average Water Depth	% Cobble	Mixed Woody & Herb. Riparian Veg.*	Total Phosphorus
Channel Width : Depth	% Boulder	Woody Riparian Veg.*	Turbidity
Stream Flow	Total % Coarse Sediment		Total Hardness
	% Pool Habitat		Specific Conductance
	% Run Habitat		Atrazine
	% Riffle Habitat		
	Low Coarse Substr. Embedd.*		
	Moderate Coarse Substr. Embedd.*		
	High Course Substr. Embedd.*		
	No Riffles w/ Cobble/Boulder Substr.*		
	Amount of Woody Debris		
	% Instream Cover		

* Categorical variable: values are either 1 (occurs) or 0 (does not occur).

In the second step, Canonical Correspondence Analysis (CCA) was used to ordinate the fish assemblage data against a master list of 46 stream environmental variables belonging to five categories (Table 4-6). Thirty-nine of the variables are continuous-type variables and seven are categorical variables for which a value of 1 or 0 is assigned, depending on whether the condition occurs (1) or doesn't occur (0) within each sample.

Table 4-7 summarizes the results of direct gradient analysis (i.e., ordination of species composition constrained by combinations of environmental variables). There were two or three variables within each category that explained a significant amount of variance in fish assemblage composition. The first variable listed within each category axis (i.e., gradient, % coarse substrate, % bare lower stream bank, turbidity) was the strongest correlated with the first canonical axis. Similar correlated variables are listed in parentheses. Generally, physical habitat characteristics were more strongly correlated and explained a larger proportion of the variance in fish assemblage composition than water quality characteristics. Turbidity and nitrate-nitrogen were the water quality variables that explained the greatest amount of variance in fish assemblage data.

The direct gradient analysis model including the entire set of 46 environmental variables produced an eigenvalue of 0.530 for the first canonical axis. The fish assemblage variance explained by axes 1-4 was 20.8%, which equates to 57% of the total sample variance captured by axes 1-4 in the unconstrained (CA) ordination. Constraining the analysis to the eleven primary stream environmental variables listed in Table 4-7 resulted in a first canonical axis eigenvalue of 0.433. The total fish species variance explained by these eleven variables was 72% of the total variance explained by all 46 variables. Stated another way, less than 25% of the stream variables explained more than 70% of the total species-environment relationship.

Table 4-7. Results of CCA direct gradient analysis of fish species composition and select stream environmental variables from candidate reference stream sites: 1994-1998.

Unconstrained Correspondence Analysis (CA) 1st axis eigenvalue = 0.900 Length of 1st axis gradient = 5.1 standard deviation units Total species variance among sites that is explained by Axis 1 – Axis 4 = 36.2%				
Canonical Correspondence Analysis (CCA)	Category of Stream Environmental Variable			
	Stream Dimensions	Substrate / Instream Habitat	Stream Bank / Riparian	Water Quality
CCA Primary environmental variables (covariable)	1.Gradient 2.Drn. Area (Channel Width) 3.Wdth:Dpth	1.% Coarse Substrate (% Fines) 2.%Cobble 3.% Riffle	1.% Bare Low Bank 2. Bank Rating 3.% Shade	1.Turbidity (Susp. Solids) 2.Nitrate-N
CCA 1st axis eigenvalue (p-value) constrained by primary environmental variable	0.314 (p=0.005)	0.307 (p=0.005)	0.347 (p=0.005)	0.203 (p=0.04)
% species-variance explained by primary environmental variables (Axis 1)	4.6%	4.5%	5.1%	3.0%
Cumulative % species variance explained by all environmental variables (Axes 1– 4) in category	11.2%	11.8%	10.2%	8.4%
CCA including all 46 environmental variables	0.530 (p=0.005) 20.8% total species variance (Axes 1–4)			
CCA including 11 primary environmental variables	0.443 (p=0.005) 14.7% total species variance (Axes 1-4)			

Figures 4-10 - 4-13 display the results CCA analysis of Correspondence between fish species and stream environmental variables. Fish species abbreviations used in the graphs are listed in Table 4-4.

Figure 4-10 can serve as an example to demonstrate the important aspects of the CCA result plots. Each arrow represents an environmental variable in the analysis. The length of each arrow is a direct expression of strength in terms of the amount of species variance explained by that variable. The amount of variance explained by an environmental variable increases in direct proportion to the length of the arrow. Each point on the plot represents a fish species and the x,y coordinates of each point correspond to the weighted-average species scores as determined by the abundances of each species in each sample, with species variances maximally dispersed along the environmental gradient axes. To reduce clutter, the number of fish species displayed in each plot has been reduced to only the species with variances that are best fitted by the ordination axes. The ordination axes are expressed in standard deviation units of species turnover. Species that are separated by four or more standard deviation units apart do not overlap in their occurrence among samples.

The relationships between individual fish species and environmental variables can be evaluated by examining where each species is plotted in relation to the various arrows representing environmental variables. Each arrow represents a gradient of increasing levels in the direction the arrowhead is pointed. The environmental gradient is not limited to the length of the arrow itself. It can be extended in front of the arrowhead and in the opposite direction through the plot origin. The peak abundance of each species along the gradient represented by a particular environmental variable can be found by drawing an imaginary perpendicular line from each species dot to where it intersects the arrow's plane.

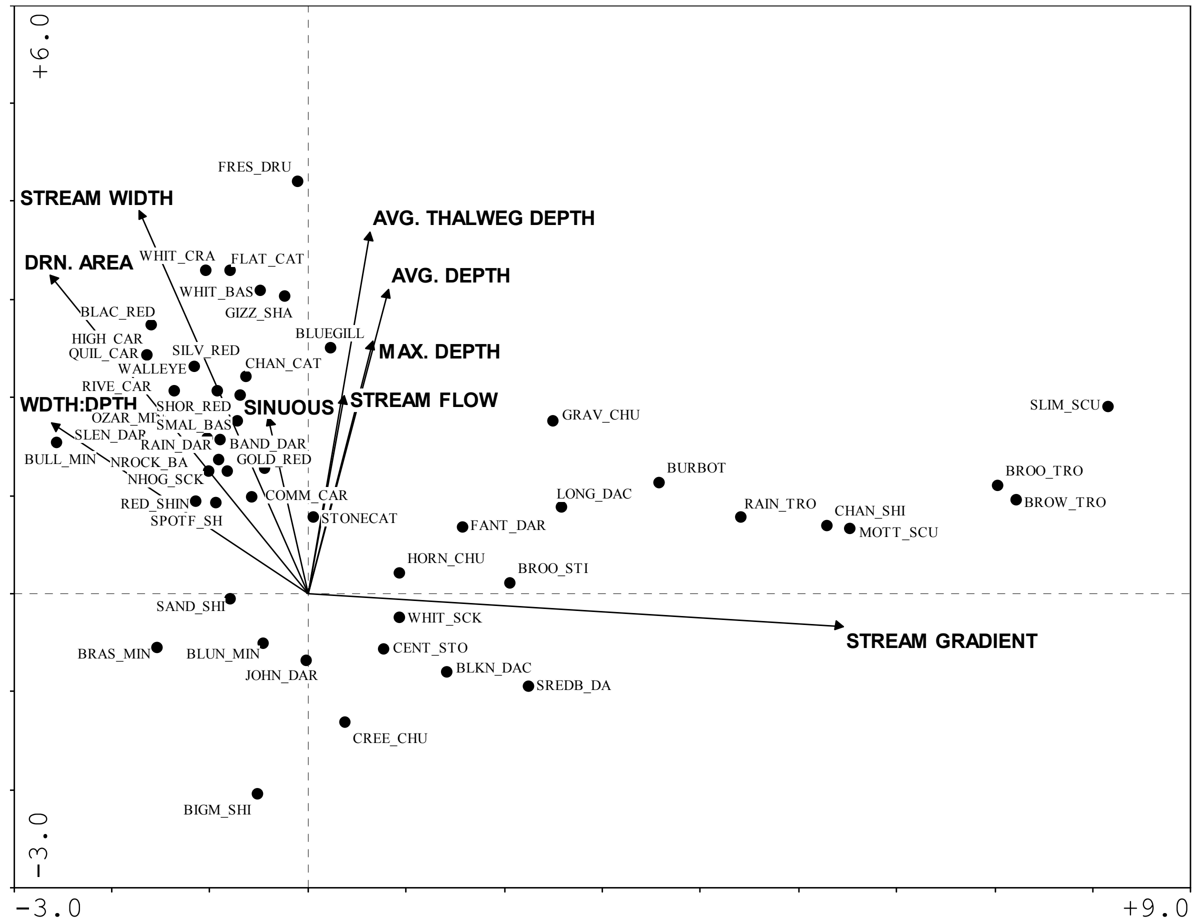

Figure 4-10. Canonical Correspondence Analysis (CCA) ordination plot of fish species abundance and stream dimension variables.

Figure 4-10 shows the strength of fish species associations with various stream dimension variables. The first (x) axis is essentially a stream gradient relationship that is stretched far to the right of the origin by fish species such as slimy sculpin, brown trout, brook trout, and mottled sculpin. These species occur in the relatively high gradient, cold-water streams of the Paleozoic Plateau (#52b) in Northeast Iowa.

The second (y) axis is a shorter gradient that is mostly correlated with watershed drainage area, stream width, and average thalweg depth. Fish species plotted toward the bottom of the plot, such as bigmouth shiner, creek chub, southern redbelly dace, and blacknose dace typically occur in small, headwater streams. Toward the top of the ordination plot, species such as freshwater drum, flathead catfish, and white bass were found mostly in medium to large wadeable rivers and streams.

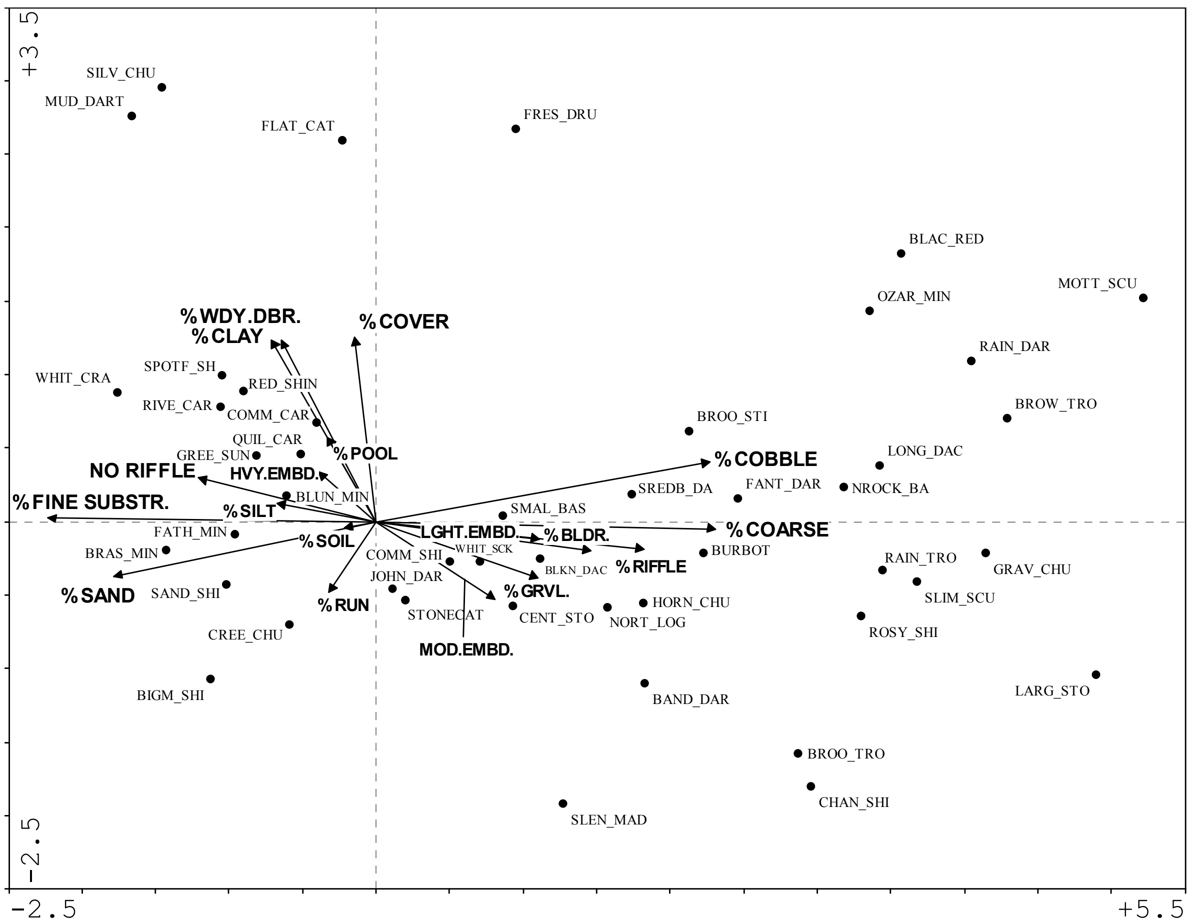

Figure 4-11. CCA of fish species abundance and instream habitat variables.

Figure 4-11 shows the CCA results of fish assemblage relationships with instream habitat variables. Percent coarse substrate, particularly the amount of cobble-size substrate, produced the strongest gradient among variables in the instream habitat category. As expected, the percentage of total fine substrate was strongly, inversely correlated with percent total coarse substrate. Fish species plotted on the left-hand side of the origin were most abundant at sample sites having high amounts of fine sediment, while species plotted to the far right had a strong affinity for sites with abundant coarse substrate. The second axis is much shorter, and therefore, explains less of the variance in fish species composition than amount of coarse substrate. Percent abundance of instream cover, % clay substrate, and % woody debris frequency of occurrence are the most strongly correlated variables with the second axis.

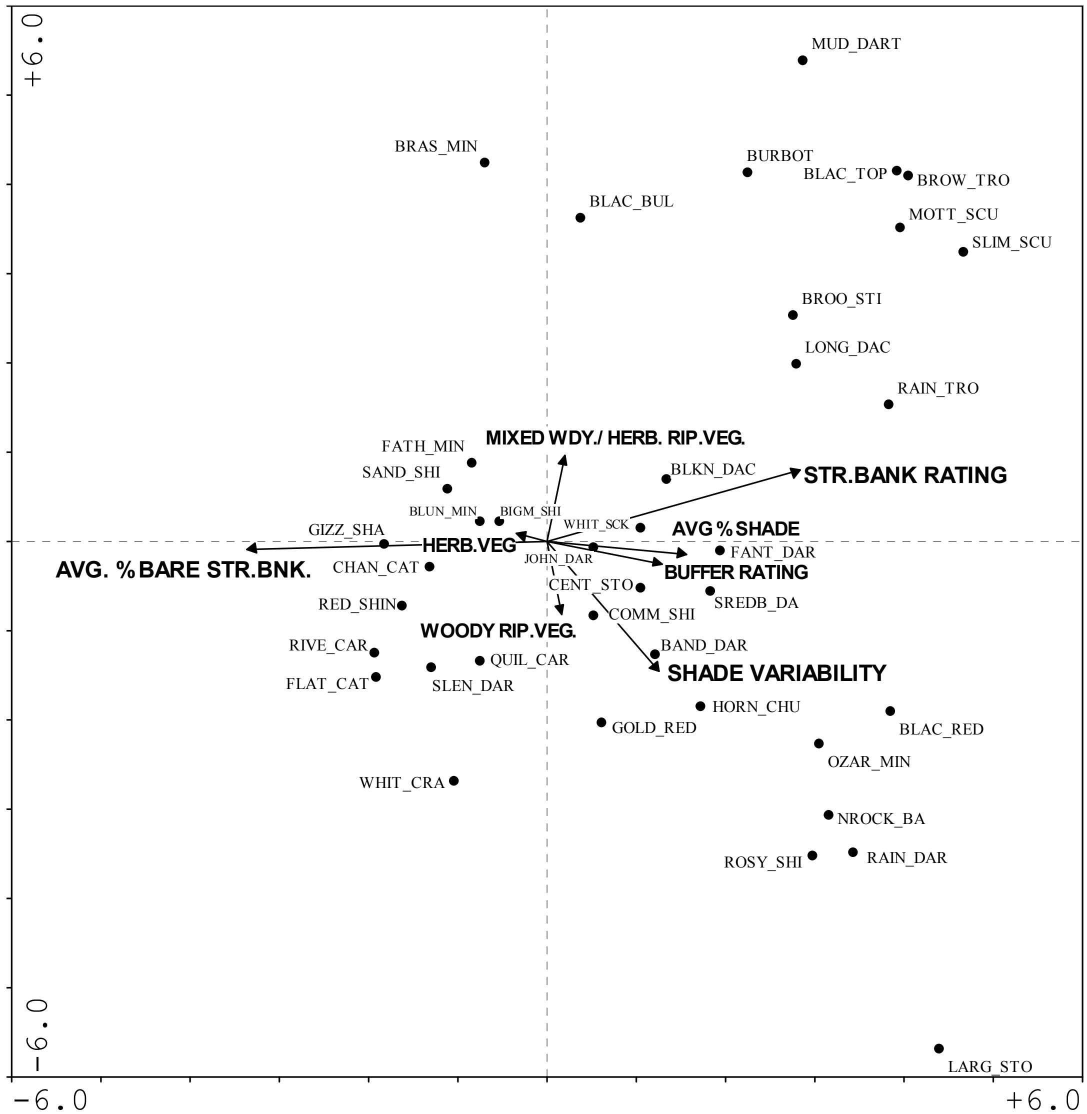

Figure 4-12. CCA of fish species abundance and stream bank / riparian environmental variables.

Figure 4-12 shows the association of fish species and stream bank and riparian environmental variables. The average percentage of bare lower stream bank was one of the longest gradients of the environmental variables included in the CCA analysis. The bank condition rating variable, which is visually rated and takes into consideration upper bank stability and vegetation cover, was inversely correlated with % bare lower stream bank. Therefore, sampling sites having high percentages of bare lower stream bank tended to also receive low ratings for overall bank condition.

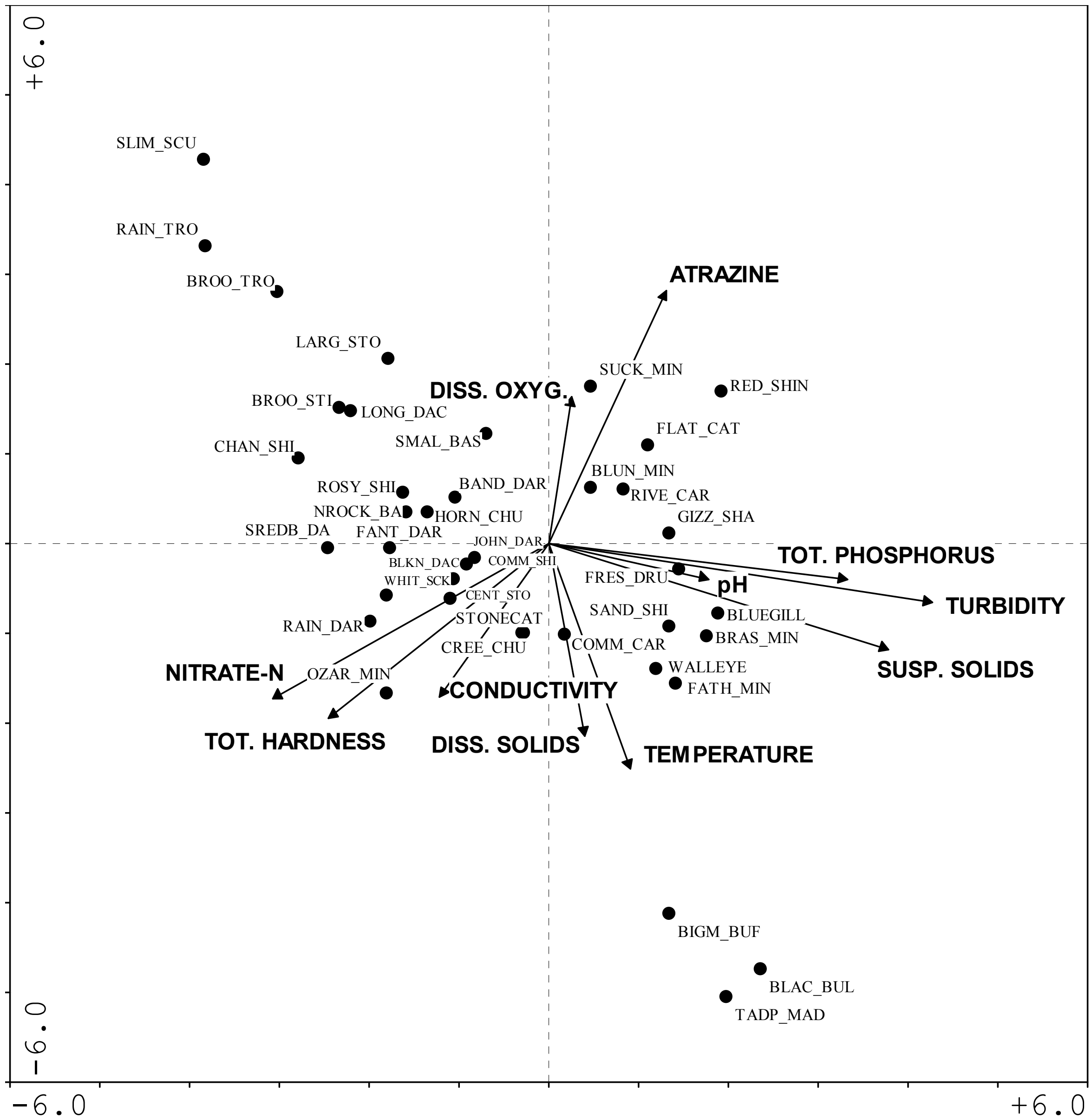

Figure 4-13. CCA of fish species abundance and water quality variables.

Figure 4-13 shows the association of fish species abundance and water quality variables. Turbidity and suspended solids were the two strongest explanatory variables correlated with the first canonical axis. Fish species with projection points displayed on the right side of the origin (e.g., red shiner, black bullhead) were most abundant at sites with above-average levels of turbidity and suspended solids, while those represented by arrowheads on the left side of the origin (e.g., rainbow darter, slimy sculpin) were most abundant at sites with below-average levels. The arrow representing total phosphorus is pointed in the same direction as the arrows representing turbidity and suspended solids. A large proportion of total phosphorus in Iowa's surface waters occurs in association with particulates, so it is not surprising that these variables would be correlated. On the first axis, nitrate-nitrogen is a weaker, but still significant explanatory variable of fish assemblage variation. The second axis is much weaker than the first, and it is correlated mostly with temperature and atrazine.

Figure 4-14. CCA ordination plot of fish assemblage composition and primary stream environmental variables from Table 4-7.

Figure 4-14 shows the associations of fish species abundance and the eleven primary environmental variables identified through CCA and correlation analysis (Table 4-7). Several interesting species-species associations and species-environmental associations are evident. For example, the cluster of fish species in the lower right quadrant of the plot is indicative of a fish assemblage found predominantly in Northeast Iowa that has a strong preference for streams with coarse substrates and riffle habitat.

As indicated by the relative lengths of arrows depicted in the plot, the three strongest explanatory variables of fish species abundance were: 1) stream gradient; 2) percent bare lower stream bank; and 3) percent total coarse substrate. Stream gradient was inversely correlated with stream size (drainage area) and width:depth ratio. Percent bare lower stream bank was correlated with turbidity and inversely correlated with stream bank condition rating. Percent coarse (rock) substrate was correlated with percent cobble-size substrate and percent riffle habitat.

Relationships within ecoregions

For seven Level IV ecoregions, CCA and RDA (Redundancy Analysis) were used to identify the stream environmental variables that appeared to be the most strongly related with stream fish assemblages. RDA is a linear form of canonical ordination analysis that is more suitable than CCA when the lengths of primary ordination axes are generally less than two standard deviation units (ter Braak 1995). The ecoregion analyses was done partly to see if there was consistency across ecoregions in important explanatory variables, and partly to evaluate whether specific habitat variables might be helpful in further classification of reference sites. Knowledge of natural environmental gradients that influence fish assemblage structure can be used to establish appropriate reference conditions and biological criteria, and also to ensure that comparisons between test sites and reference sites are valid.

Table 4-8 lists the stream environmental variables that explain the largest amount of variability in stream fish assemblages within each ecoregion. No consistent pattern was evident. Two ecoregions had bank and riparian condition as the most highly correlated variables, two other ecoregions had stream size (drainage area) as the most important variable, and the remaining three ecoregions had instream habitat, longitude, and substrate composition as primary environmental variables.

Table 4-8. Results of direct gradient analyses to determine the most strongly correlated environmental variables with fish assemblage composition within Level 4 ecoregions (Figure 3-2). *Significant covariables are listed in parentheses.*

	Level 4 Ecoregion						
	Paleozoic Plateau (52b)	Loess Flats and Till Plains (40a)	Northwest Iowa Rolling Loess Prairies (47a)	Des Moines Lobe (47b)	Iowan Surface (47c)	Steeply Rolling Loess Prairies (47e)	Rolling Loess Prairies (47f)
Number of Sample Sites	12	7	6	20	21	10	21
CA 1st axis eigenvalue and length of gradient (standard deviation units)	0.902 (4.45)	0.355 (2.18)	0.393 (1.76)	0.509 (3.71)	0.369 (2.58)	0.394 (2.17)	0.634 (3.73)
CCA/RDA Primary environmental variables (covariable)	1.Bank Condition Rating 2.Gradient 3.Suspended Solids	1Drainage Area (Stream Flow, Stream Width) 2.Gradient	1..Bank Condition Rating (Buffer Rating) 2. % Woody Debris (% Tot. Fines)	1.Longitude 2.% Silt 3. Buffer Rating	1. % Coarse (% Tot. Fines, % Avg. Bare Str. Bank) 2. Drain.Area	1. % Pool 2. Nitrate-N (Hardness) 3. % Clay	1. Drain.Area 2. % Sand 3. % Avg. Shade
CCA/RDA 1st axis eigenvalue (p-value) constrained by primary environmental variable	0.710 (CCA) (p=0.01)	0.503 (RDA) (p=0.015)	0.553 (RDA) (p=0.005)	0.402 (CCA) (p=0.005)	0.322 (CCA) (p=0.005)	0.533 (RDA) (p=0.015)	0.551 (CCA) (p=0.005)
% species-variance explained by primary environmental variables (Axis 1)	25.3%	50.3%	55.3%	16.3%	14.4%	53.4%	16.6%

Benthic Macroinvertebrate Assemblage

The wadeable stream biocriteria project has helped to fill information gaps pertaining to Iowa's benthic macroinvertebrate populations. Through 2001, approximately 435 distinct benthic macroinvertebrate taxa had been collected. The number of taxa increases each year as sampling continues. The University of Iowa Hygienic Laboratory (UHL) documents benthic macroinvertebrate collections and maintains a specimen voucher collection. UHL has worked with outside experts to document many new collection records for Iowa.

Aquatic insects are by far the most abundant and diverse group of benthic macroinvertebrates collected (Figure 4-15). In 1994-1998 standard-habitat samples, 95% of the total number of organisms and 81% of the benthic macroinvertebrate taxa (taxonomically distinct types) were aquatic insects. The number of mayfly (Ephemeroptera) taxa exceeds the number of taxa representing the other aquatic insect orders. However, Chironomidae, a diverse family of Dipterans, are not identified to genus or species in this project. This group potentially contains a very high number of taxa that have yet to be adequately documented in Iowa.

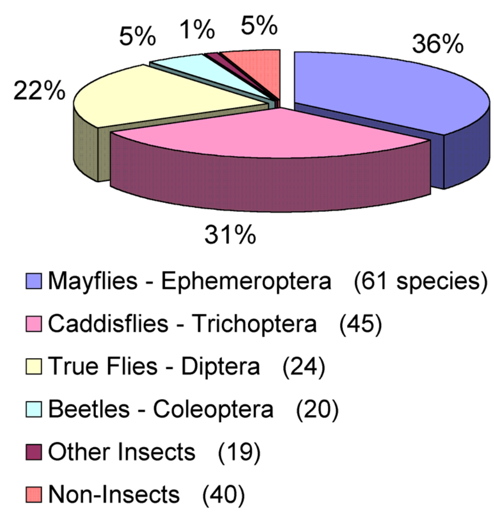

Figure 4-15. Proportional abundance of various groups of benthic macroinvertebrates in standard-habitat samples from wadeable rivers and streams: 1994-1998. (Numbers of species or taxa within each group are listed in parentheses.)

A secondary benefit from the stream biocriteria project has been increased knowledge of Iowa's biological diversity. For example, sampling results have demonstrated how levels of benthic macroinvertebrate diversity vary across Iowa's ecoregions. For example, the average number of benthic macroinvertebrate taxa per multi-habitat sample was highest (36) for stream sites located in the Iowan Surface (47c) and lowest (22) among sites in the Loess Hills and Rolling Prairies (47e).

Statewide sampling has led to documenting many species that were previously not recorded from Iowa, including species within two important orders of aquatic insects. Sampling for the biocriteria development project and other recent sampling in Iowa have resulted in first state records for 27 mayfly (Ephemeroptera) species (McCafferty et al. 2003) and 33 stonefly (Plecoptera) species (Heimdal et al. 2004). Mayflies and stoneflies are valuable indicators of stream health because of their known sensitivity to pollution.

Many freshwater mussels are included on the state and federal lists of threatened and endangered species. The sampling methods and objectives of this project were not designed to document the occurrence of mussel species in Iowa's streams. Because of the imperiled status of many species, live mussels typically were not disturbed when observed during sampling. Only a small number of mussel species have been collected since the project began, and none of these is considered threatened or endangered.

Regional Patterns

Similar to the analysis of fish assemblage data, a statistical analysis of the 1994-1998 benthic macroinvertebrate assemblage data was also performed. The analysis was part of a project that evaluated candidate biological metrics and examined relationships between environmental variables and benthic macroinvertebrate assemblage structure (Hubbard 2000). Some of the key findings from the study are discussed below.

Canonical Correspondence Analysis (CCA) was used to examine the effect of ecoregions on benthic macroinvertebrate assemblage structure. The results were consistent with CCA results for fish assemblage structure. Benthic macroinvertebrate assemblages of stream sites in the Paleozoic Plateau (52b) ecoregion were significantly different than benthic macroinvertebrate assemblages in all other ecoregions. The environmental variables that were most strongly associated with the Paleozoic Plateau sample sites were stream gradient, amount of coarse substrate, amount of riffle habitat, and stream habitat quality score. Owing to the unique geology (in Iowa) of this region, streams in the Paleozoic Plateau tend to rank among the highest in these habitat categories. Benthic macroinvertebrate assemblages of streams located in the adjacent Iowan Surface (47c) ecoregion shared the most similarity with Paleozoic Plateau assemblages; however, there was enough variability among sites that the ecoregion as a whole was not distinguishable from other ecoregions.

Environmental Variables

CCA was also used to examine the strength of relationships between 38 stream environmental variables and benthic macroinvertebrate structure. Forward selection of environmental variables was performed using the CANOCO statistical analysis software (Ter Braak et al. 1998). The results of the analysis were consistent with CCA results for fish assemblage structure. The analysis identified twelve variables that correlated the most strongly with stream benthic macroinvertebrate assemblages (Table 4-9). These twelve variables explained a significant amount of the total variance in benthic macroinvertebrate assemblages among stream sites included in the analysis.

The amount of benthic macroinvertebrate assemblage variability explained by the ordination analysis (9.3%) was slightly lower than the amount of fish assemblage variability explained by 11 environmental variables (14.7%). The results might suggest that physical habitat is a slightly better predictor of fish assemblages than benthic macroinvertebrate assemblages. However, there is also a possibility that sampling bias is partially responsible for the difference. Physical habitat data are collected and summarized at the stream reach scale. The same is true of fish assemblage data. In contrast, the benthic macroinvertebrate data included data from replicate (standard-habitat) samples only. If benthic macroinvertebrate data from multi-habitat (reach-wide) samples had also been included, perhaps a stronger association between benthic macroinvertebrate assemblages and physical habitat variables would have been found.

Table 4-9. Environmental variables correlated with benthic macroinvertebrate assemblage structure: standard habitat samples, 1994-1998.

Stream Morphology / Watershed	Instream Habitat	Streamside Vegetation	Water Chemistry
Stream Gradient	Habitat Index Score	Riparian Veg. Rating	Nitrate+Nitrite-N
Drainage Area	% Coarse Substrate	% Canopy Shading	Conductivity
	Riffle Embedd. Rating		
	% Run Habitat		
	% Riffle Habitat		
	% Gravel Substrate		

The effect of environmental variables on benthic macroinvertebrate structure was examined among sample sites within ecoregions. The results were similar to the fish assemblage analysis results, and demonstrated again that within any particular ecoregion there are one or more environmental variables that explain a significant amount of variability in biological assemblage structure. The variables that correlate strongest with assemblage structure, however, were not necessarily the same within each ecoregion. As the next section demonstrates, an understanding of how biological assemblages are influenced by local environmental attributes can be beneficial in developing reference conditions that are representative of different types of streams that occur within an ecoregion.

4.3 Stream Classification

Landscape classification schemes, such as ecoregions, are often used to capture and reduce the natural variability in reference stream characteristics across broad geographic areas, thereby improving the sensitivity of biological assessments. Beyond landscape-scale patterns in stream characteristics, there are natural gradients in stream characteristics, such as stream size and gradient, that should also be considered when developing a stream classification system.

To evaluate the strength of several alternative stream classification schemes, an analysis of reference site fish assemblage and benthic macroinvertebrate assemblage similarity was conducted. Classification strength was tested using methods described by Van Sickle (1997) and Van Sickle and Hughes (2000). Fish and benthic macroinvertebrate species abundance data from 100 reference sites were used in the analysis. The Bray-Curtis similarity index was calculated for all possible pairings of reference sites. Index values can range from 0 (no similarity) to 1 (total similarity) for any pairing of two sites. The MEANSIM6 software program (U.S.EPA / Western Ecology Division) was used to quantify classification strength (CS), which is defined as the difference of mean within-class similarity (WSim) and mean between-class similarity (BSim).

$$CS = Wsim - BSim$$

Interpretation of Classification Strength Graphs

Bar Graphs (e.g., Figure 4-16) are a convenient way to illustrate the relative strength of different classification schemes. The left end of each bar corresponds to the mean amount of similarity among sites belonging to different classification groups (i.e., between class [Bsim]). The right end of each bar corresponds to the mean amount of similarity among sites belonging to the same classification group (i.e., within class [Wsim]). The width of the bar corresponds to classification strength [CS] (i.e., difference of mean within class similarity and between class similarity), the wider the bar, the greater the classification strength. The position of the bars on the Bray-Curtis index scale (x-axis) is an indicator of the relative level of similarity. Bars that are aligned on the left side of the scale generally indicate less similarity in benthic macroinvertebrate or fish assemblage structure than bars that are placed farther to the right.

Fish Assemblage

Based on fish assemblage similarity analysis, the following ranking of classification strength (CS) was obtained: ecoregions > landform regions > hydrologic basins > Strahler stream order (Figure 4-16). Maximum CS was 0.10, which equates to an overall increase of 10% in fish assemblage similarity attributable to Level 4 ecoregion classification. Ecoregion and drainage basin boundaries are displayed in Figure 4-19.

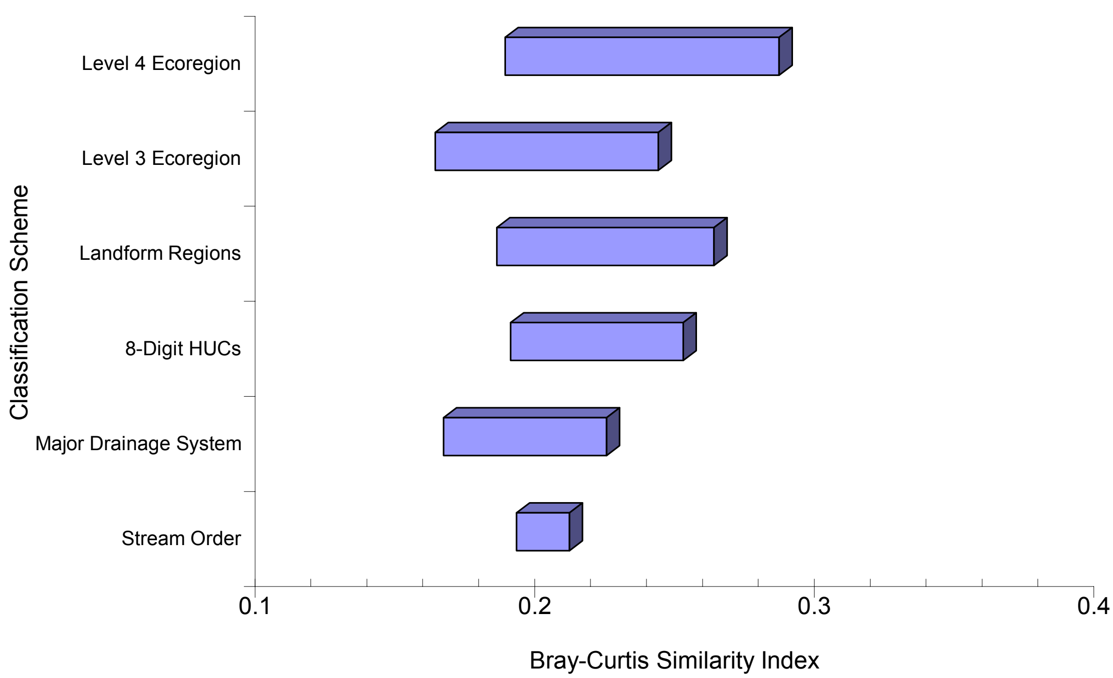

Figure 4-16. Stream classification strengths based on fish assemblage similarity.

With three ecoregions, 47(b), 47(c), and 47(f) (Figure 4-19), there were enough sample sites to examine the effects of adding layers of classification based on habitat and stream size. For habitat, sites were classified as either "riffle" or "non-riffle" sites. Riffle sites were required to possess each of the following characteristics: (a) % sample reach as riffle ≥ 10%; (b) % substrate as cobble or larger- size rock ≥ 10%; (c) total % rock substrate ≥ 30%. Sites were also assigned to one of two stream size classes: (1) headwater (2nd order); (2) medium-to-large wadeable streams (3rd, 4th and 5th order).

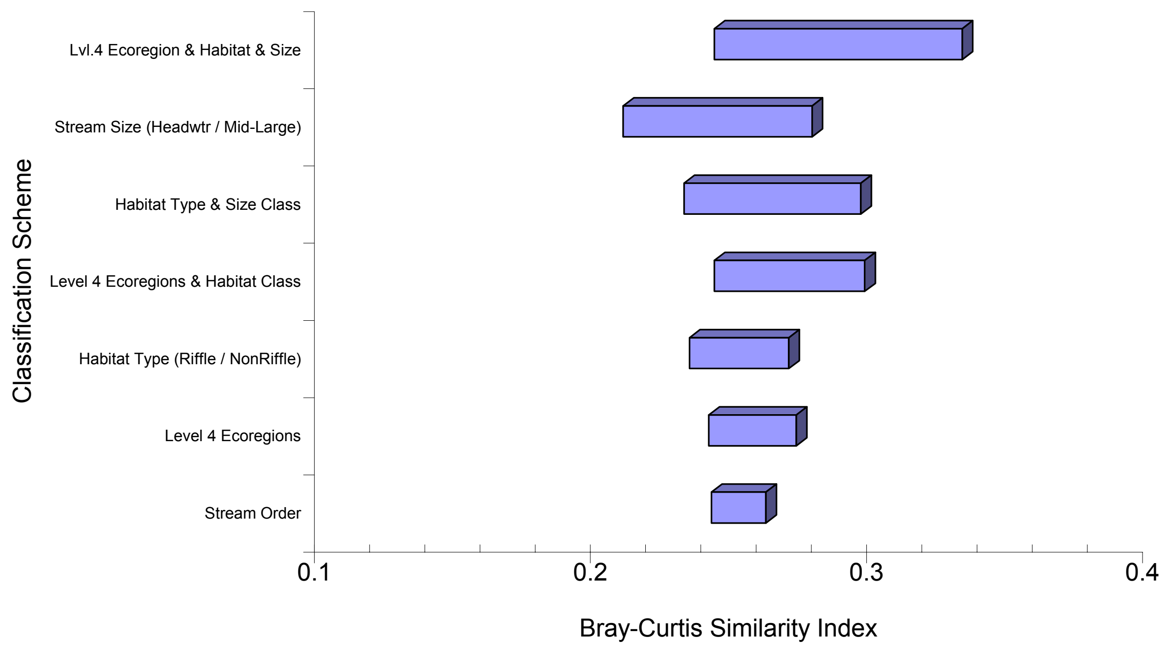

Figure 4-17. Stream classification and fish assemblage similarity: A comparison of stream reference sites in three, Level IV ecoregions (47b, 47c, 47f).

Figure 4-17 displays results from the CS analysis of sites from 47(b), 47(c) and 47(f) ecoregions. CS was highest (0.09) for a combination of classification layers including ecoregion, habitat type, and stream size. Stream size (headwater vs. mid-large streams) produced the next highest CS (0.07). All classification combinations of ecoregions, habitat, and stream size provided higher CS than ecoregions alone. These results demonstrate the importance of considering other classification strata besides ecoregions when establishing stream reference conditions.

Benthic Macroinvertebrate Assemblage

Classification strength (CS) based on the similarity of benthic macroinvertebrate assemblages was evaluated using the same methods as fish assemblage similarity. The ranking of landscape CS based on benthic macroinvertebrate assemblage similarity was nearly identical to fish assemblage similarity, except that CS was slightly weaker. For example, Level 4 ecoregions produced a CS of only 0.05 for benthic macroinvertebrate assemblages compared to 0.10 for fish assemblage CS.

Refined CS testing was done using reference site data from ecoregions 47(b), 47(c) and 47(f) (Figure 4-19). As with the fish assemblage analysis, sites were classified by habitat type and stream size. Sites were also grouped by benthic macroinvertebrate sample type: a) rock substrates (Hess or Surber samples), or b) wood-plate artificial substrate (Hester-Dendy samples). Sample type classifications essentially reflect differences in micro-scale habitat.

Figure 4-18 displays the results of the CS analysis of benthic macroinvertebrate assemblage similarity in ecoregions 47(b), 47(c) and 47(f). Interestingly, the highest CS was based on sample type (0.06), which was three times stronger than ecoregion CS (0.02). Habitat-type (i.e., riffle vs. non-riffle) CS was less than sample type (CS), but slightly greater than ecoregion CS. Overall, these findings demonstrate the need to consider stream micro- and macro-habitat characteristics, in addition to regional classification, when developing reference conditions for bioassessment purposes.

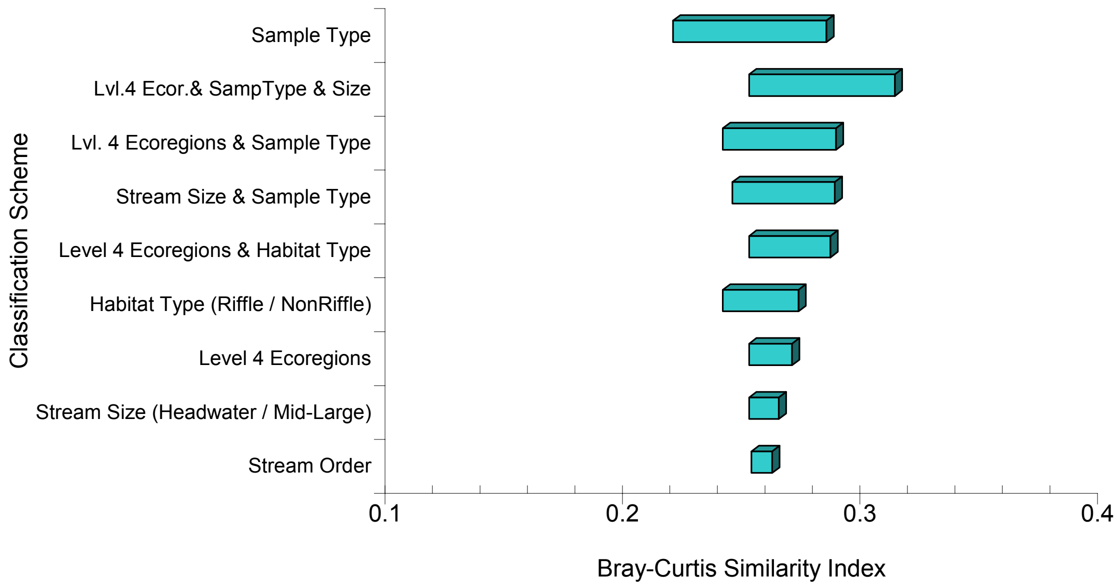

Figure 4-18. Stream classification and benthic macroinvertebrate assemblage similarity: A comparison of stream reference sites in three Level IV ecoregions (47b, 47c, 47f).

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Summary and Conclusions

Several useful findings were obtained from the statistical analysis of stream classification factors:

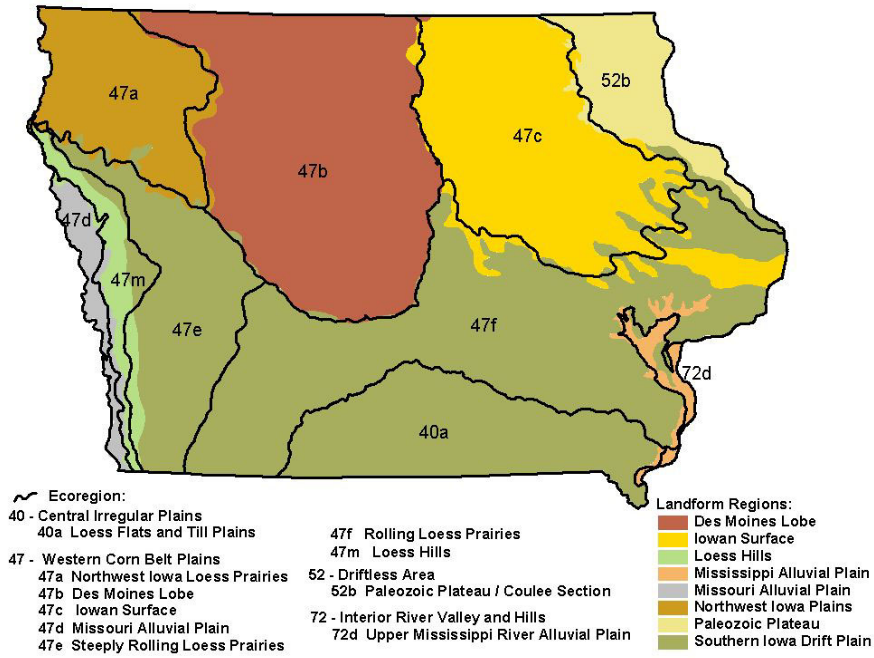
- Differences in benthic macroinvertebrate and fish assemblage structure occur at varying spatial scales. The analysis found significant differences in aquatic community structure at stream reach and sub-reach scales of physical habitat, as well as differences at the drainage basin and regional scales.

- Ecoregions and other landscape classification schemes explain a significant, but relatively small amount of variability in benthic macroinvertebrate and fish assemblage structure. Aquatic communities in the Paleozoic Plateau (52b) and Iowan Surface (47c) ecoregions in Northeast Iowa differ the most from aquatic communities in the rest of Iowa, particularly those in southern and western Iowa.

- Ecoregions are a slightly better classification framework than alternative classification schemes including landform regions, major drainage basins, and stream order. Similarity analysis results demonstrated that regional-scale stream classification could be improved by combining ecoregion and drainage basins.

- Multivariate ordination analysis found a wide array of stream environmental variables that explain a significant amount of the variability in stream biological community structure. Benthic macroinvertebrate and fish assemblage similarity analysis results demonstrated that stream classification strength could be improved by incorporating habitat or stream size classes within ecoregions.

- Further refinement of stream classification can help reduce the variability among reference sites and reference conditions. However, one potential drawback of creating additional stream classes is that it would necessitate the identification and verification of more reference sites.



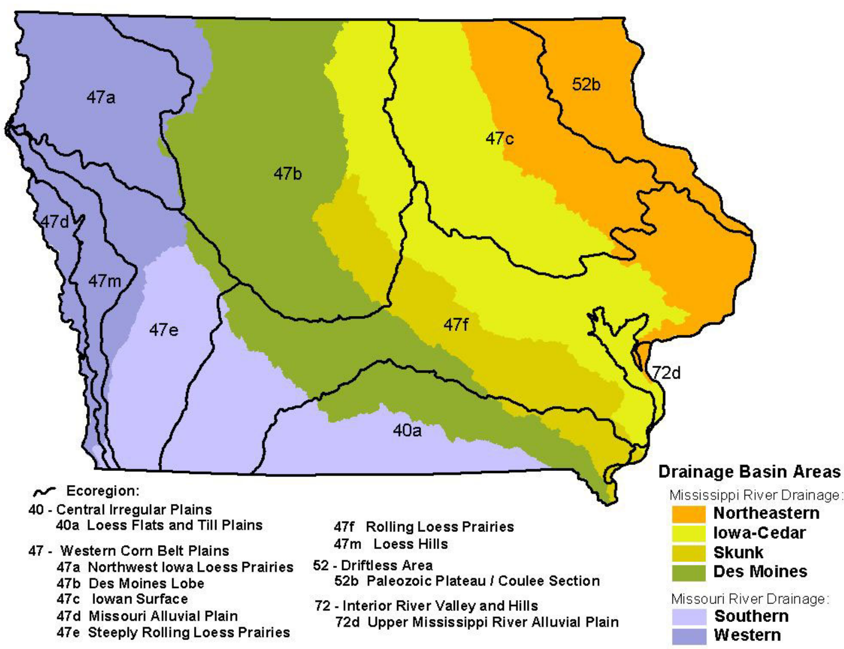


Figure 4-19. Ecoregion boundaries in relation to landform regions of Iowa (top) and major drainage basin units referenced in Iowa's water quality standards (bottom).

Level III ecoregions are identified by the numeric designator (e.g., 40 – Central Irregular Plains) and Level IV ecoregions are identified by the alphabetic designator following the number (e.g., 40a – Loess Flats and Till Plains).

5 Biological Data Metrics and Indexes

Before biological sample data can become assessment information that is useful for resource managers and policy makers, a data synthesis process must first be completed. Early attempts at biological data synthesis usually involved calculating a single indicator such as Simpson's diversity index (*H'*). The single indicator approach, however, was not effective when applied across broad geographic areas and wide-ranging stream conditions (Barbour et al. 1995). Beginning in the 1980's, a new movement in biological assessment emerged with the advent of the multi-metric index. A metric is a quantifiable attribute or characteristic of the aquatic community that is ecologically relevant and responds predictably along an environmental disturbance gradient (Barbour et al. 1995; Karr and Chu 1999a; U.S. EPA 1996). Typically, several metrics are combined to obtain a composite index that has greater utility than each of the component metrics.

The multi-metric approach was first demonstrated by Karr (1981; 1986) using the Index of Biotic Integrity (IBI) as a tool to evaluate stream conditions in agricultural watersheds of the Midwest. Since then, the IBI approach has been adapted throughout the United States and internationally not only for stream fish assemblages, but other biological assemblages and other types of freshwater ecosystems (e.g., Hughes and Oberdoff 1999; McDonough and Hickman 1999; Mundahl and Simon 1999; Whittier 1999; U.S. EPA 2002). Assessments that are based on more than one biological assemblage (e.g., algae, amphibians, benthic macroinvertebrates, fish, and macrophytes) also provide a broader assessment of resource condition and have greater sensitivity to detect environmental degradation (Kremen 1992; Yoder and Rankin 1995).

IDNR began evaluating potential benthic macroinvertebrate and fish metrics using sample data from the 1994 pilot study (IDNR 1996). Useful metrics share the following characteristics (Barbour et al. 1995): a) relevant in biological terms and also from a resource management perspective; b) sensitive to environmental stressors; c) able to distinguish effects of human disturbance from natural variation;

d) cost-effectively measured without harm to the aquatic resource. A metric review process was completed in 1999 utilizing a process patterned after analysis techniques described in the bioassessment literature (Barbour et al. 1995; Barbour et al. 1996; Hughes et al. 1998; Mundahl and Simon 1999). The best metrics were combined to make the Benthic Macroinvertebrate Index of Biotic Integrity (BMIBI) and the Fish Index of Biotic Integrity (FIBI). The BMIBI and FIBI and their component metrics are described in report parts 5.1 and 5.2, respectively. Part 6 describes how the indices initially have been used to assess biological conditions in Iowa's wadeable streams and rivers.

5.1 Benthic Macroinvertebrate Index of Biotic Integrity (BMIBI)

The BMIBI is a composite index comprised of twelve individual metrics that are designed to provide an objective, quantitative measure of stream biological condition based on characteristics of the benthic macroinvertebrate assemblage. The 12 component metrics were selected from a candidate list of 38 candidate metrics (Table 5-1) found in biological assessment literature (Barbour et al. 1992; Barbour et al. 1995; Barbour et al. 1999; DeShon 1995; Karr and Chu 1999b). These literature sources describe the metrics, discuss their ecological basis and patterns of response to environmental disturbance, and identify where the metrics have been used in various regions of the U.S. In selecting candidate metric for evaluation, a determination of which metrics could be calculated using the data collected for this project was also done.

Each candidate metric was evaluated for the following characteristics: a) ease and expense of measurement; b) measurement variability; c) response across gradients of stream quality; d) duplication of other metrics. The metrics are grouped in five general categories. Each candidate metric is also distinguished by the type of sample data from which it is calculated.

- Metrics calculated using proportional abundance data obtained from Standard-habitat samples are denoted in Table 5-1 by the letter "***S***". At each site, a triplicate set of standard-habitat samples is collected from either rock or wood substrates that are situated in riffle or shallow run habitat.

- Metrics calculated using species presence/absence data obtained from a Multi-habitat sample are denoted in Table 5-1 by the letter "***M***". One multi-habitat sample is collected at each site by handpicking macroinvertebrates from all accessible types of benthic habitat including silt, sand, muck, rock, detritus, wood, root mat, and vegetation.

Table 5-1. Biological data metrics evaluated for use in the Benthic Macroinvertebrate Index of Biotic Integrity (BMIBI).

Metric Category				
Taxa Composition (S)	Balance / Diversity (S)	Richness (S/M)	Tolerance (S)	Trophic Guilds (S)
Baetidae : Ephmrptr.	% Dom. Taxon	# Coleoptera taxa	Iowa Tolerance Index	% Collector gthr.
EPT: Chrnmd.	% 3-Dom.Taxa	# Diptera taxa	Mod. Hilsenhoff Biotic Index	% Dom. functional feeding group
Hydropsychidae : Trichoptera	% 5-Dom. Taxa	# Ephmrptr. taxa	% Sensitive taxa	% Filterers
% Chironomidae	Shannon's Diversity Index	# EPT taxa	% Tolerant taxa	% Predators
% Coleoptera		# Hemiptera taxa		% Scrapers
% Diptera		# Odonata taxa		Scrprs. : filtrs.
% Ephmrptr.		# Plecoptera taxa		Scprs. : scrprs. + fltrs.
% EPT taxa		# Sensitive taxa		% Shredders
% Megaloptera		# Total taxa		
% Oligochaeta		# Trichoptera taxa		
% Plecoptera				
% Trichoptera				

(S) Standard-habitat, proportional abundance data; (M) Multi-habitat presence/absence data

5.1.1 Metric Review Process

The four-step process described below was used to evaluate candidate metrics. The evaluation utilized 1994-1997 benthic macroinvertebrate sample data from reference sites and test sites. Table 5-2 contains a summary of metric evaluation results.

1. Measurement (sampling) variability.

The Coefficient of Variation (CV), which is simply the sample standard deviation divided by the sample mean, was used to compare the relative amount of sample variability among candidate benthic macroinvertebrate metrics. For standard-habitat metrics, the CV from each triplicate set of samples was calculated and the average CV was obtained. Replicate samples were not available to evaluate benthic macroinvertebrate metrics calculated from multi-habitat sample data. Instead, the metric variability of annual samples was evaluated based on data from three reference sites that were sampled in four consecutive years (1994-1997). A mean CV value from the three sites was obtained and the rating categories described below were used.

Candidate metrics received a variability rating of low, medium, or high based on the following guidelines: CV values ranging from 0 – 0.25 were rated as "low" variability; CV's ranging from 0.25 – 0.50 were assigned a rating of "moderate" variability; CV values greater than 0.50 received a rating of "high" variability.

2. Discriminatory Power.

Each candidate metric's ability to distinguish reference sites from impacted sites was evaluated using a graphical method and a statistical method. The graphical analysis, after Barbour et al. (1996), involved a comparison of box and whisker plots representing metric values from reference sites and impacted sites (Figure 5-1). Each metric received a rating from 0 (poor discriminatory power) – 3 (strong discriminatory power) based on the observed degree of separation between reference site and impacted site median values and interquartile ranges. Only data from the Des Moines Lobe (47b) and Rolling Loess Prairies (47f) ecoregions were included in the analysis because the number of impacted sites sampled in other ecoregions was insufficient. Impacted sites were identified based on the presence of observable physical habitat or water quality impacts, specifically including channelization, livestock grazing, and wastewater effluent. A combination of these impacts was present at several sites.

In the statistical analysis of metric discriminatory power, Analysis of Covariance (AOCV) was used to calculate signal:noise ratios for the candidate metrics. The approach used was adapted from Kaufmann et al. (1999). Ecoregion and site-type were used as the main effects in the AOCV model. The signal:noise ratio was defined as the AOCV "F-statistic" result for site-type effect, which represents the ratio of metric variability between types of sites (i.e., reference vs. impact) to metric variability within site-types. Essentially, the larger the F-statistic, the greater is the metric "signal" (i.e., ability to distinguish reference sites from impacted sites) in relation to the metric "noise" (within group variability).

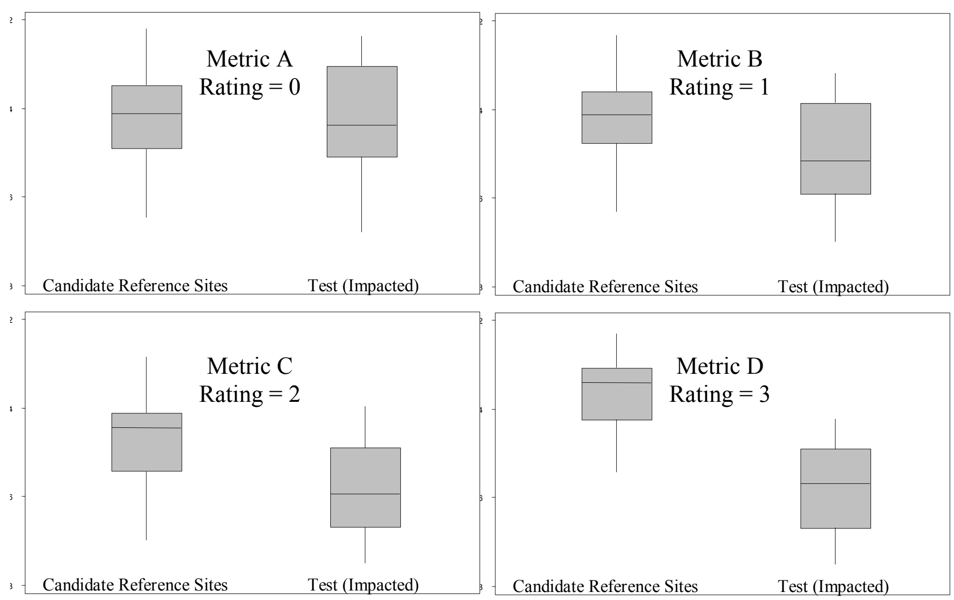


Figure 5-1. Example of graphical method for evaluating metric discriminatory power (after Barbour et al. 1996).

Metric A, the reference and impacted interquartiles (IQs) overlap and each median value lies within the range of the opposing IQ (rating = 0, weak discriminatory power); Metric B, the IQ ranges overlap and one median value lies outside the range of the opposing IQ (rating = 1); Metric C, the IQs overlap and each median value lies outside the opposing IQ (rating = 2); Metric D, the IQs do not overlap and each median value lies outside the opposing IQ (rating = 3; strong discriminatory power).

Three categories for rating metric discriminatory power based on signal:noise ratio were used:

1) Weak. Candidate metrics with a signal:noise ratio < 4 were not able to detect a significant difference between reference site and impacted sites at the 95% confidence level ($p>0.05$).
2) Moderately Strong. Candidate metrics with signal:noise ratio from 4 – 8 were able to detect a statistically significant difference between reference sites and impacted sites ($p \leq 0.05$-0.01)
3) Strong. Candidate metrics with signal:noise > 8 were able to detect a difference at the 99% confidence ($p<0.01$) level.

3. Stream Gradient Response.

Karr et al. (1986) described the differences in sensitivity to environmental disturbance among individual IBI metrics as a strength of the multi-metric index approach. Ideally, a well-designed IBI should contain metrics that respond at both low and high disturbance levels, and would also contain metrics that respond consistently across a broader range of environmental conditions.

The responses of Iowa candidate benthic macroinvertebrate metrics to gradients in physical habitat and water quality were evaluated by correlation analysis and visual examination of scatter plots. Two independent stream quality indicators, Barbour and Stribling (1991) habitat quality index and water turbidity level, were used in the analysis. The correlation analysis determined the direction and degree of correlation (r-value) and the significance level (p-value) of the linear relationships between metrics and independent water quality variables. Scatter plots were constructed for visual examination of response patterns and thresholds (Karr and Chu 1999c) with the metric (response) variable on the y-axis and the independent stream quality variable on the x-axis.

Metrics were characterized as having a broad response when the correlation analysis and scatter plot examination revealed a consistent linear relationship with one or both independent stream quality indicators. A metric was rated as having a narrow response when the linear correlation was weak or not significant; however, the scatter plot examination identified what appeared to be a response threshold at a specific level in one or both stream quality indicators. Metrics were rated as having an indefinable response when there was no correlation with either stream indicator, and examining scatter plots revealed no response threshold.

4. Redundancy

The final step in the metric review process involved examining the amount of correlation or excessive redundancy among candidate metrics. A metric that is highly correlated ($r > 0.81$) with another metric is considered potentially redundant in that it might not contribute a significant amount of new information to the overall assessment of stream biological condition (U.S. EPA 1998b; Mundahl and Simon 1999). In developing a multi-metric biological index, care should be taken to not bias the index by including several redundant metrics. Potentially redundant metrics are listed in the far right column of Table 5-2.

5.1.2 Metric Review Summary and Recommendations

Results of the candidate metric review are summarized in Table 5-2. Twelve metrics were considered most useful and recommended for the BMIBI. The twelve metrics provide representation from each of the categories listed in Table 5-1 including: 3 composition metrics, 1 balance/dominance metric, 5 taxa richness metrics, 1 pollution tolerance metric, and 2 trophic composition metrics. The number and array of metrics is consistent with recommendations for constructing a multi-metric index that is responsive to wide-ranging levels and types of human influence (Barbour et al. 1999; Karr and Chu 1999b).

The following six BMIBI metrics are considered "core" metrics because they exhibit the least measurement variability, greatest power of impact discrimination, and the broadest range of response: 1) MH-taxa richness; 2) SH-taxa richness; 3)MH-EPT taxa richness; 4) SH-EPT taxa richness; 5) % 3-dominant taxa; 6) biotic index.

The remaining six metrics exhibit greater measurement variability (error) and/or a narrow range of response. These metrics are recommended for inclusion in the BMIBI because they broaden the dimensionality of the index and increase its capacity to discriminate sites that rank at the high or low range of the biological condition gradient. The additional metrics also do not appear to add significant redundancy to the index.

As a final step in the metric evaluation process, a correlation result matrix of the BMIBI and twelve component metrics was obtained. All twelve metrics were significantly correlated in the correct (expected) direction in relation to the BMIBI. None of the metrics was highly correlated (r >0.81) with the index, suggesting that none of the individual metrics are excessively dominant or redundant.

Table 5-2. Summary of benthic macroinvertebrate data metrics evaluated for use in Iowa wadeable streams.

Data Metric	Expected Direction of Response to Declining Stream Quality	Amount of Metric Sampling Variability	Impacted Site Discriminatory Power	Stream Gradient Response Range	Redundancy (correlation r >0.81)
BMIBI Metrics					
1. MH-taxa richness	<	low	moderately strong	broad	
2. SH-taxa richness	<	low	moderately strong	broad	SH-EPT, % 5-Dom. Taxa, Shannon's H'
3. MH-EPT richness	<	low	strong	broad	# MH-Ephmrptr. taxa
4. SH-EPT richness	<	low	moderately strong	broad	SH-taxa, # SH-Ephmrptr. taxa
5. MH-sensitive taxa	<	medium	strong	broad	
6. % 3-dominant taxa	>	low	strong	broad	% Dom. Taxon, % 5-Dom. Taxa, Shannon's H'
7. Biotic index	>	low	strong	broad	
8. % EPT	<	low	moderately strong	narrow	
9. % Chironomidae	>	high	strong	narrow	% Diptera
10. % Ephemeroptera	<	medium	moderately strong	narrow	
11. % Scrapers	<	medium	moderately strong	narrow	
12. % Dom. functional feeding group	>	low	moderately strong	narrow	
BMIBI (composite of above 12 metrics)	<	low	strong	broad	
Metrics not selected for BMIBI					
Baetidae : Ephmrptr.	>	medium	strong	broad	
EPT: Chrnmd.	<	high	strong	narrow	
Hydropsychidae : Trichoptera	>	low	moderately strong	narrow	
% Coleoptera	<	high	strong	narrow	
% Diptera	>	high	strong	narrow	% Chironomidae
% Megaloptera	<	high	weak	indefinable	
% Oligochaeta	>	high	weak	indefinable	
% Plecoptera	<	medium	weak	indefinable	
% Trichoptera	<	high	weak	indefinable	% Filterers
% Dom. Taxon	>	low	strong	broad	% 3-Dom. taxa, % 5-Dom. taxa, Shannon's (H'
% 5-Dom. Taxa	>	low	strong	broad	SH-taxa, % Dom. taxon, % 3-Dom. taxa, Shannon's H'
Shannon's Diversity Index (H')	<	low	strong	broad	SH-taxa, % Dom. taxon, % 3-Dom. taxa, % 5-Dom. taxa
# MH-Coleoptera taxa	<	high	weak	indefinable	
# SH-Coleoptera taxa	<	medium	weak	indefinable	
# MH-Ephmrptr. taxa	<	medium	strong	narrow	MH-EPT
# SH-Ephmrptr. taxa	<	low	strong	narrow	SH-EPT
# MH-Hemiptera taxa	>	high	weak	indefinable	# SH-Hemiptera
# SH-Hemiptera taxa	>	low	weak	indefinable	# MH-Hemiptera
# MH-Odonata taxa	>	high	weak	indefinable	
# SH-Odonata taxa	>	high	moderately strong	narrow	
# MH-Plecoptera taxa	<	low	moderately strong	narrow	
# SH-Plecoptera taxa	<	medium	weak	indefinable	
Iowa Tolerance Index	>	high	weak	indefinable	
% Sensitive taxa	<	high	moderately strong	broad	
% Tolerant taxa	>	high	strong	broad	
% Collector gthr.	>	medium	weak	indefinable	% Filterers
% Filterers	>	high	weak	indefinable	% Coll. gthr., % Trichop.
% Predators	<	high	weak	indefinable	
% Shredders	<	high	weak	indefinable	
Scrprs. : filtrs.	<	high	weak	indefinable	
Scprs. : scrprs. + fltrs.	<	medium	weak	indefinable	

5.1.3 BMIBI Metric Descriptions and Scoring Criteria

The twelve BMIBI metrics quantify various attributes of the benthic macroinvertebrate assemblage that relate to taxa richness, assemblage balance, pollution tolerance, and trophic (feeding) guild composition. The metrics vary in how they are quantified (i.e. integer, proportion, real number); therefore, the ranges of possible values are not equivalent. In order to construct a multi-metric index in which each metric is assigned equal weight, it is first necessary to convert raw metric data to standardized, unitless metric scores (Karr et al. 1986; U.S. EPA 1996).

The procedures described by Hughes et al. (1998) were used to convert raw metric data into standardized BMIBI metric scores ranging from 0–10. The first step was to create scatter graphs of the raw metric data plotted against stream size (see Figure 5-3). Metric adjustments for stream size are a common element of IBI adaptations (Smogor and Angermeier 1999). In a comparative analysis, Log10 surface watershed drainage area was chosen over average stream width and Strahler stream order as a surrogate measure of stream size.

Following procedures described by Karr et al. (1986) and Lyons (1992), an optimum line (e.g. maximum species richness) was established on each metric plot. The optimum line was visually fitted through the data such that 5% of the metric values would fall above the line and the remaining 95% of the values would fall below (Karr et al. 1986, Lyons 1992). It is important to note that only reference site data were used to establish the optimum levels. Sloping optimum lines were drawn for metrics that exhibited a linear relationship with stream size. After Lyons (1992), the sloped line was changed to a horizontal line at the asymptotic point in optimum metric levels (see Figure 5-3). For metrics lacking a linear relationship with stream size, a horizontal optimum line was drawn through the data (see Figure 5-6). In some cases, the metric optimum line has been established on an inverted y-axis (see Figure 5-6).

After establishing optimum lines, metric scores for individual samples can be determined by linear interpolation (Hughes et al. 1998). A maximum score of ten is given to metric values that are plotted on or above the optimum level (the reverse would be true of metrics that operate on an inverted scale). A minimum score of zero is assigned to values that fall on or below the minimum level, which is usually set equal to the minimum possible metric value. Metric values that fall somewhere between the optimum and minimum levels receive a score between 0 and 10. The scoring range is continuous and can include decimals. For example, a score of 7.5 would be given for a metric value that is plotted 75% of the linear distance between the minimum and optimum levels (Figure 5-2).

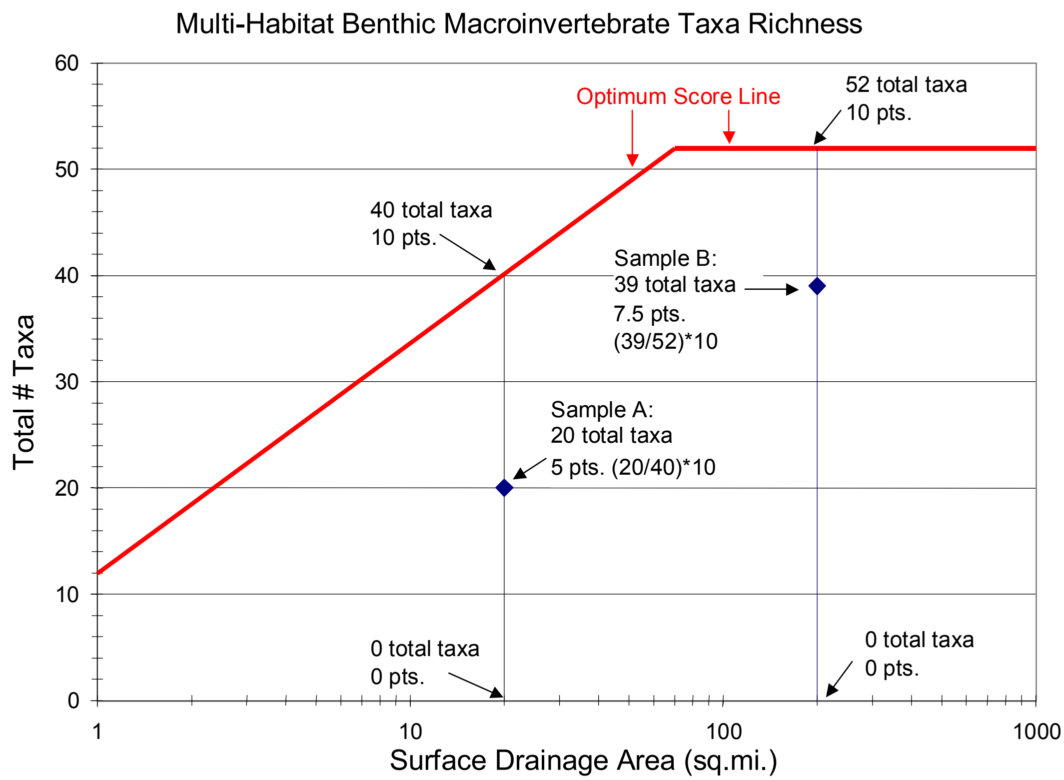


Figure 5-2. Example of metric scoring for Sample A (surface drainage area = 20 sq.miles; 20 total taxa) and Sample B (surface drainage area = 200 sq.miles; 39 total taxa)

Metric Descriptions

Taxa richness metrics:

1. Multi-habitat Taxa Richness (MHTR) is the total number of benthic macroinvertebrate taxa handpicked from all the different types of benthic habitat that occur in a sampling reach (e.g. cobbles, detritus, root mats, vegetation, woody debris). As stream size increases from creek to small river, the optimum level of benthic macroinvertebrate taxa richness generally increases and then levels off (Figure 5-3).

Benthic macroinvertebrate taxa richness decreases as habitat complexity and/or water quality decrease. The highest levels of taxa richness are generally found in streams that have good water quality and diverse benthic habitat. Conversely, low taxa richness is found in streams that have extreme flow fluctuations, monotonous habitat characteristics, and poor water quality.

2. Standard-habitat Taxa Richness (SHTR) is the total number of taxa identified in a standard-habitat subsample of 100 organisms. Two types of standard-habitat samples are collected: 1) coarse rock substrates in riffle/run habitat; 2) artificial, wood-plate substrates deployed in shallow runs. The second type is collected in streams that lack riffles and coarse substrates.

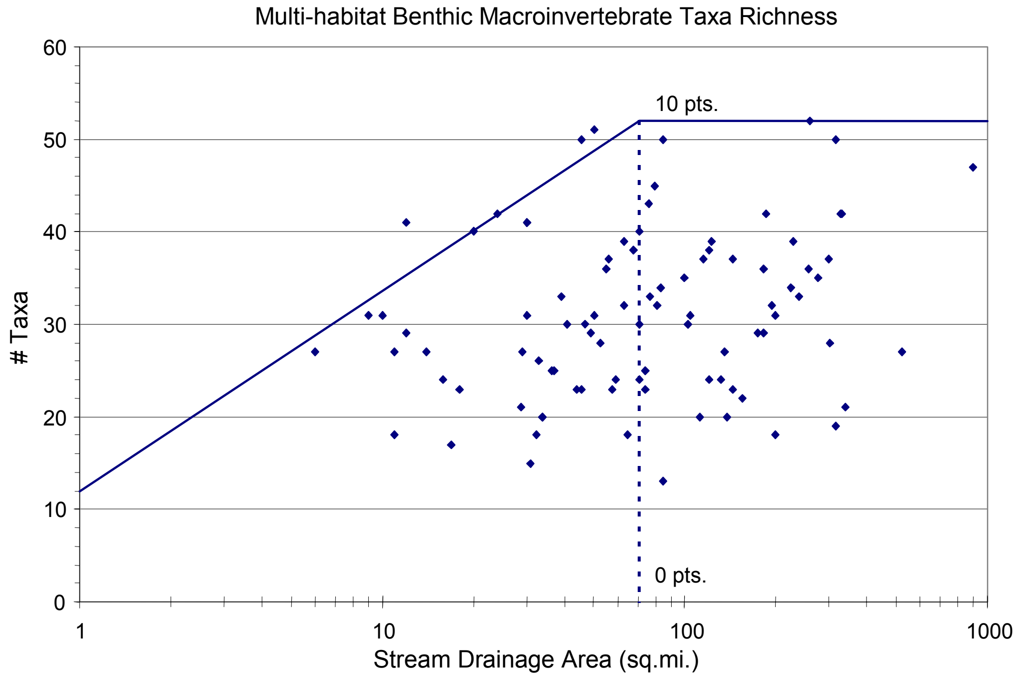
Rock or wood substrates situated in flowing water can support abundant and diverse benthic macroinvertebrate assemblages. Healthy Iowa streams will support twenty or more taxa in a relatively small area (<0.1 m^2). As water quality declines, the benthic macroinvertebrate assemblage becomes less diverse.

3. Multi-habitat EPT richness (MHEPT) is the total number of EPT taxa handpicked from all the different types of benthic habitat in the sampling reach. EPT taxa are benthic macroinvertebrates that belong to the pollution-sensitive aquatic insect orders: Ephemeroptera, Plecoptera, and Trichoptera. Pollution sensitivities of EPT taxa range from extremely sensitive to moderately tolerant. Many EPT taxa are adversely impacted by toxic contaminants, such as heavy metals and insecticides. High quality streams support relatively high numbers of EPT taxa. As stream quality declines, the number of EPT taxa also declines. The MHEPT metric has a broad range of response to varying water quality and habitat conditions.

4. Standard-habitat EPT richness (SHEPT) is the number of EPT taxa identified in a standard-habitat subsample of 100-organisms. Many EPT taxa have a strong affinity for coarse substrates situated in flowing water. In healthy streams, relatively high numbers of EPT taxa are expected to colonize this type of habitat. An absence or reduction in EPT taxa suggests there is a water quality problem since suitable habitat for colonization is present. A low number of EPT taxa can also suggest that food resources are unbalanced and providing EPT organisms of a particular functional feeding group (e.g., collector-filterer organisms) a competitive advantage over other EPT taxa.

Note: It might seem redundant or unnecessary to include taxa richness and EPT richness metrics from both multi-habitat and standard-habitat samples. However, there is an important difference in the scale of measurement that ensures both metrics contribute to a stronger biological assessment. The multi-habitat taxa richness metric reflects habitat availability and suitability at the stream reach scale in addition to responding to water quality conditions. Standard habitat samples are more indicative of water quality alone since habitat is standardized across sites.

When both types of samples are included, there are several possible assessment outcomes. For example, a healthy stream with good water quality and benthic habitat diversity will ordinarily support high total numbers of taxa and EPT taxa in both the standard habitat and multi-habitat samples. Conversely, a stream with poor habitat and water quality will yield relatively few taxa in both types of samples. In streams where water quality is acceptable but benthic habitat is lacking, taxa richness might be reasonably high in the standard-habitat sample and low in the multi-habitat sample.



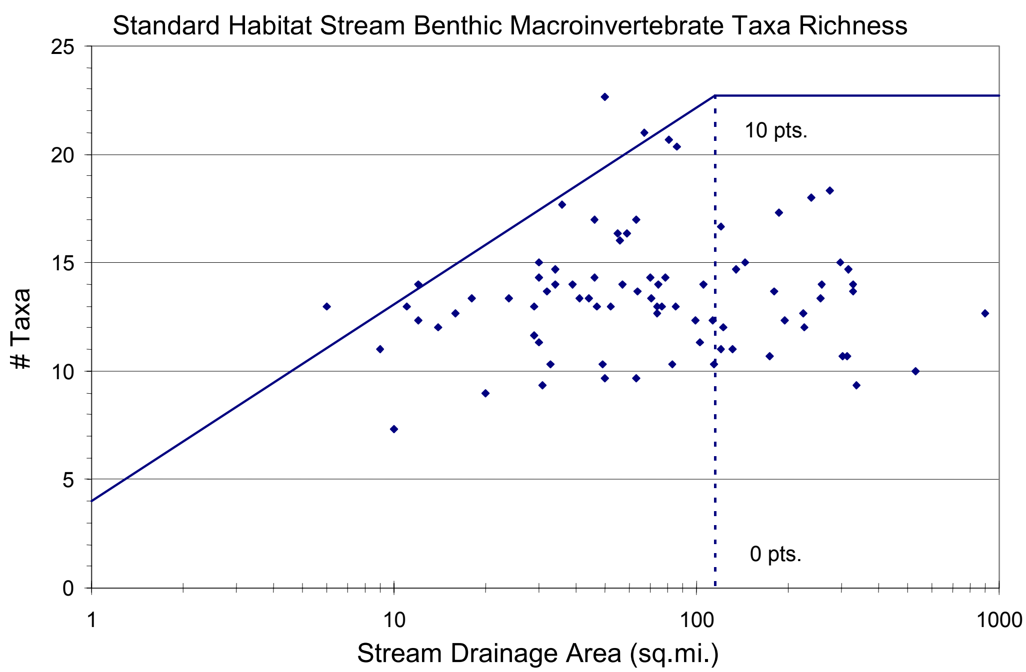
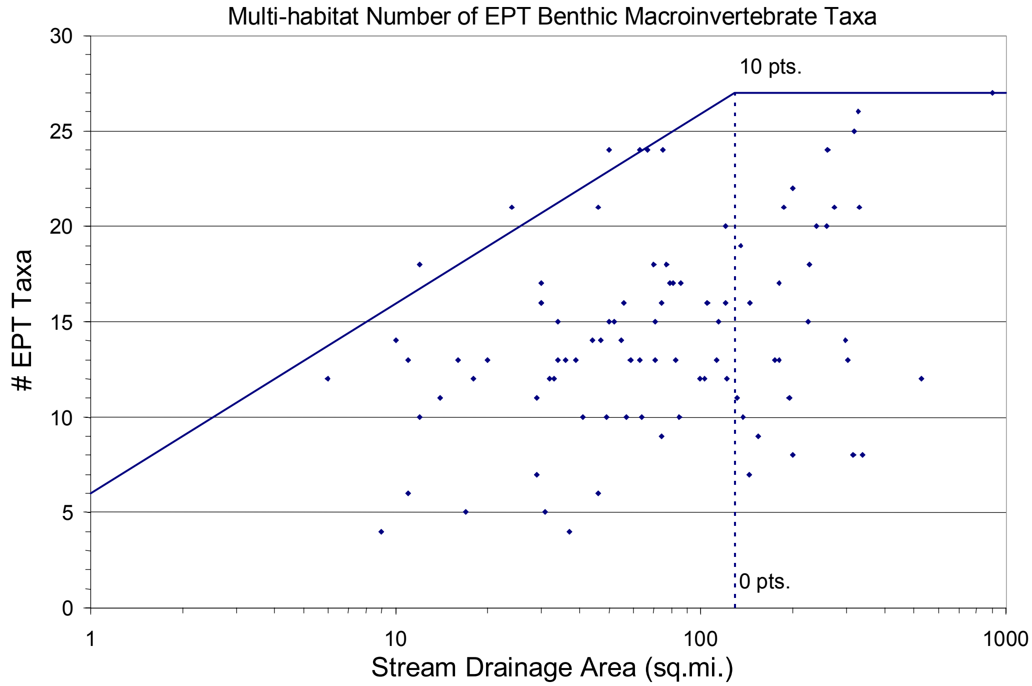


Figure 5-3. Multi-habitat taxa richness metric (MHTR) (top) and standard-habitat taxa richness metric (SHTR) (bottom).



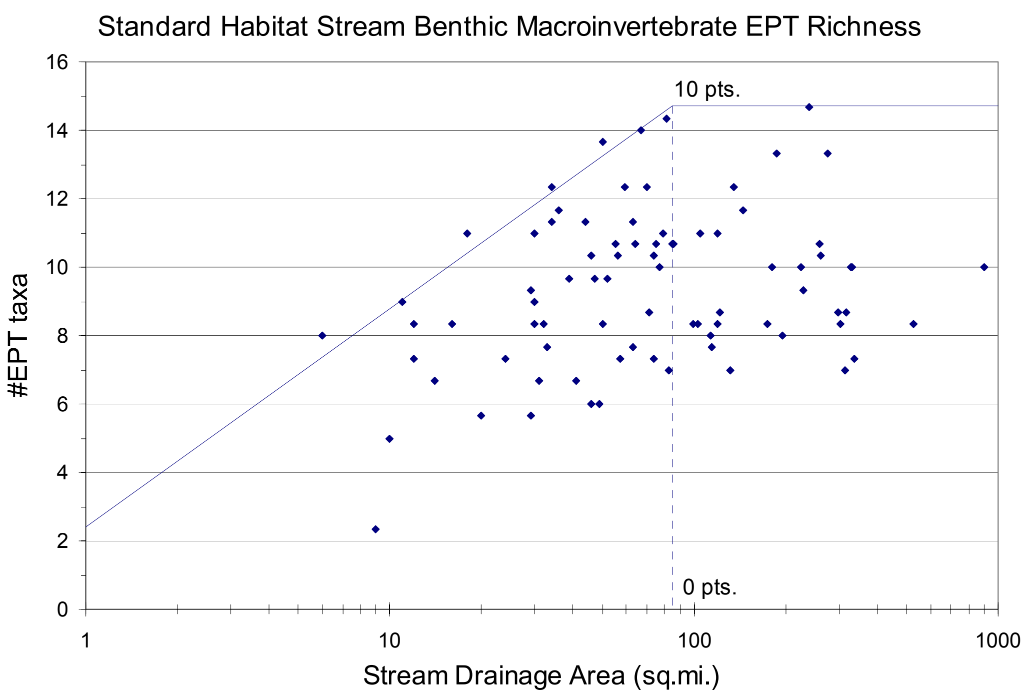


Figure 5-4. Multi-habitat EPT taxa richness metric (MHEPT) (top) and standard EPT taxa richness metric (SHEPT) (bottom).

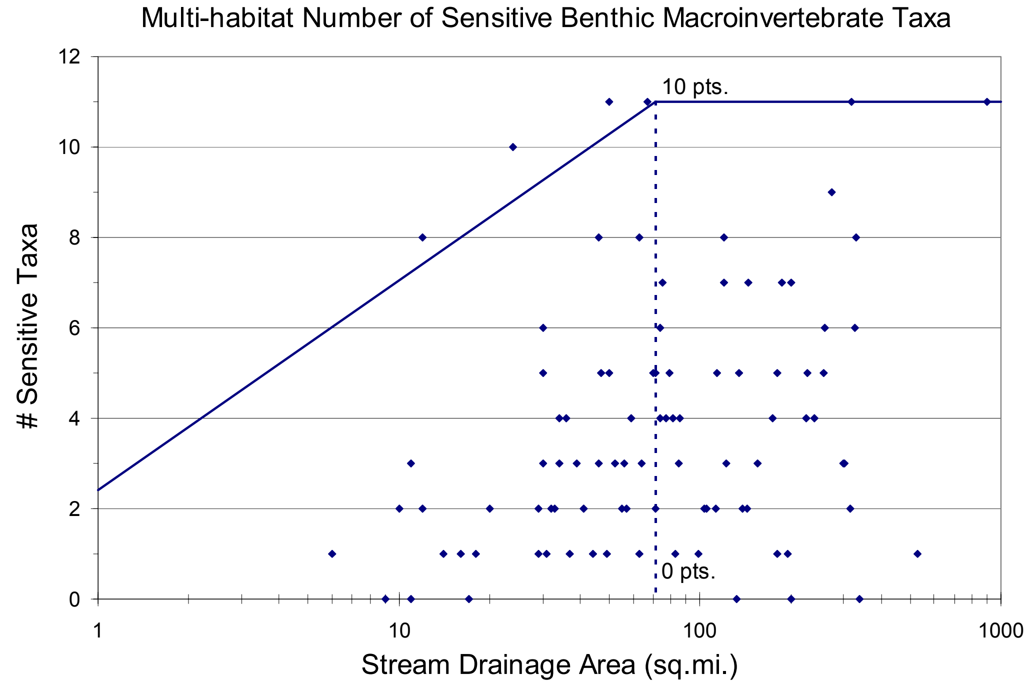
5. Multi-habitat Sensitive Taxa Richness (MHSTR) is the number of sensitive taxa handpicked from different types of benthic habitat in the sampling reach. Sensitive taxa are defined as those which have a tolerance value of three or less on the Hilsenhoff Biotic Index scale from 0 (no organic enrichment) –10 (severe organic pollution). This group includes the most pollution-sensitive of the EPT taxa and several non-EPT taxa. The number of sensitive taxa is expected to decline as stream water quality declines. With increasing nutrient availability and organic enrichment, sensitive benthic macroinvertebrate taxa are replaced by more tolerant, facultative organisms.

The following metrics utilize proportional abundance data and are only calculated from standard-habitat samples:

6. Percent abundance of 3-dominant taxa (P3DOM) is the proportion of the total number of organisms represented by the three most-abundant taxa. This metric is an indicator of benthic macroinvertebrate assemblage balance. P3DOM is inversely related to stream biological condition. Healthy warm water streams have diverse benthic macroinvertebrate assemblages in which the majority is comprised of numerous taxa. As stream conditions degrade, an increasingly higher proportion of the assemblage is comprised of just a few opportunistic taxa.

7. Biotic Index (BINDX) is adapted from the Hilsenhoff Biotic Index, which was developed as an indicator of stream organic enrichment (Hilsenhoff 1987). The BINDX metric increases in response to increased nutrient and organic enrichment impacts including excessive algal or macrophyte growth and dissolved oxygen depletion. To calculate the metric, the proportional abundance of each taxon in the sample is multiplied by its tolerance value. The products are then summed to obtain a weighted-average tolerance score. BINDX metric values can range from 0 (no organic pollution) to 10 (severe organic pollution); however, in Iowa's streams metric values rarely exceed 6.0. To improve the metric's sensitivity, a minimum (zero score) line was drawn horizontally at the lowest measured metric value among reference sites (Figure 5-6).

8. Percent abundance of EPT taxa (PEPT) is the proportion of organisms belonging to the aquatic insect orders: Ephemeroptera, Plecoptera, and Trichoptera. In healthy streams, EPT taxa are usually abundant on stable rock or wood substrates situated in flowing water. As water quality impacts or siltation problems become severe, EPT organisms tend to be replaced by tolerant organisms. Many EPT taxa are particularly sensitive to toxic contaminants such as ammonia, metals, and insecticides. Their absence or rare occurrence in standard habitat samples is strong evidence of a water quality problem. In Iowa streams, The PEPT metric seems to have a narrow range of response that is mostly observed in streams experiencing acute or chronic water quality impacts.



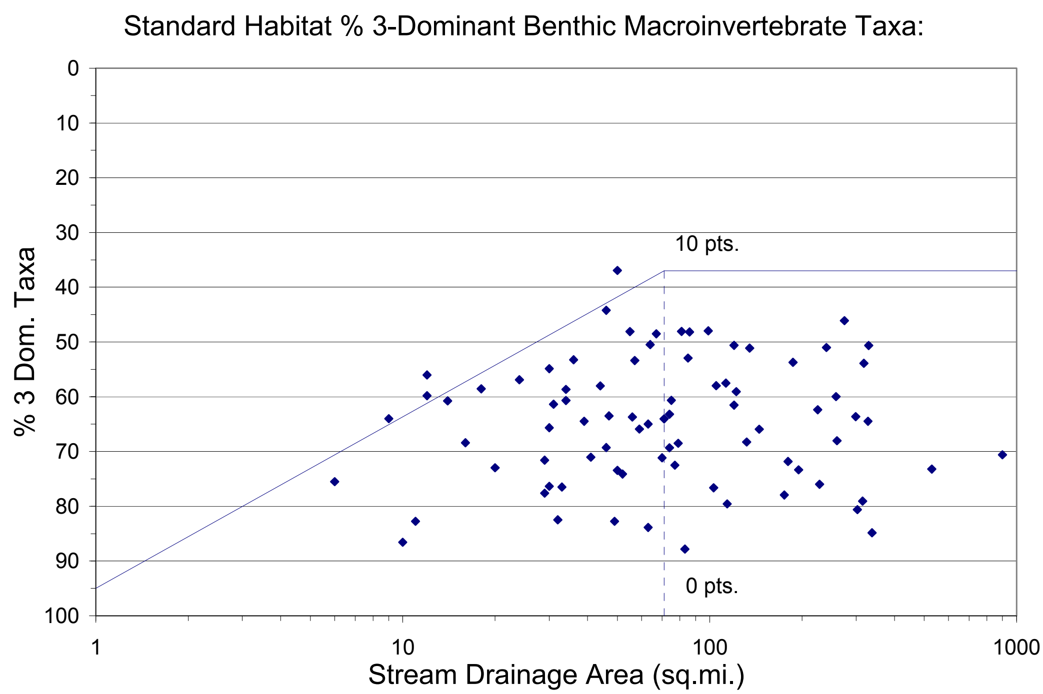
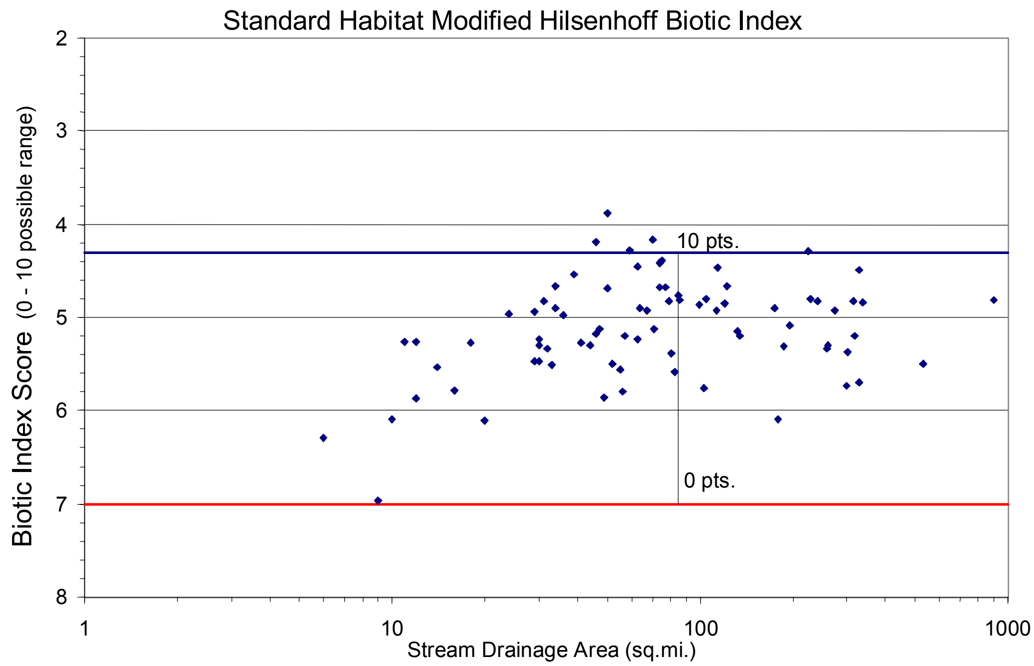


Figure 5-5. Multi-habitat sensitive taxa metric (MHSTR) (top) and percent abundance of 3-dominant taxa (P3DOM) metric (bottom).



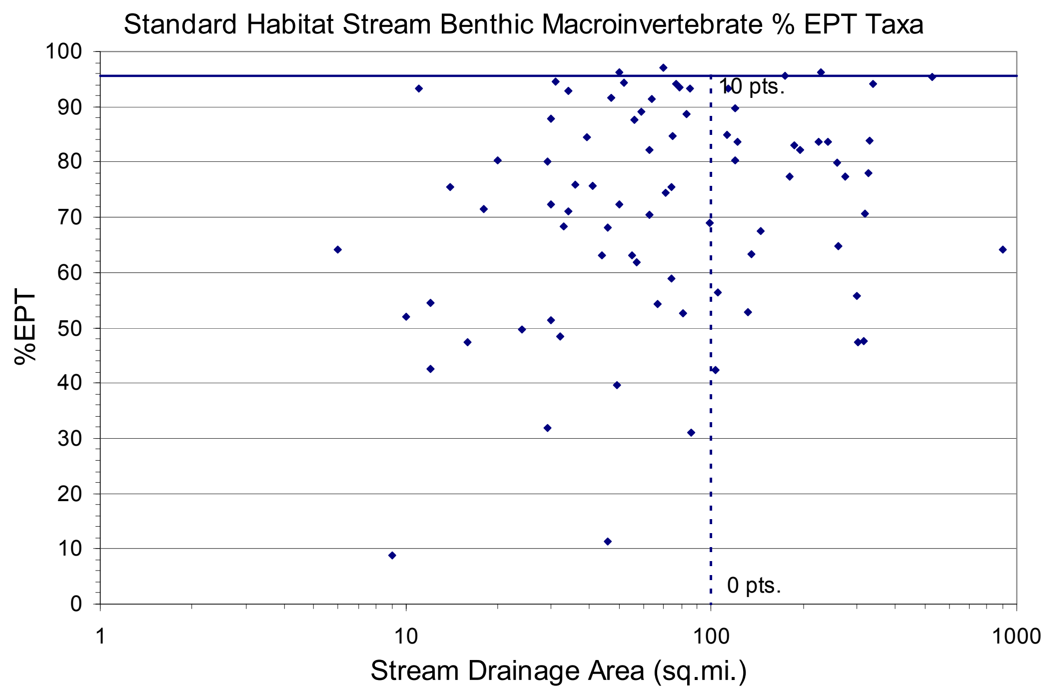


Figure 5-6. Biotic Index (BINDX) metric (top) and percent abundance of EPT taxa (PEPT) metric (bottom).

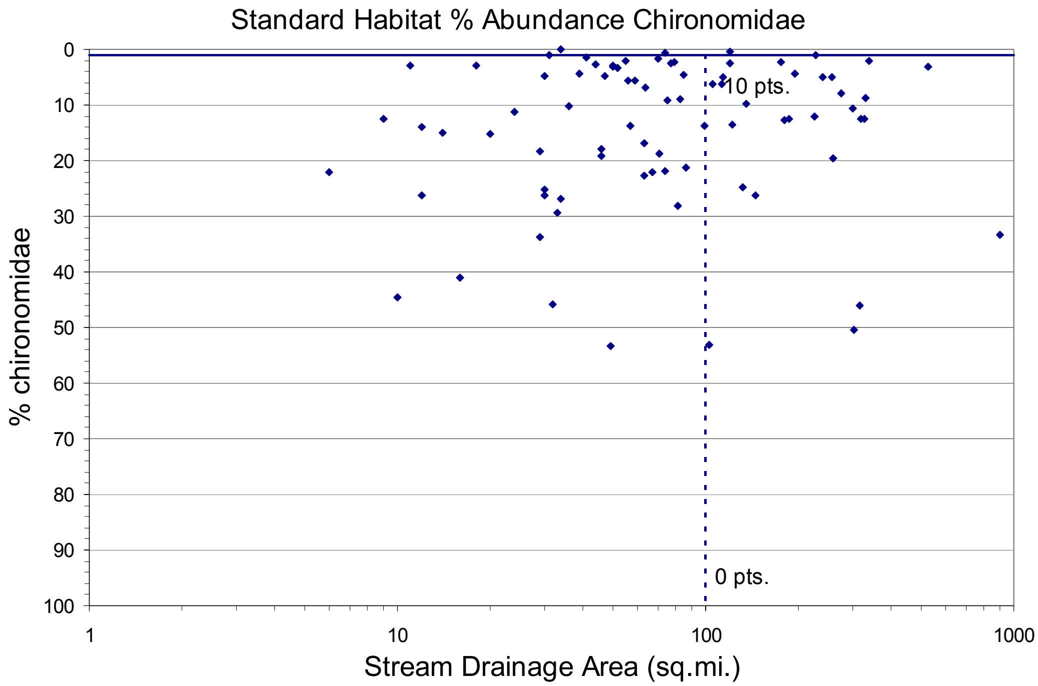
9. Percent abundance of Chironomidae (PCHR) is the proportion of organisms belonging to the midge family (Chironomidae) of aquatic dipterans (true flies). Midges are a very large and diverse group of aquatic insects that are a normal component of healthy streams. Some chironomidae taxa are sensitive to pollution impacts, while others are very tolerant of pollution impacts such as organic enrichment, sedimentation, and toxic metal loading. In Iowa streams, chironomids ordinarily comprise a relatively small proportion of the organisms in standard-habitat samples. Where significant water quality impacts occur, however, the proportional abundance of chironomids often increases dramatically. The %CHR metric has a relatively narrow range of response that is mostly observed toward the lower end of the stream quality spectrum.

10. Percent abundance of Ephemeroptera taxa (PEPHM). Ephemeroptera (mayflies) are normally abundant in healthy Iowa streams. As a group, they are pollution-sensitive, and several taxa disappear quickly as stream disturbance increases. Mayflies compete with many other benthic macroinvertebrates for food resources and limited space on coarse substrates such as rocks or woody debris. At intermediate levels of organic enrichment, mayfly taxa are often replaced by filter-feeding caddisflies (Trichoptera).

11. Percent abundance of scraper organisms (PSCR). The proportion of organisms belonging to the scraper functional feeding group generally decreases as streams become more organically enriched. The main food sources utilized by scraper organisms include periphyton (attached algae) and organic matter contained in the bio-film that occurs on hard substrates. As streams become more enriched, collector gatherer organisms (e.g., Baetidae) or collector filterer organisms (e.g., Simulidae, Hydropsychidae) often become dominant in response to greater availability of fine particulate organic matter (FPOM). With stream enrichment, there is also a shift from unicellular forms of periphyton to filamentous algae, which is not as efficiently utilized by scrapers. Filamentous algae also provide a good environment for colonization by opportunistic taxa.

12. Percent abundance of dominant functional feeding group (PDFFG) is the proportional abundance of organisms belonging to the numerically dominant functional feeding group. The metric measures the degree of imbalance in the trophic structure of the benthic macroinvertebrate assemblage. Functional feeding group assignments for Iowa's benthic macroinvertebrate taxa are adapted from Merritt and Cummins (1995). In healthy streams, most benthic macroinvertebrates living on coarse substrates belong to one of three functional feeding groups: 1) scraper; 2) collector-filterer; 3) collector-gatherer. Organisms belonging to other functional feeding groups such as macrophyte (herbivore) piercer, predator, and shredder are typically present, but much less abundant.

As stream disturbance increases, one functional feeding group tends to dominate the benthic macroinvertebrate assemblage and trophic diversity is reduced (Barbour et al. 1999). Extreme dominance by one functional feeding group would indicate there is an imbalance in the stream's trophic structure or food web. For example, elevated levels of phytoplankton (FPOM) released from a wastewater lagoon or upstream impoundment could cause an imbalance favoring collector filterer organisms.



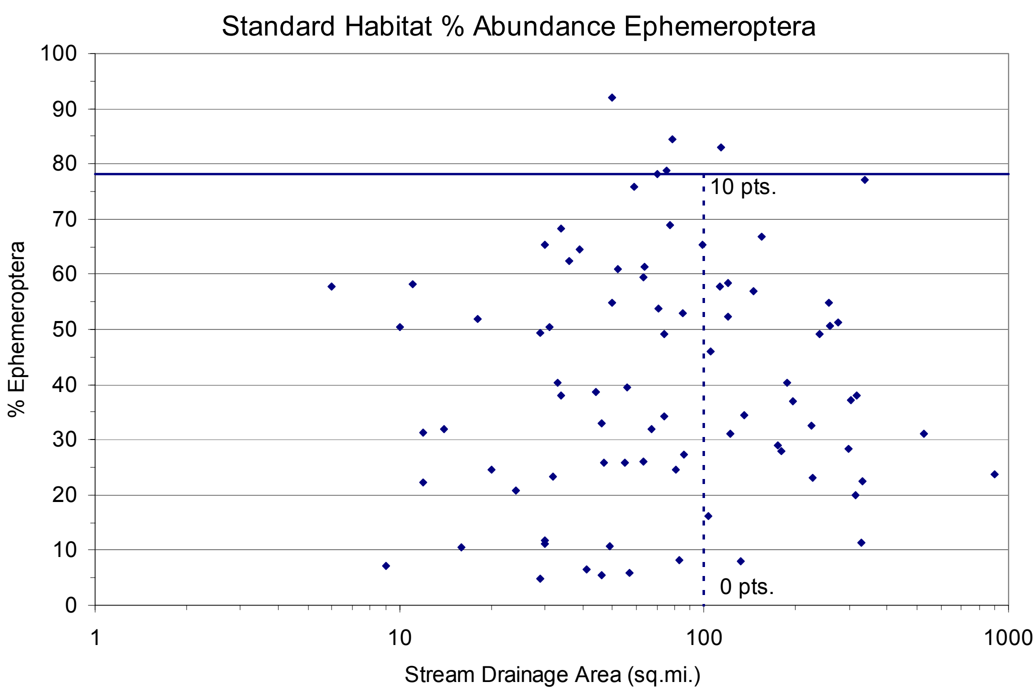
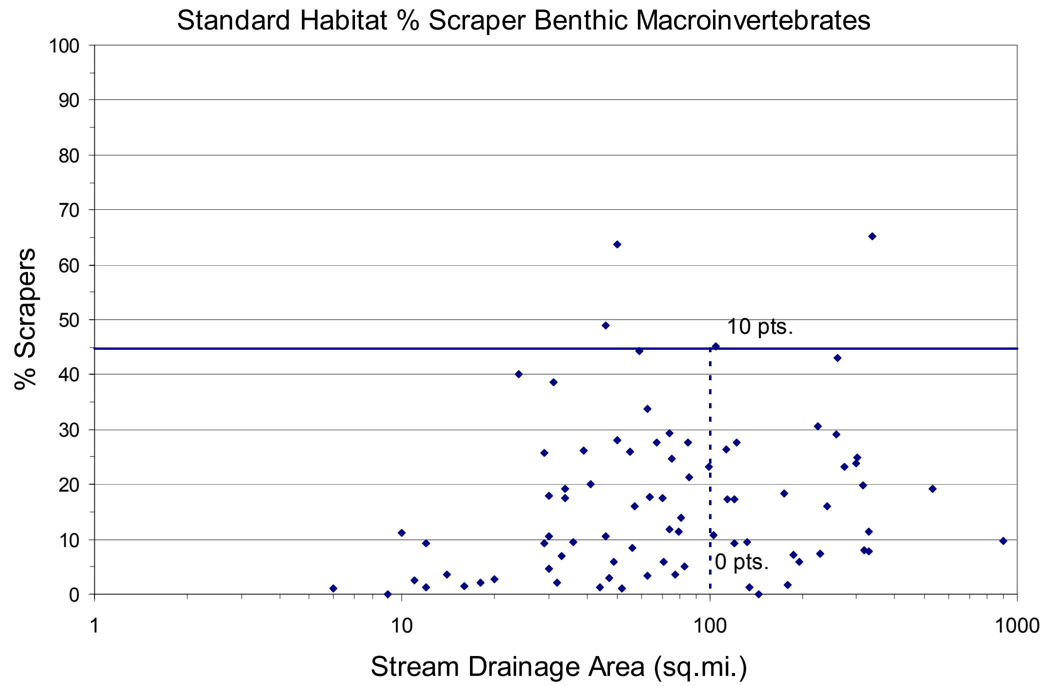


Figure 5-7. Percent abundance of Chironomidae taxa (PCHR) metric (top) and percent abundance of Ephemeroptera taxa (PEPHM) metric (bottom).



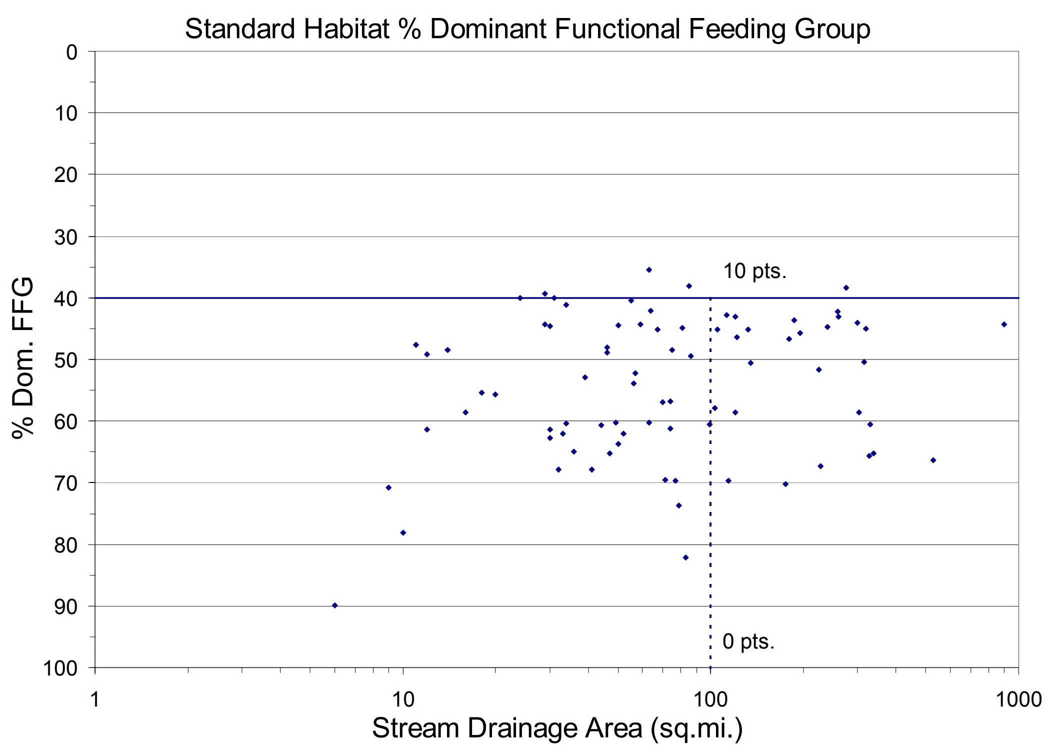


Figure 5-8. Percent abundance of scraper organisms (PSCR) metric (top) and percent abundance of dominant functional feeding group (PDFFG) metric (bottom).

5.1.4 Calculating the Index

There are four basic steps to calculating the BMIBI:

1) assign classifications and tolerance values to sample data;
2) calculate metrics;
3) apply scoring formulas to obtain standardized metric scores;
4) combine metric scores to obtain BMIBI score.

Table 5-3 lists the metric scoring formulas and instructions for calculating the BMIBI. Benthic macroinvertebrate classifications and tolerance values are listed in Appendix A1.1. Two examples of calculating the BMIBI using metric data are shown in Table 5-4. Appendix A1 contains more detailed, step-by-step example calculations using benthic macroinvertebrate data from two stream sites.

The scoring range of the BMIBI is from 0 to 100. Table 5-5 contains qualitative scoring categories (i.e., excellent, good, fair, poor), and a description of the benthic macroinvertebrate assemblage attributes associated with each category. It is important to remember that the categories reflect contemporary biological conditions in Iowa's wadeable streams. Because of data limitations, it would be difficult, if not impossible, to quantify the natural, pre-European biological condition of Iowa's streams in comparable terms. A descriptive and qualitative analysis, however, would be useful to define an historic benchmark at the top of the biocondition scale to measure progress toward restoring the biological integrity of Iowa's rivers and streams.

Table 5-3. BMIBI metric scoring formulas.

#	Metric	Abbreviation	Stream Drainage Area Criterion[1]	Metric Scoring Formula
1	Multi-habitat taxa richness	MHTR	LDA≤1.85 LDA>1.85	(#MH-taxa/(12 + 21.7*LDA))*10 (#MH-taxa/52)*10
2	Standardized-habitat taxa richness	SHTR	LDA≤2.06 LDA>2.06	(#SH-taxa/(4 + 9.08*LDA))*10 (#SH-taxa/22.7)*10
3	Multi-habitat EPT richness	MHEPT	LDA≤2.11 LDA>2.11	(#MH-EPT taxa/(6 + 9.93*LDA))*10 (#MH-EPT taxa/27)*10
4	Standardized-habitat EPT taxa richness	SHEPT	LDA≤1.93 LDA>1.93	(#SH-EPT taxa/(2.4 + 6.37*LDA))*10 (#SH-EPT taxa/14.7)*10
5	Multi-habitat sensitive taxa richness	MHSTR	LDA≤1.85 LDA>1.85	(#MH-snstv.taxa/(2.4 + 4.66*LDA))*10 (#MH-snstv.taxa/11)*10
Metrics 6-12 are calculated using standard-habitat sampling data only				
6	% abundance 3-dominant taxa	P3DOM	LDA≤1.85 LDA>1.85	((100 - %3dom.taxa)/(100-(95-31.35*LDA))*10 ((100-%3domsp.)/63)*10
7	Biotic index	BINDX	All streams	((7-Bindx)/2.7)*10
8	% abundance EPT taxa	PEPT	All streams	(%EPT/95.5)*10
9	% abundance Chironomidae	PCHR	All streams	(100-%Chrnmd.)/98.98)*10
10	% abundance Ephemeroptera taxa	PEPHM	All streams	(%Ephmr./78.2)*10
11	% abundance scraper organisms	PSCR	All streams	(%scrpr./44.7)*10
12	% abundance dominant functional feeding group	PDFFG	All streams	((100-%dom.ffg.)/60)*10

[1]LDA = Log10 Stream Drainage Area (square miles)

<u>Benthic Macroinvertebrate Index of Biotic Integrity (BMIBI) Computation Steps</u>:
1) Obtain benthic macroinvertebrate taxa classifications and tolerance values from Appendix A1-1.
2) Calculate metrics (refer to metric descriptions in Section 5.1.3 and instructions in Appendix A1-4).
3) Compute the metric score for each of the twelve BMIBI metrics; apply the appropriate metric formula depending on the stream watershed drainage area. Each metric scoring range is continuous from 0 - 10 (round metric scores to one decimal place); minimum score = 0.0, maximum (optimum) score = 10.0. In computing metric scores, values less than zero or values exceeding ten may occur. Metric scores less than zero are rounded up to zero; metric scores greater than ten are rounded down to ten.
4) Calculate BMIBI score. BMIBI = ((Sum of metric scores 1 - 12)*10)/12. Round BMIBI score to nearest integer; possible scoring range is 0 - 100.

Table 5-4. BMIBI computation examples.

	Keigley Branch – Story Co. Watershed Assessment Site. LDA = 1.63 (43 sq.mi.)		
Metric:	Metric Value	Applicable Metric Scoring Formula	Metric Score
1. MHTR	41	(MHTR /(12 + 21.7*LDA))*10	8.7
2. SHTR	12.5	(SHTR/(4 + 9.08*LDA))*10	6.6
3. MHEPT	17	(MHEPT/(6 + 9.93*LDA))*10	7.8
4. SHEPT	8.5	(SHEPT/(2.4 + 6.37*LDA))*10	6.6
5. MHSTR	6	(MHSTR/(2.4 + 4.66*LDA))*10	6.0
6. P3DOM	73.7	((100 - P3DOM)/(100-(95-31.35*LDA))*10	4.7
7. BINDX	3.79	((7-BINDX)/2.7)*10	10.0*
8. PEPT	83.7	(PEPT/95.5)*10	8.8
9. PCHR	0.5	(100-PCHR)/98.98)*10	10.0*
10. PEPHM	79.1	(PEPHM/78.2)*10	10.0*
11. PSCR	63.6	(PSCR/44.7)*10	10.0*
12. PDFFG	63.6	((100-PDFFG)/60)*10	6.1
BMIBI Score (Sum 12 metric scores / 12) x 10 (round to nearest integer)			**79**
* metric score was rounded down to max. poss. score of 10.			
	Sugar Creek near Moscow – Muscatine Co. Watershed Assessment Site. LDA = 2.34 (219 sq.mi.)		
Metric:	Metric Value	Applicable metric scoring formula	Metric Score
1. MHTR	18	(MHTR/52)*10	3.5
2. SHTR	9.7	(SHTR/22.7)*10	4.3
3. MHEPT	9	(MHEPT/27)*10	3.3
4. SHEPT	7.7	(SHEPT/14.7)*10	5.2
5. MHSTR	1	(MHSTR/11)*10	0.9
6. P3DOM	79.7	((100-P3DOM)/63)*10	3.2
7. BINDX	6.18	((7-BINDX)/2.7)*10	3.0
8. PEPT	87.9	(PEPT/95.5)*10	9.2
9. PCHR	11.1	(100-PCHR)/98.98)*10	9.0
10. PEPHM	11.4	(PEPHM/78.2)*10	1.5
11. PSCR	0.5	(PSCR/44.7)*10	0.1
12. PDFFG	75.4	((100-PDFFG)/60)*10	4.1
BMIBI Score (Sum 12 metric scores / 12) x 10 (round to nearest integer)			**39**

Table 5-5. BMIBI qualitative scoring ranges.

Biological Condition Rating	Characteristics of Benthic Macroinvertebrate Assemblage
76-100 (Excellent)	High numbers of taxa are present, including many sensitive species. EPT taxa are very diverse and are numerically dominant in benthic macroinvertebrate samples. Habitat and trophic specialists, such as scraper organisms, are present in good numbers. All major functional feeding groups (ffg) are represented, and no particular ffg is excessively dominant. The assemblage is diverse and reasonably balanced with respect to the abundance of each taxon.
56-75 (Good)	Taxa richness is slightly reduced from optimum levels; however, good numbers of taxa are present, including several sensitive species. EPT taxa are fairly diverse and numerically dominate the assemblage. The most-sensitive taxa and some habitat specialists may be reduced in abundance or absent. The assemblage is reasonably balanced, with no taxon excessively dominant. One ffg, often collector-filterers or collector-gatherers, may be somewhat dominant over other ffgs.
31-55 (Fair)	Levels of total taxa richness and EPT taxa richness are noticeably reduced from optimum levels; sensitive species and habitat specialists are rare; EPT taxa still may be dominant in abundance; however, the most-sensitive EPT taxa have been replaced by more-tolerant EPT taxa. The assemblage is not balanced; just a few taxa contribute to the majority of organisms. Collector-filterers or collector-gatherers often comprise more than 50% of the assemblage; representation among other ffgs is low or absent.
0-30 (Poor)	Total taxa richness and EPT taxa richness are low. Sensitive species and habitat specialists are rare or absent. EPT taxa are no longer numerically dominant. A few tolerant organisms typically dominate the assemblage. Trophic structure is unbalanced; collector-filterers or collector-gatherers are often excessively dominant; usually some ffgs are not represented. Abundance of organisms is often low.

Recently, the biological criteria program of the U.S. EPA has endorsed the adaptation of a multi-tiered biological condition gradient (Davies 2003; Jackson 2003). The gradient captures various levels of biological condition from natural (biological integrity) to highly impaired (i.e., not meeting Section 101(a)(2) CWA "fishable" interim use goal). The biocondition gradient establishes a consistent framework for conveying biological information to resource managers and the public, and it can also serve as a template for refining water quality standards and aquatic life use designations.

The conceptual biocondition gradient consists of six tiers that encompass changes in structural and functional biological attributes of the aquatic community along a gradient of human influence. Structural community attributes are mostly related to species composition, while functional attributes are more related to biological processes such as growth and reproduction of organisms, organic matter decomposition and primary production.

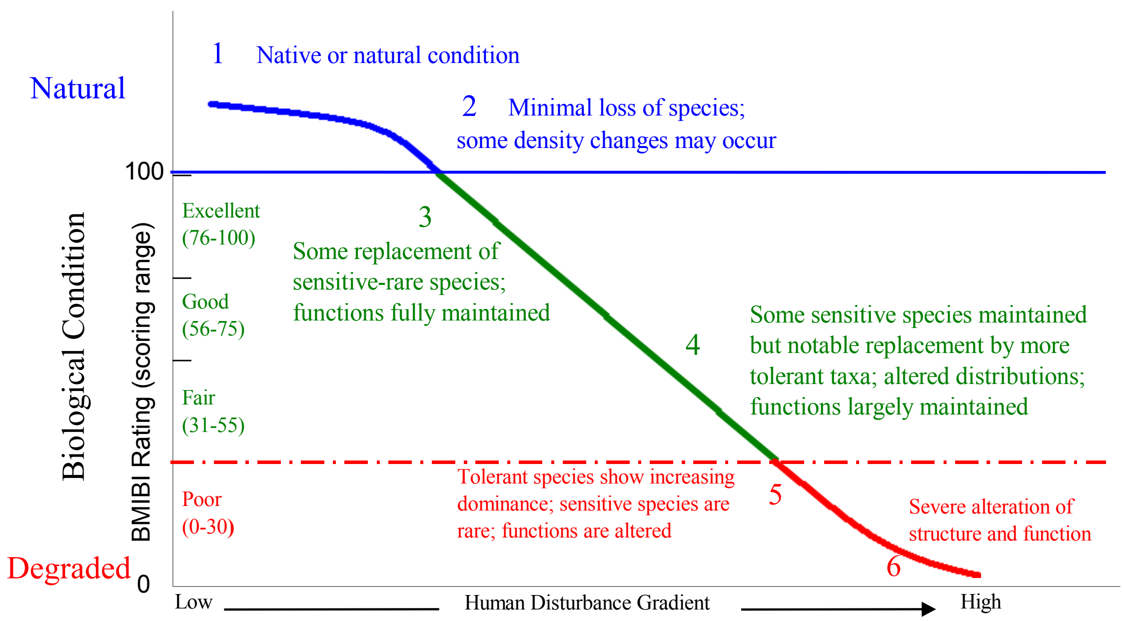


Figure 5-9. Benthic Macroinvertebrate Index of Biotic Integrity (BMIBI) qualitative scoring ranges (excellent, good, fair, poor) in relation to a conceptual tiered biological condition gradient (after Davies 2003).

Although additional customization for Iowa might be needed, Figure 5-9 depicts how the BMIBI qualitative categories might align within the tiered biocondition gradient (Davies 2003). The range of biological conditions that is measurable using the BMIBI probably encompasses Tiers 3-6. In light of the widespread alterations of Iowa's landscape and historic losses of fish and mussel species described in Part 1 of this report, it is unlikely that any Iowa streams currently possess the biological attributes of Tiers 1 or 2. Tiers 3 and 4, which encompass gradually increasing losses of rare and sensitive native species and slight changes in biological functions, probably capture the biocondition in most of

Iowa's rivers and streams. Tier 5 is the level at which biological structure and function is altered to the point where the interim CWA Section 101(a)(2) "fishable" use goal is not likely met. Tier 6 is a highly degraded biological condition that occurs at the highest levels of human disturbance. Sampling results presented below and in Part 6 indicate that a relatively small, but significant, proportion of Iowa streams probably belong in Tiers 5 or 6.

BMIBI Sample Results

BMIBI scores from 1994-1998 sample sites ranged from 15 (poor) – 90 (excellent), and the median score was 63 (good). Most of the scores were rated either good (60%) or fair category (23%). Only 10% of the values were rated as excellent, and 7% were rated as poor. The distribution of scores was probably skewed toward good biological condition since two-thirds of the sites sampled between 1994-1998 were candidate reference sites. The 1994-1998 sample sites are listed in Appendix 3.1, and the metric and BMIBI scores from each site are listed in Appendix 3.2.

5.1.5 Ecoregion Patterns

The ranges of BMIBI scores from 1994-1998 candidate reference sites are displayed in Figure 5-10. Ecoregions explained a significant amount of variability in BMIBI scores (Kruskall-Wallis Analysis of Variance; $p<.001$). Where sample sizes are sufficiently large, statistically significant differences between ecoregions can be detected. For example, BMIBI scores from the Des Moines Lobe (47b) ($n=20$; median = 70) were significantly higher on average than BMIBI scores from the Rolling Loess Prairies (47f) ($n=22$; median = 60). The large variability of BMIBI scores observed in most ecoregions suggests that other factors, such as physical habitat or water quality, are important determinants of BMIBI levels.

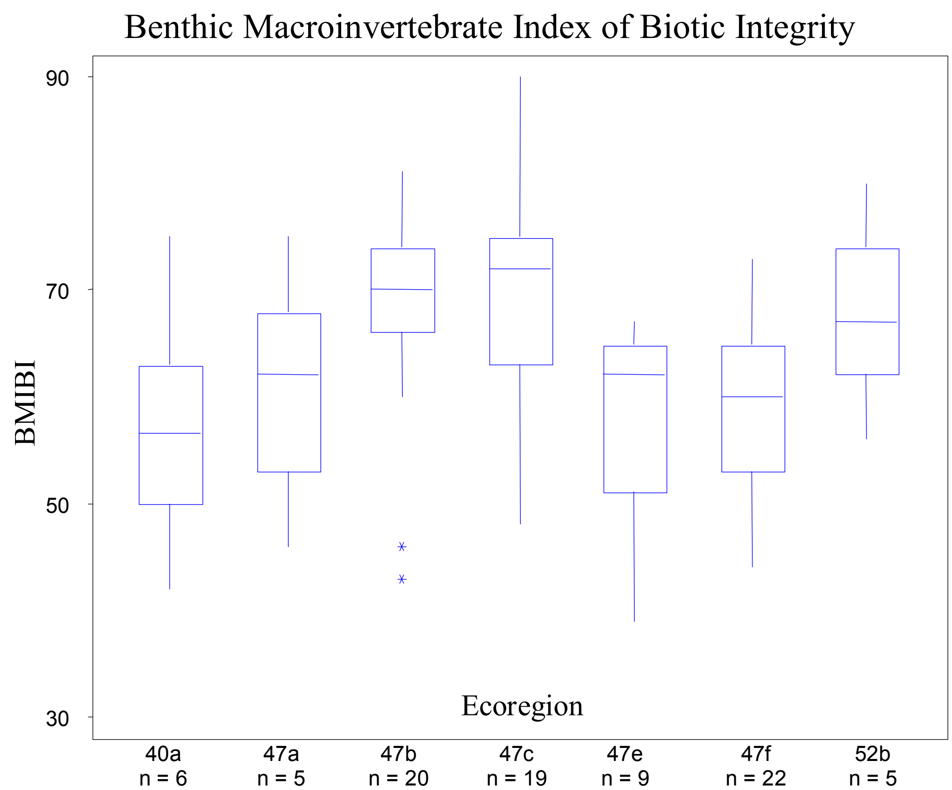


Figure 5-10. Box and whisker plot of 1994-1998 reference site BMIBI scores by ecoregion *(see Figure 3.3)*.

5.1.6 Discrimination of Impacted Sites

An important attribute of a biological indicator is the ability to distinguish least-disturbed reference sites from heavily impacted test sites. To test the BMIBI's discriminatory capability, a statistical analysis of BMIBI scores was conducted using data from reference sites and impacted sites in two ecoregions. The ecoregions, Des Moines Lobe (47b) and Rolling Loess Prairies (47f), were among the few that had sufficient numbers of both types of sites to conduct the analysis. The group of impacted sites included typical stream disturbances such as channelization, riparian livestock grazing, and wastewater discharges.

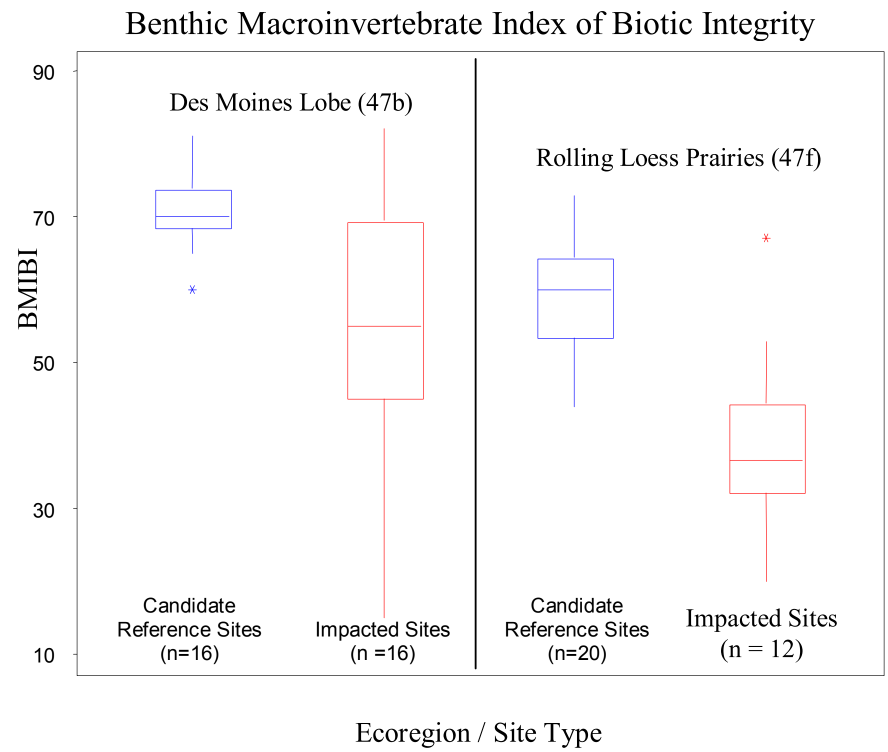


Figure 5-11. Box and whisker plot comparison of candidate reference site and impacted site BMIBI scores from the Des Moines Lobe (47b) and Rolling Loess Prairies (47f) ecoregions.

Figure 5-11 shows good separation of the two types of sites within each ecoregion. Statistical analysis results confirmed the BMIBI was able to distinguish the reference group from the impacted group. In statistical terms, the average rank of candidate reference site BMIBI scores was significantly greater than the average rank of impacted site scores (Mann Whitney rank sum; $p<0.05$) for both ecoregions tested.

5.1.7 Season and Sample Month

Three candidate reference sites were sampled spring, summer, and fall from 1994-1998 to examine the temporal variability of the BMIBI and the appropriateness of the sample index period. The summer samples were collected during the normal index period (July 15 - October 15), while the spring and the fall samples were collected outside of the index period. In particular, there was a need to evaluate how BMIBI levels differed between and within seasons. It is important to evaluate seasonal variations in the BMIBI because inconsistent or biased samples could lead to invalid bioassessment conclusions. Season-related factors that could affect BMIBI sample results include benthic macroinvertebrate life cycles, flow stability, and sampling conditions.

Sampling during the summer-early fall index period generally produced the highest and most consistent BMIBI scores (Figure 5-12). Summer samples resulted in the highest BMIBI score at each of the sites tested. The average rank of summer BMIBI scores was significantly higher than spring BMIBI scores (Mann Whitney rank sum $p<0.05$). BMIBI score variation of summer samples was also less. The average BMIBI coefficient of variation was 0.06 for summer samples compared to 0.18 and 0.14 for spring and fall samples, respectively. From this limited data, it appears the summer - early fall sample index period is preferable to spring or fall for producing optimal and consistent BMIBI scores.

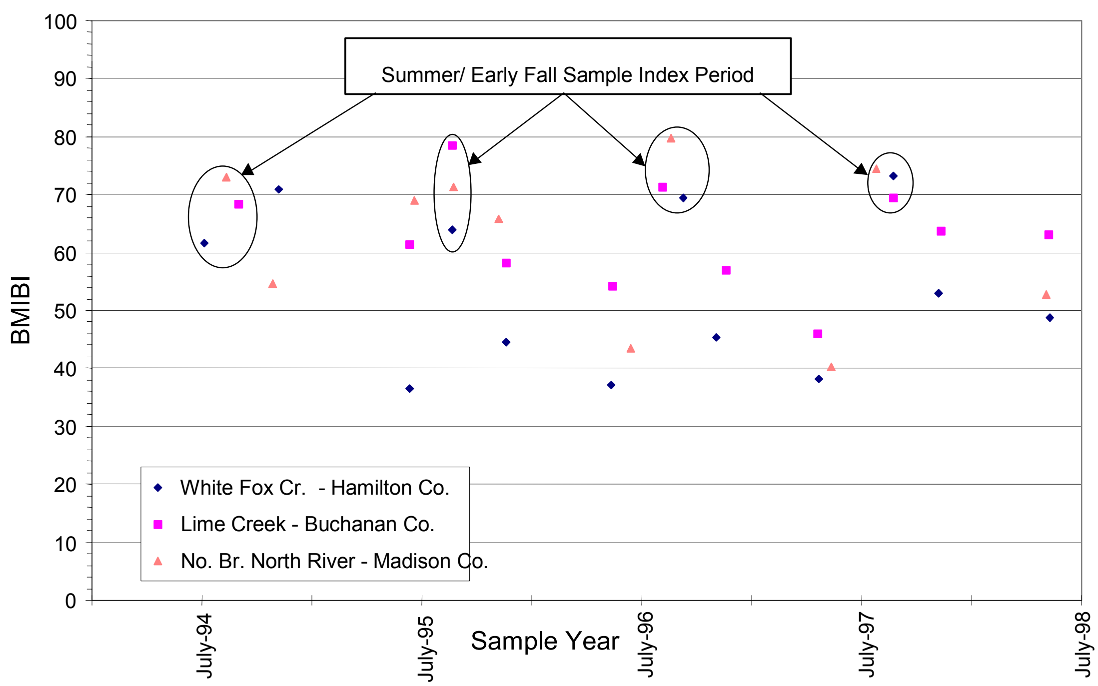


Figure 5-12. Benthic Macroinvertebrate Index of Biotic Integrity (BMIBI) scores from 1994-1998 seasonal sampling sites.

Reference sites sampled from 1994-2001 show no apparent trend or bias in BMIBI score with respect to sampling time (month) within the July 15 - October 15 index period (Figure 5-13). The current sample index period appears to provide satisfactory results with respect to between and within sample-season variation.

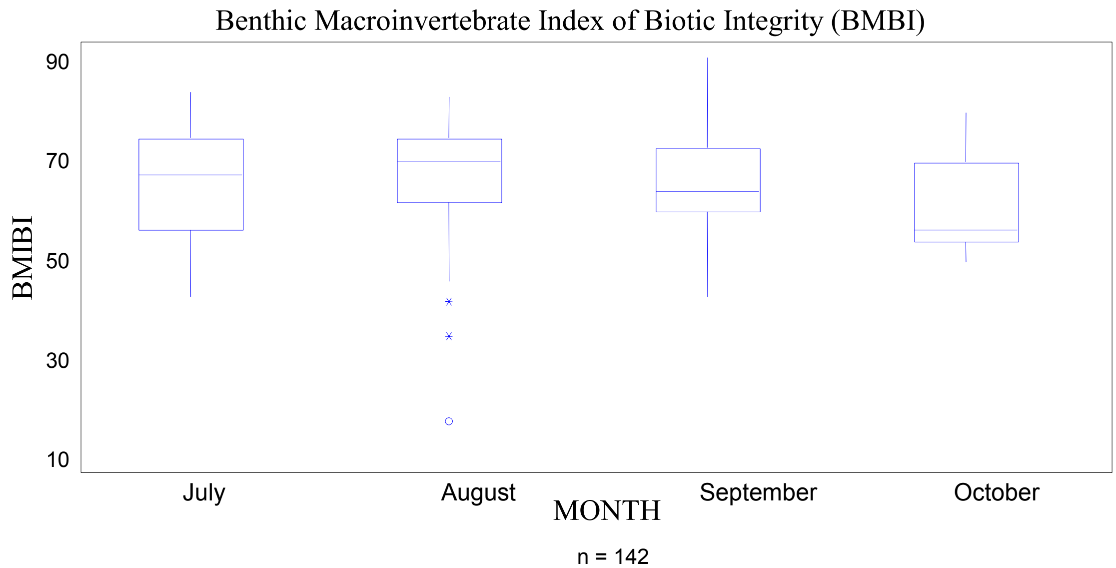


Figure 5-13. 1994-2001 BMIBI sample results by month.

5.1.8 Standard-Habitat Sample Type

Data analysis results presented in Part 4 demonstrated that differences in benthic macroinvertebrate taxa composition are associated with differences in micro-scale habitat characteristics such as substrate. There was greater similarity among benthic macroinvertebrate assemblages sampled from rock substrates in riffle habitat than with assemblages sampled from wood substrates in run habitat. This raises the question would BMIBI scores also differ significantly depending on the type of benthic macroinvertebrate sample collected? To evaluate this possibility, a two-sample rank sum test was used to compare BMIBI scores from wood plate substrate samples with BMIBI scores from rock/riffle samples. Data from 1994-1998 candidate reference sites located in three ecoregions were included in the analysis. Sample data from other ecoregions were not sufficient to be included in the analysis.

Overall, there was no significant difference in the mean BMIBI rank from artificial substrate samples compared to the mean BMIBI rank from riffle samples. Figure 5-14 shows substantial overlap in the quartile ranges of BMIBI scores grouped by ecoregion and sample type. In both the Des Moines Lobe and Iowan Surface ecoregions, the variability of BMIBI scores from artificial substrates was much larger than the variability of BMIBI scores from riffle samples.

The observation that differences in benthic macroinvertebrate taxa composition were related to substrate type is not necessarily contradictory with the observation that BMIBI levels do not appear to differ by substrate type. The BMIBI is an assemblage-level indicator, and therefore, it is not strongly influenced by species identity or the presence/absence of any particular species. For example, if Species A has the same trophic classification and pollution sensitivity as Species B, it can be substituted to derive the same BMIBI metric scores.

The limited data presented here suggest it may not be necessary to establish separate biocriteria for different types of benthic macroinvertebrate standard-habitat samples. This data set, however, is not well suited for isolating the effects of sample type. Side-by-side sample method comparisons are a better approach for this purpose. One study of Sny Magill Creek in Northeast Iowa compared benthic macroinvertebrate metric levels calculated using data from wood plate substrates with metric levels calculated from rock substrate samples collected in adjacent riffles (Schueller et al. 1992). No statistically significant differences in metric levels were found, and it was concluded that either sample collection method was acceptable for long-term monitoring purposes.

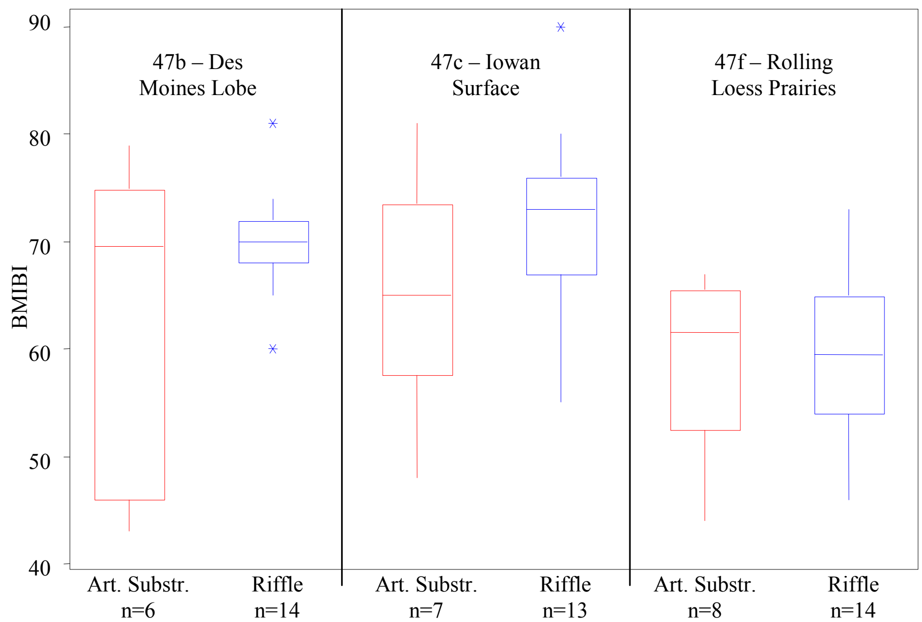


Figure 5-14. Comparison of BMIBI scores using data from two types of standard-habitat samples: 1) artificial substrate (wood-plate) samples; 2) riffle (rock substrate) samples.

5.1.9 Relationships with Physical Habitat and Water Quality Variables

BMIBI scores from 1994-1998 sample sites were correlated with a number of independent physical habitat variables (Table 5 -6). The variables most strongly correlated with the BMIBI, percent coarse rock substrate (r = 0.42) and percent silt substrate (r = -0.48), are substrate composition variables (Figure 5-15). BMIBI scores tended to be higher among sites with abundant coarse substrates and lower among sites where silt was abundant. Habitat variables that are related to stream size (e.g., depth, width, flow, watershed size) were not correlated with the BMIBI. One reason for this could be that scoring for several metrics is adjusted by watershed size.

There were proportionally fewer correlations between the BMIBI and water quality variables and they were generally weaker than correlations with physical habitat variables (Table 5-6; Figure 5-16). Total phosphorus was the most strongly correlated water quality variable (r=-0.42). For most sites, water quality sampling consisted of a single grab sample taken during biological sampling. Without additional sampling, it would be hard to expect stronger correlations between the BMIBI and water quality variables. Most of the BMIBI correlations with physical habitat and water quality variables probably reflect broad regional patterns and gradients in stream conditions.

Table 5-6. Stream habitat and water quality correlations with Benthic Macroinvertebrate Index of Biotic Integrity (BMIBI) scores from 1994-1998 sample sites.

Physical Habitat Variable	Correlation Coefficient (r)*	Water Quality Variable	Correlation Coefficient (r)
% Coarse Substrate	**0.41**	**Water Temperature**	**0.29**
%Gravel Substrate	**0.35**	**Nitrate + Nitrite Nitrogen**	**0.23**
Habitat Index Score	**0.35**	Total Hardness	0.10
Streambank Rating	**0.34**	pH	0.07
%Riffle Habitat	**0.29**	Dissolved Oxygen	0.03
%Boulder Substrate	**0.27**	Atrazine	0.02
%Cobble Substrate	**0.26**	Specific Conductance	-0.03
Riparian Buffer Strip Rating	**0.24**	Total Dissolved Solids	-0.13
Stream Channel Slope	**0.23**	Total Suspended Solids	-0.15
Amount of Stream Shade Variation	**0.17**	**Turbidity**	**-0.21**
Stream flow	0.16	**Total Phosphorus**	**-0.42**
Stream Width:Depth Ratio	0.14		
%Run Habitat	0.12		
Avg. Stream Width	0.10		
Ave. Stream Shade Amount	0.06		
Surface Watershed Area	0.06		
Stream Maximum Depth	0.01		
Stream Segment Sinuousity	-0.04		
%Sand Substrate	-0.05		
Avg. Stream Thalweg Depth	-0.07		
Avg. Stream Depth	-0.08		
%Frequency of Large Woody	**-0.18**		
%Clay Substrate	**-0.24**		
%Pool Habitat	**-0.24**		
%Instream Cover	**-0.27**		
%Bare Streambank	**-0.32**		
%Total Fine Substrates	**-0.38**		
%Silt Substrate	**-0.48**		

* Pearson correlation coefficient "r-value". Bold-highlighted variables have significant linear relationships with BMIBI scores ($p<0.05$).

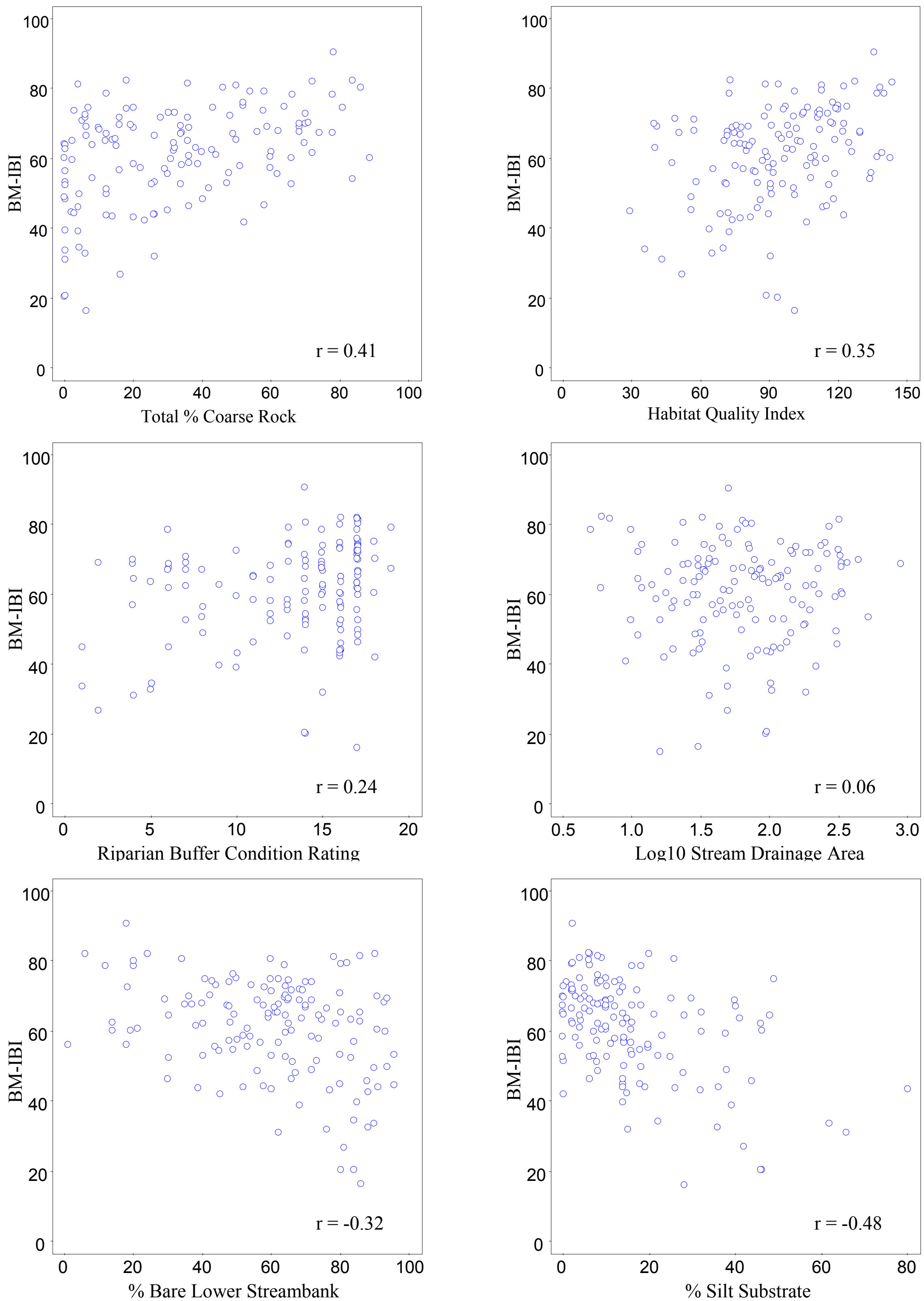


Figure 5-15. Scatter plots of Benthic Macroinvertebrate Index of Biotic Integrity (BMIBI) versus select stream physical habitat variables.

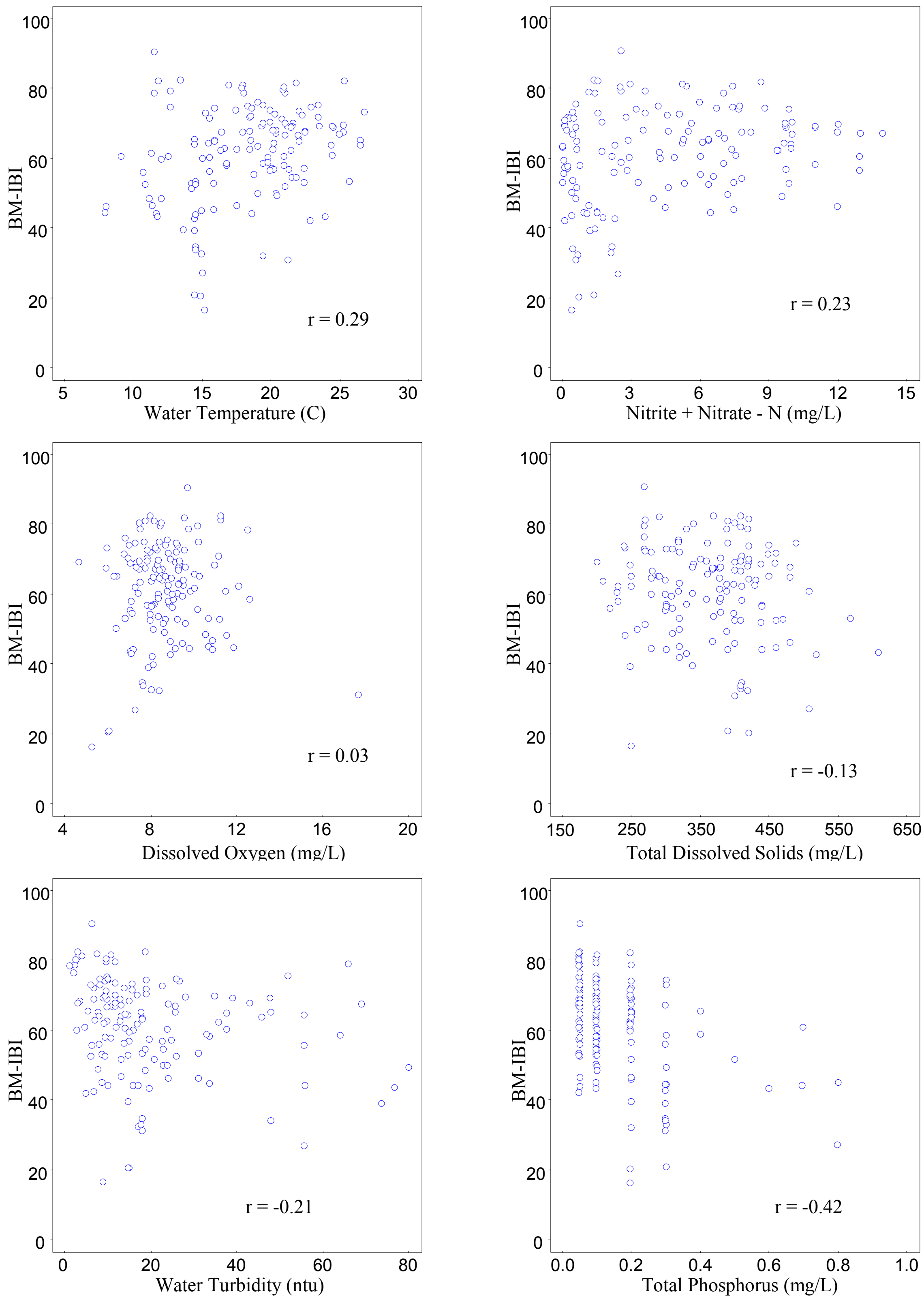


Figure 5-16. Scatter plots of Benthic Macroinvertebrate Index of Biotic Integrity (BMIBI) versus select stream water quality variables.

5.2 Fish Index of Biotic Integrity (FIBI)

The Fish Index of Biotic Integrity (FIBI), like the BMIBI, is a composite index of several individual metrics that provide an assemblage-level assessment of stream biological condition. The FIBI contains twelve metrics that quantify different aspects of stream fish assemblages, including: species richness, composition and tolerance; proportion of individuals belonging to specific feeding and habitat groups; fish abundance and health.

The FIBI was developed using data from 100 candidate reference sites and 55 test sites located in eight ecological regions of Iowa. The sites were sampled between 1994 and 1998. Reference sites were chosen to represent least-disturbed stream habitats within the ecoregions they are located. Test sites were chosen to represent some of Iowa's most common stream impacts such as channelization, riparian livestock grazing, and wastewater discharges, or they were chosen as part of a watershed assessment project.

FIBI metrics were calibrated using reference site data from warm water perennial streams. The responses of some metrics, particularly species richness metrics, to changes in stream quality are different in cold water streams (Lyons 1992; Lyons et al. 1996) than warm water streams. Application of the FIBI to cold-water fish assemblage data may lead to erroneous conclusions about stream condition. Therefore, it is strongly recommended the FIBI only be applied to perennial warm water streams. The Midwest cold water stream IBI's developed by Lyons et al. (1996) and Mundahl and Simon (1997) are potentially useful alternatives for assessing Iowa's cold water streams.

5.2.1 Metric Review

The same methods used to evaluate candidate BMIBI metrics were also used to evaluate candidate FIBI metrics. The candidate list included 31 metrics was compiled from bioassessment literature including: Barbour et al. (1995); Barbour et al. (1999); Karr et al. (1986); Karr and Chu (1999b); Lyons (1992); Niemala et al. (1999); OEPA (1987). These literature sources describe the metrics, discuss their ecological basis and patterns of response to environmental disturbance, and identify where the metrics have been used in various regions of the U.S. In selecting candidate metric for evaluation, a determination of which metrics could be calculated using the data collected for this project was also done.

The candidate metrics were assigned to five general categories (Table 5-7). As described in Section 5.1, the review process looked at four aspects of metric performance: 1) measurement variability (sampling error); 2) discriminatory power; 3) stream quality gradient response; 4) redundancy (excessive correlation between metrics).

Table 5-7. Biological data metrics evaluated for use in the Fish Index of Biotic Integrity (FIBI).

Metric Category				
Species / Taxa Richness	Balance / Diversity / Composition	Trophic and Reproductive Guilds	Tolerance	Fish Abundance and Condition
1. number of (#) benthic invertivore sp. 2. # darter sp. 3. # native fish sp. 4. # native minnow sp. 5. # round-bodied sucker sp. 6. # sensitive sp. 7. # sucker sp. 8. # sunfish sp.	9. percent abundance (%) dominant fish species 10. % 3-dominant fish species 11. % 5-dominant fish species 12. evenness index 13. Shannon's Diversity Index (H') 14. % green sunfish 15. % pioneering species 16. % round-bodied suckers 17. % white suckers	18. % benthic invertivores 19. % invertivores 20. % omnivores 21. % top carnivores 22. % complex parental care (nest) spawners 23. % pelagophils + % pelagolithophil spawners 24. % simple lithophil spawners 25. % simple lithophils + % lithophil brood hiding spawners	26. % intolerant fish 27. % tolerant fish 28. Fish assemblage tolerance index	29. catch per unit effort 30. adjusted catch per unit effort (tolerant fish subtracted) 31. % DELTS (deformaties, eroded fins, lesions, tumors)

The results of the evaluation process are presented in Table 5-8. Twelve metrics were recommended for the FIBI, including at least one metric from each of the five categories. The number and array of metrics is consistent with recommendations for construction of a multi-metric index that is responsive to wide-ranging levels and types of human influence (Barbour et al. 1999; Karr and Chu 1999b).

Six metrics were considered "core" metrics because they showed the least measurement variability, greatest discriminatory powers, and broadest ranges of response. The core metrics are 1) #native fish species; 2) #sucker species; 3) #sensitive species; 4) #benthic invertivore species; 5) % 3-dominant taxa; 6) fish assemblage tolerance index. The blend of species richness, balance/dominance, and tolerance types of metrics that make up the FIBI core metric group is similar in composition to the types of core BMIBI metrics.

The other recommended metrics showed greater measurement variability and/or narrower ranges of response. These metrics will continue to be evaluated. For now, however, the metrics are included because they broaden the dimensionality of the FIBI and increase its ability to discriminate sites at low and high ends of the stream quality continuum. Two metrics, percent abundance top carnivores and adjusted catch per unit effort, particularly need further scrutiny. Both metrics are widely used in other bioassessment programs (Barbour et al. 1999) and have been retained until a more conclusive analysis is completed.

The last step in the metric evaluation process was to examine correlations between the FIBI and its twelve component metrics. The analysis found that all twelve metrics had a significant linear relationship with the FIBI and responded in the expected direction (e.g., metric increases with increasing FIBI). None of the metrics was strongly correlated (i.e., $r > 0.81$) with the FIBI, suggesting that no individual metric or type of metric is overly dominant within the index.

Table 5-8. Evaluation results for candidate fish assemblage metrics.

Metric	Direction Of Response To Declining Stream Conditions	Metric Variability (Sampling Error)	Impacted Site Discriminatory Power	Stream Gradient Response Range	Potential Redundancy (R >0.81)
FIBI metrics:					
# native fish species	<	low	moderately strong	broad	# sucker sp., # benthic invertivore sp., # Round-bodied sucker sp.
# sucker species	<	low	moderately strong	broad	# native fish sp., # Round-bodied sucker sp., # benthic invertivore species
# sensitive species	<	low	strong	broad	
# benthic invertivore species	<	low	strong	broad	# native fish sp., # Round-bodied sucker sp., # sucker species, # Darter sp.
% 3-dominant fish species	>	low	strong	broad	% Dom. Sp.
% benthic invertivores	<	medium	strong	broad	fish assemblage tolerance index, Evenness
% omnivores	>	medium	moderately strong	narrow	
% top carnivores	<	high	weak	narrow	
% simple lithophil spawners	<	medium	strong	broad	
fish assemblage tolerance index	>	low	strong	broad	% benthic invertivore sp., %Intolerant fish sp.
adjusted catch per unit effort	<	medium	week	narrow	Total catch per unit effort
% fish with DELTs	>	high	weak	narrow	
FIBI (composite of above 12 metrics)	<	low	strong	broad	
Metrics not selected for FIBI:					
Shannon's H'	<	low	strong	broad	% Dom. Sp, % 3-dom. fish sp.
Evenness	<	low	moderately strong	narrow	% Dom. Sp, % benthic invertivores
% Dom. Sp.	>	low	strong	broad	Shannon's H', % 3-dom. fish sp., Evenness,
% 5-Dom. sp.	>	low	strong	broad	% Dom. Sp, % 3-dom. fish sp, Shannon's H'
%Round-bodied sucker sp.	<	medium	moderately strong	broad	
%White suckers	>	medium	weak	broad	
Total catch per unit effort	>	medium	week	undefinable	adjusted catch per unit effort
%Pioneering sp.	>	low	moderately strong	narrow	% Tolerant fish sp.
Total catch per unit effort	<	medium	weak	undefinable	
%Pelagolithophil spawners	>	medium	weak	undefinable	
%Simple lithophil + lithophil brood hider spawners	>	low	weak	broad	
% complex parental care (nest) spawners	>	low	weak	undefinable	
# Darter sp.	<	low	strong	broad	# benthic invertivore species
# Round-bodied sucker sp.	<	low	moderately strong	broad	# native fish species, # sucker species, # benthic invertivore species
# Fish families	<	low	moderately strong	broad	
# sunfish sp.	<	low	weak	undefinable	
# native minnow sp.	<	low	weak	broad	
%Intolerant fish sp.	<	medium	strong	broad	fish assemblage tolerance index
% Tolerant fish sp.	>	low	strong	broad	%Pioneering sp.
%Invertivore fish sp.	<	low	moderately strong	narrow	

5.2.2 Metric Descriptions and Scoring Criteria

Scatter plots of FIBI metrics were created using candidate reference site sampling data from 1994-1998 (Figures 5-16 - 5-21). The same procedures used to establish optimum score lines for BMIBI metrics were used to establish optimum score lines for FIBI metrics (see Section 5.1.3). Adjustments were made for FIBI metrics that exhibit a linear relationship with stream size. The first four metrics, native fish species richness, number of sucker species, number of sensitive fish species, and number of benthic invertivore species, each include a scoring adjustment for major river basin (i.e. Mississippi River or Missouri River). As described in Part 3, Iowa streams in the Missouri River basin contain significantly fewer fish species than streams in the Mississippi River basin. To establish appropriate reference expectations for species richness metrics, separate optimum levels for each basin were developed.

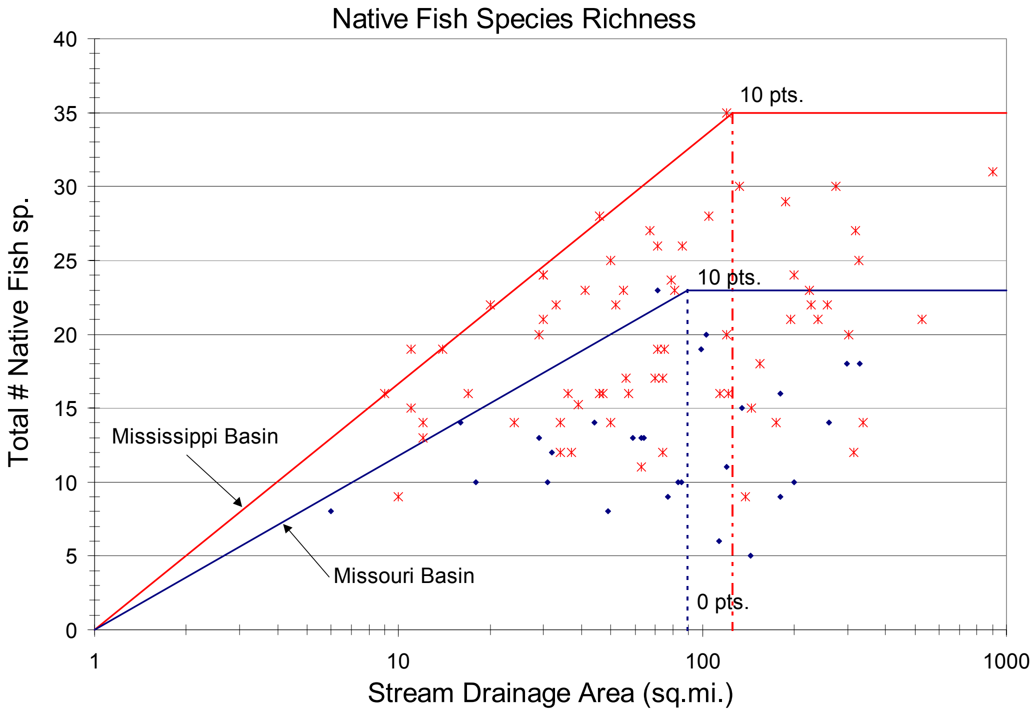
1. Native Fish Species Richness (NTVSP) is the total number of native fish species collected from the designated sample reach. In warm water streams, the number of native fish species is expected to decrease with declining stream quality. The presence of many native fish species indicates that physical habitat and water quality are suitable to meet the diverse needs of many different species. As reference stream size increases, the optimum level of native fish species richness generally increases (Figure 5-17). The metric has a broad range of response across varying levels of stream quality indicators.

Introduced and non-native species, such as the common carp (*Cyprinus carpio*), can represent a large proportion of the fish assemblage in highly disturbed streams; therefore, these species are not counted for this metric. The bluegill (*Lepomis macrochirus*) and largemouth bass (*Micropterus salmoides*) are commonly stocked in Iowa's lakes and farm ponds. Juveniles are often found in Iowa's wadeable streams where they are not thought to successfully reproduce. Because these species can artificially inflate the native fish species metric, bluegill and largemouth bass are classified as introduced species and not counted in this metric.

2. Number of Sucker Species (SCKRSP) is the number of species belonging to the sucker family (Catostomidae). Suckers are relatively long-lived fish that live near the stream bottom in deeper areas of streams. Several native sucker species are considered habitat specialists because they feed primarily on benthic invertebrates and require silt-free, rock substrates to successfully reproduce. As reference stream size increases, sucker species richness generally increases to optimum levels (Figure 5-17). In Iowa's warm water streams, the number of sucker species is highest in streams that have good physical habitat and water quality characteristics. The metric shows a moderate range of response across varying levels of stream quality indicators.

3. Number of Sensitive Fish Species (SNSTVF). As stream conditions deteriorate, fish species that are classified as sensitive decline in abundance and will eventually disappear. Many sensitive species are habitat specialists that are less equipped to adapt to stream changes affecting their specific habitat niche. Other sensitive species are intolerant of water quality degradation, such as increases in turbidity, nutrient enrichment, and toxins. The metric has a broad range of response across varying levels of stream quality indicators. As reference stream size increases, sensitive fish species richness generally increases to the optimum level (Figure 5-18).

4. Number of Benthic Invertivore Species (BINV). Fish species classified as benthic invertivores feed predominantly on aquatic insects and other bottom-dwelling macroinvertebrates. The number of benthic invertivore species reaches its highest level in streams that have abundant amounts of stable benthic habitat. The number of benthic invertivore fish species is expected to decline in response to physical habitat alterations or water quality impacts that reduce the availability of benthic macroinvertebrates. As reference stream size increases, benthic invertivore fish species richness generally increases to the optimum level (Figure 5-18).



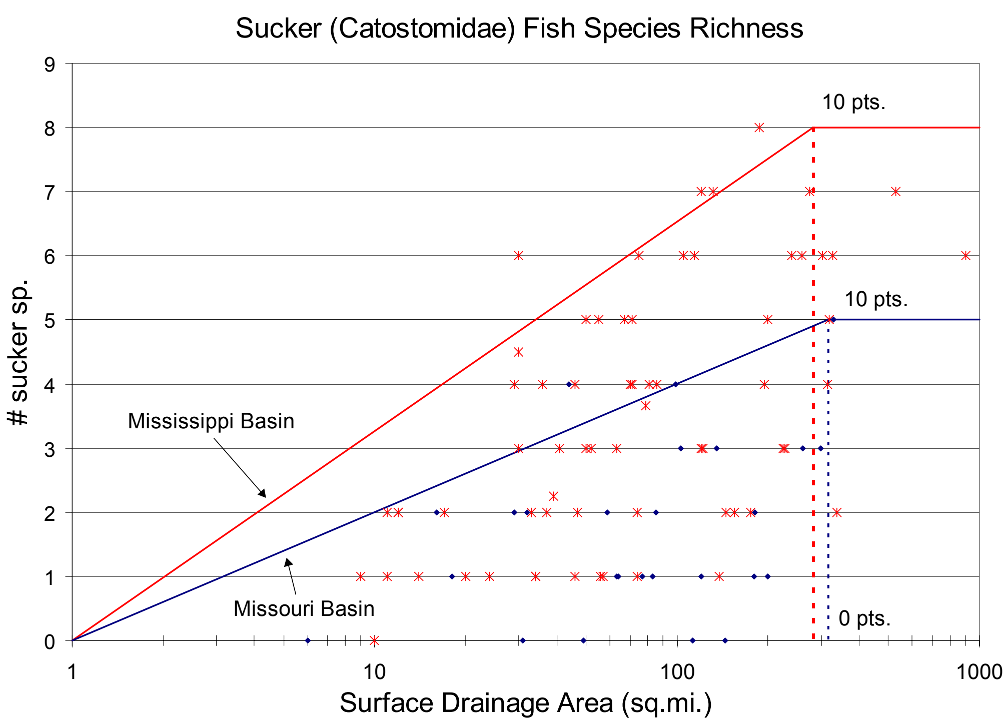
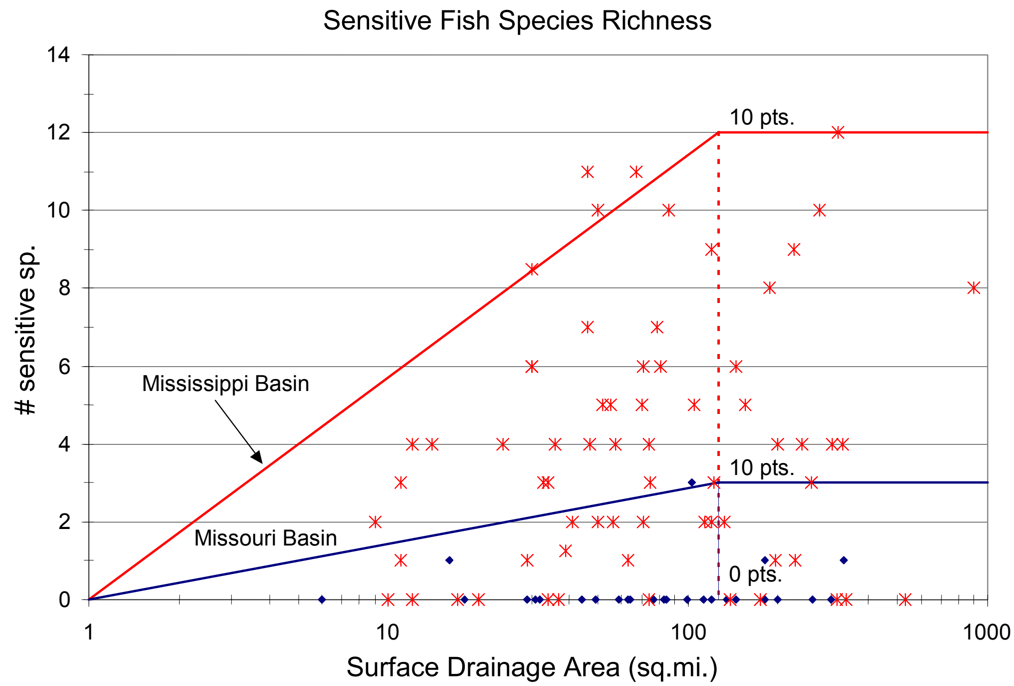


Figure 5-17. Native fish species richness (NTVSP) metric (top) and sucker (Catostomidae) species richness (SCKRSP) metric (bottom).



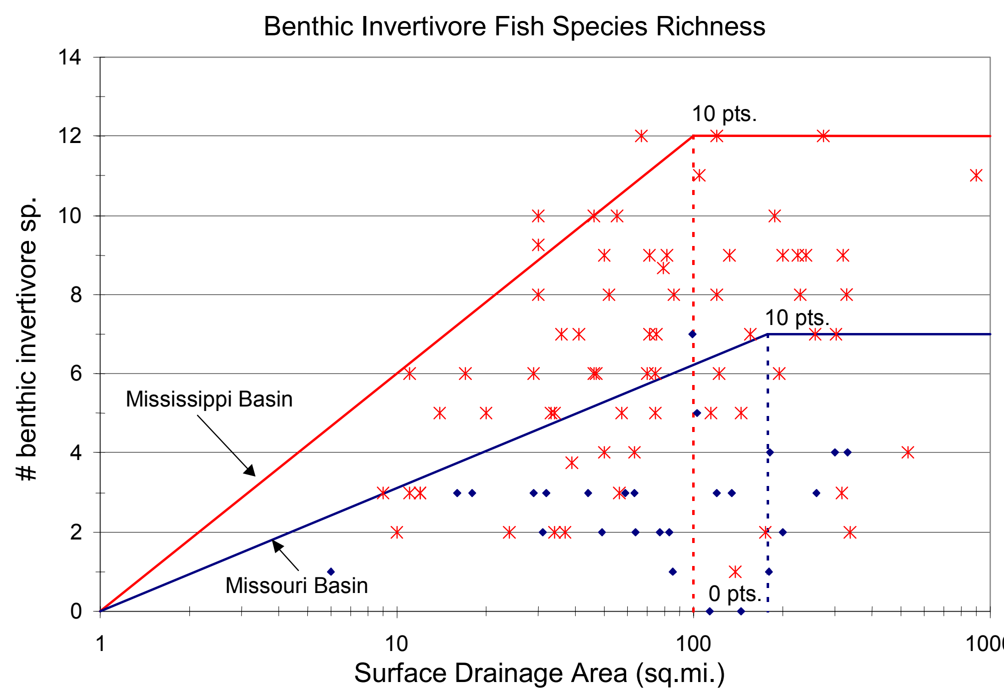


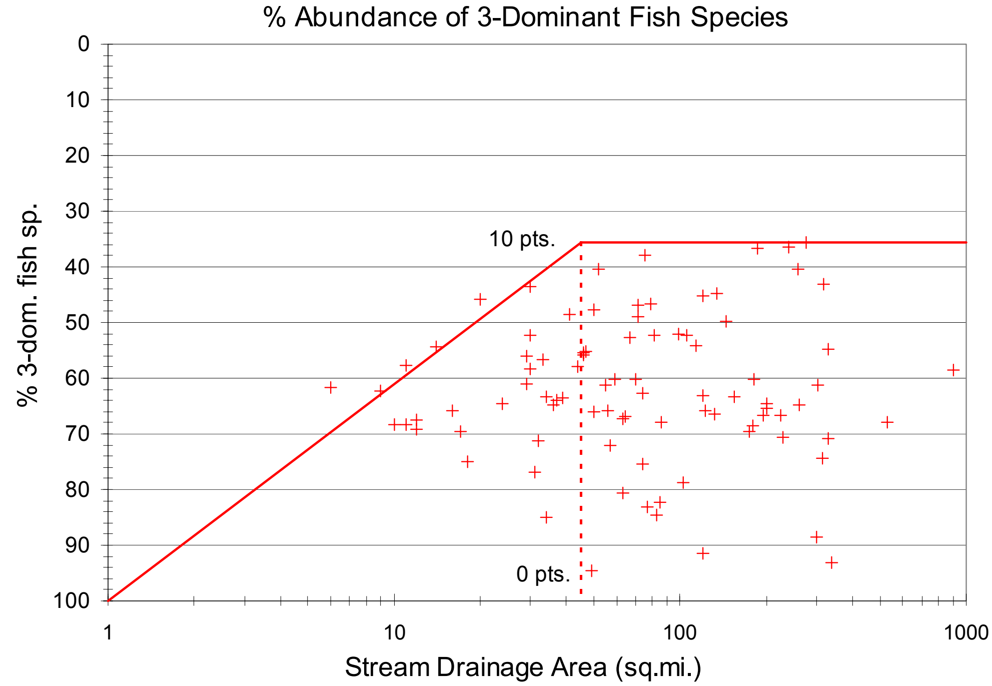
Figure 5-18. Sensitive fish species richness (SNSTVSP) metric (top) and benthic invertivore fish species richness (BINVSP) metric (bottom).

5. Percent Abundance of Three Dominant Fish Species (P3DOM) is the proportion of sampled fish represented by the three most-abundant fish species. This metric is an indicator of balance in the fish assemblage that is inversely related to stream biological condition. Healthy warm water streams have diverse fish assemblages in which a majority of individuals is distributed among many species. As stream conditions worsen, an increasingly higher proportion of the total number of fish is comprised of just a few opportunistic and tolerant species. In reference streams, the percent abundance of the three dominant fish species generally decreases with increasing stream size (Figure 5-19).

6. Percentage of Fish as Benthic Invertivores (PBINV) is the proportion of sampled fish that predominantly feed on benthic macroinvertebrates. The metric is an indicator of stream benthic habitat quality as it relates to production of aquatic insects and invertebrates for fish. Streams that are impacted by pollution or sedimentation are less likely to support abundant benthic invertebrate populations. Consequently, the proportion of fish as benthic invertivores is expected to decline in response to deteriorating stream quality.

7. Percentage of Fish as Omnivores (POMNV) is the proportion of sampled fish that are omnivorous feeders (i.e., fish diet consists of significant quantities of both plant and animal matter, including detritus). This metric is expected to increase in response to deteriorating stream quality. Omnivorous fish species have opportunistic feeding habits, and are able to derive nutritional value from a broad array of food items. Omnivorous fish generally become more abundant in streams that are enriched by nutrients and organic matter.

8. Percentage of Fish as Top Carnivores (PTOPC). The proportion of fish that are top carnivores (i.e., fish constitute a significant part of diet as adults) is an indicator of stream physical habitat complexity and stability. Top carnivore species often require pools or other areas of concealment such as woody debris snags in order to rest and stalk their prey. Viable populations of minnows and other prey fish must also be present to support large piscivorous fish. The proportion of fish as top carnivores is expected to decline in response to deteriorating stream quality.



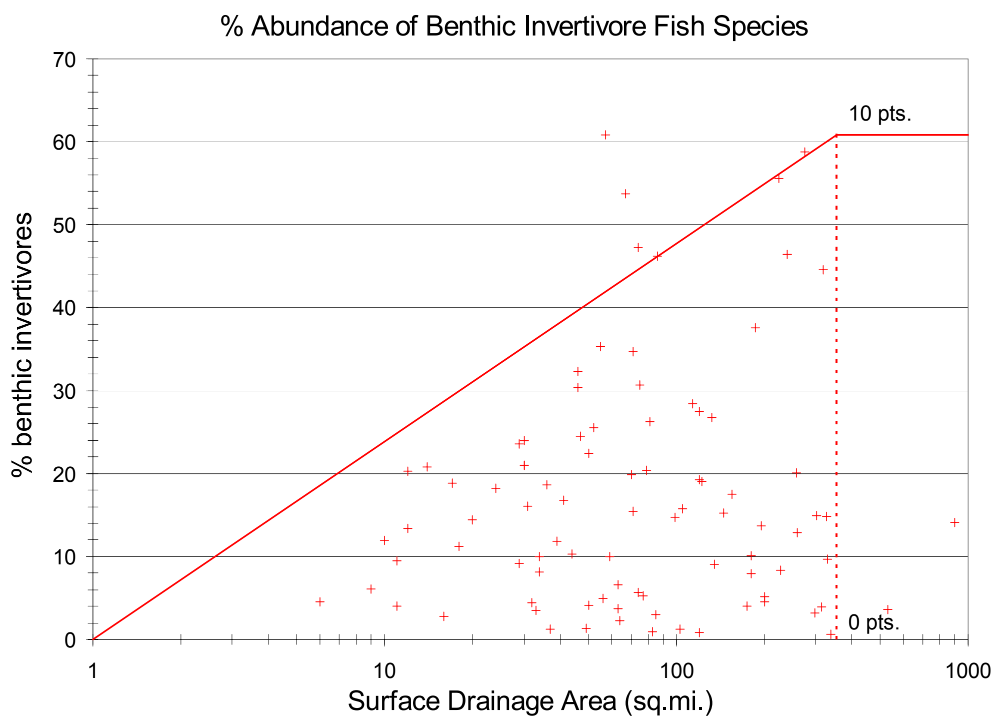


Figure 5-19. Percent abundance of three dominant fish species (P3DOM) metric (top) and percentage of fish as benthic invertivores (PBINV) metric (bottom).

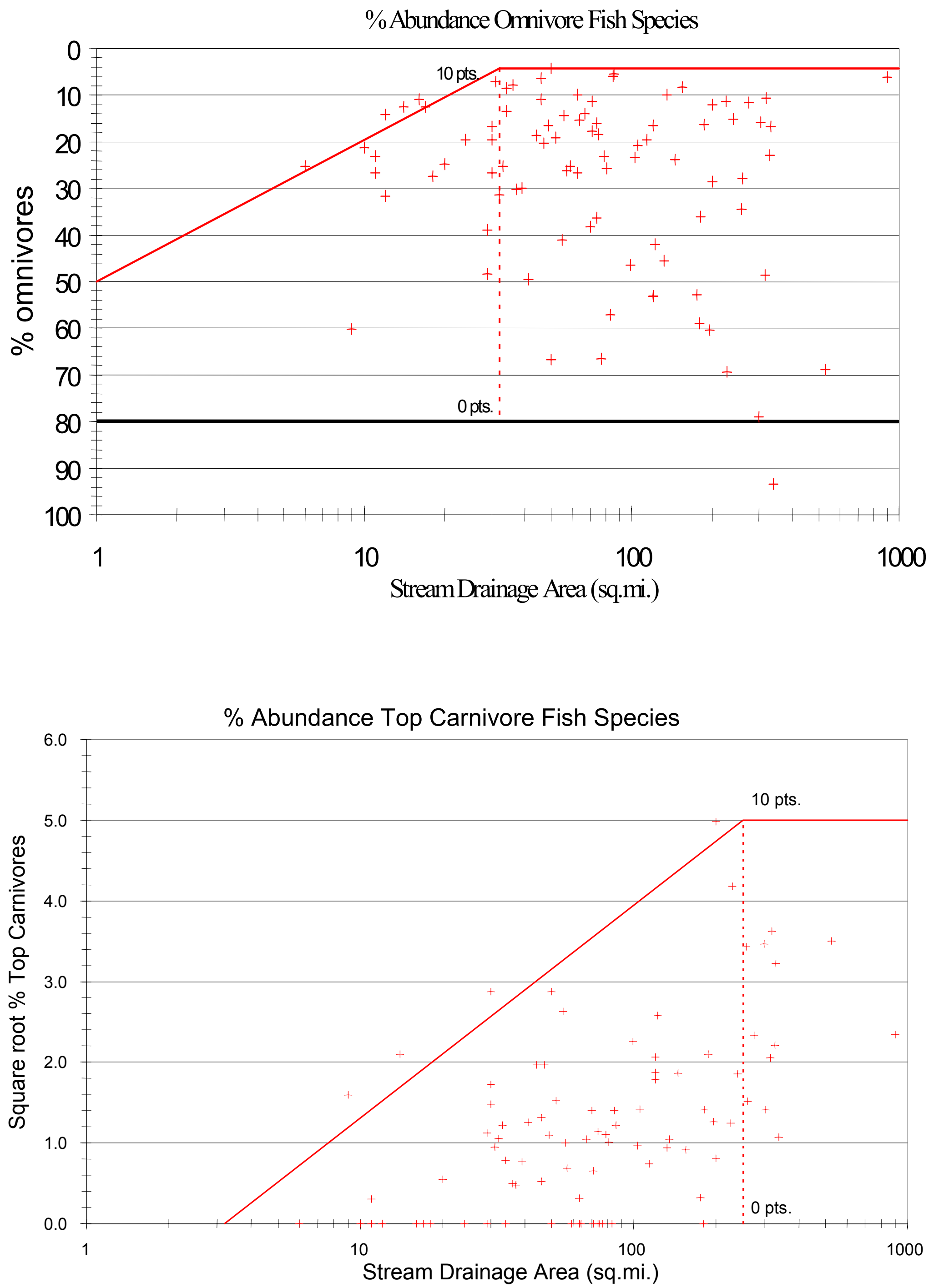


Figure 5-20. Percentage of fish as omnivores (POMNV) metric (top) and percentage of fish as top carnivores (PTOPCV) metric (bottom).

9. Percentage of Fish as Simple Lithophilous Spawners (PSLTH) is the proportion of sampled fish belonging to the simple lithophil-spawning guild. Simple lithophils lay their eggs over rock substrates in streams and provide no paternal care in terms of nest preparation or maintenance. The reproductive success of simple lithophils is adversely impacted by sedimentation, which fills in the interstitial spaces of rocks where fertilized eggs incubate. The metric is expected to decline in response to deteriorating stream quality.

10. Fish Assemblage Tolerance Index (TOLINDX). The fish assemblage tolerance index is a simplified version of the Hilsenhoff Biotic Index (Hilsenhoff 1987). The metric is calculated by summing each of the products of species proportional abundance and species tolerance value (see below). Species tolerance classifications are listed in Appendix 2.2. Each species is assigned a tolerance value of either 0 (sensitive), 5 (intermediate), or 10 (tolerant).

Fish Assemblage Tolerance Index:

$$\sum_{i=1}^{s} \frac{n_i\,(TV_i)}{N}$$

Where: s = no. species in fish assemblage sample
n_i = no. individuals of species i
TV_i = tolerance value* of species i
N = total no. individuals in sample

* fish tolerance values: sensitive species = 0; intermediate tolerance species = 5; tolerant species = 10.

Similar to how the HBI operates, a stream that supports a relatively large proportion of sensitive species and species of intermediate sensitivity will have a lower tolerance index score compared to a stream that is dominated by tolerant fish species. The fish assemblage tolerance index is expected to increase in response to declining stream quality.

Metric Scoring Adjustment for Low Fish Abundance. A scoring adjustment (SA) is used to cap the maximum possible score of metrics 5-10. The purpose of the scoring adjustment is to add additional discriminatory power to the FIBI in very degraded systems and to prevent metric scores and the FIBI from becoming artificially inflated when fish abundance is low and proportional abundance metrics are less statistically reliable. Low-end adjustments of the FIBI were developed after recommendations of Rankin and Yoder (1999) based on the Ohio bioassessment experience.

The following graduated maximum score cap is applied to proportional metrics 5-10:

- Total # fish / 500 feet stream length < 25, metric score = 0
- Total # fish / 500 feet stream length ≥ 25 and ≤ 50, maximum possible metric score = 2.5
- Total # fish / 500 ft. stream length > 50 and ≤ 75, maximum possible metric score = 5.0
- Total # fish / 500 ft. stream length > 75 and ≤ 100, maximum possible metric score = 7.5
- Total # fish / 500 ft. stream length >100, maximum possible metric score = 10.0

11. Adjusted Catch Per Unit Effort (ADJCPUE) is the number of fish collected per 100-foot stream length, excluding individuals that are classified as tolerant and/or exotic/introduced species. Healthy Iowa streams are expected to support reasonably high numbers of native fishes. High numbers of tolerant or exotic/introduced species can occur in streams that are organically enriched or disturbed. Therefore, for this metric only, fish classified in Appendix 2.2 as tolerant or exotic/introduced species are subtracted from the total number of sampled fish.

Lyons (1992) observed that fish abundance actually reaches a maximum at intermediate levels of stream disturbance. Taking this into consideration, a special procedure was used to establish the optimum line for the ADJCPUE metric (Figure 5-22). The metric values were first plotted against reference site fish index of biotic integrity (FIBI) scores calculated with all the FIBI metrics except ADJCPUE. The ADJCUE metric scores were obtained for the sites having the highest FIBI scores. The ADJCPUE optimum level was then set equal to the ADJCPUE that was matched or exceeded by 5% of sites with the highest FIBI scores.

12. Percentage of Fish with Deformities, Eroded fins, Lesions, or Tumors (PDELT) is the proportion of sampled fish that exhibit at least one DELT anomaly. Normally the proportion of fish with DELTs is very low (i.e., <2% of sample) in streams that are not subjected to chronic pollution impacts (Sanders et al. 1999). Either 5 or 10 points are subtracted from the final IBI score in cases where the proportion of fish with DELTs slightly or substantially exceeds natural background levels of occurrence for external physical anomalies (Figure 5-22).

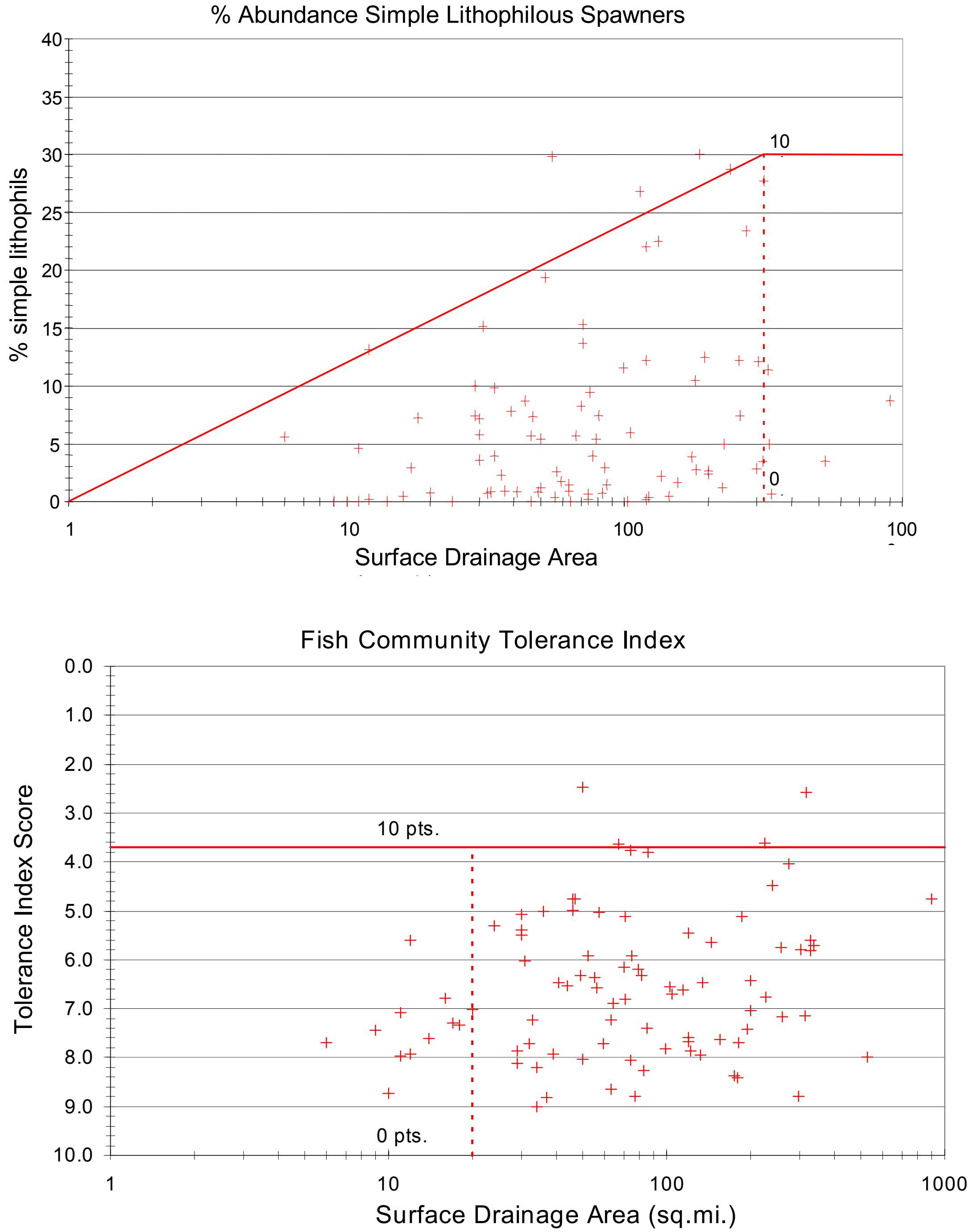
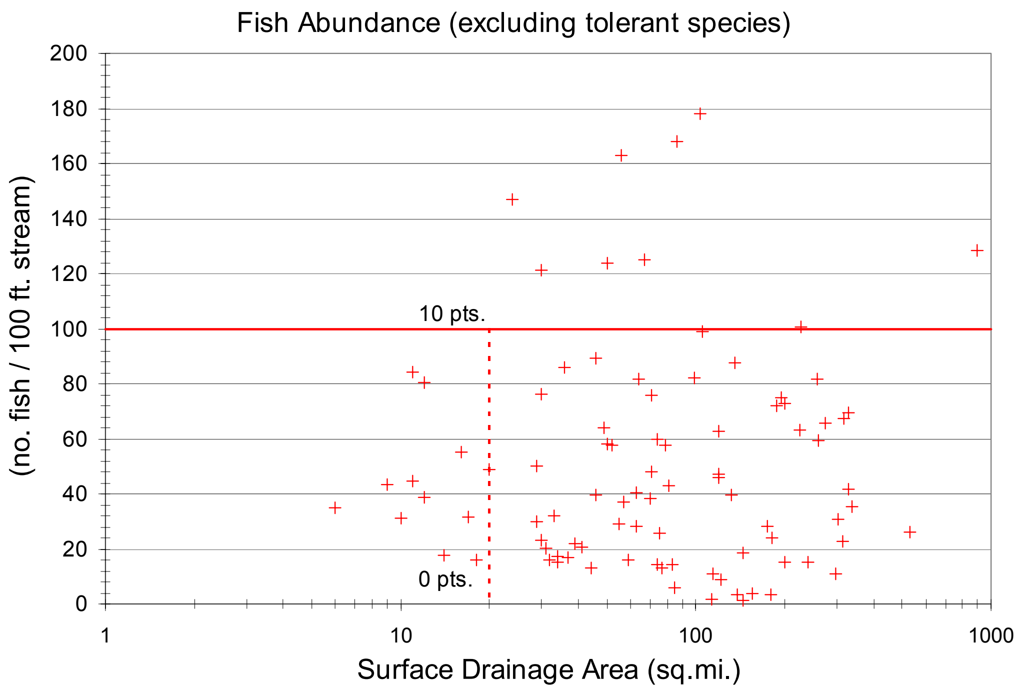


Figure 5-21. Percentage of fish as simple lithophilous spawners (PSLTH) metric (top) and fish assemblage tolerance index (TOLINDX) metric (bottom).



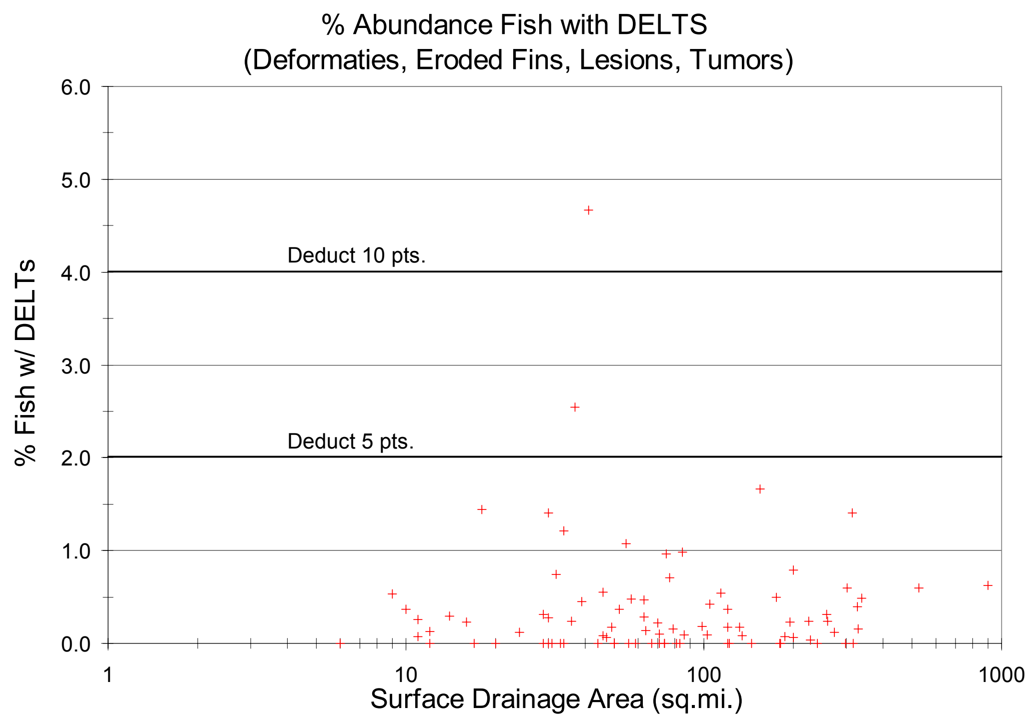


Figure 5-22. Adjusted catch per unit effort (ADJCPUE) metric (top) and percentage of fish with deformities, eroded fins, lesions and tumors (PDELT) metric (bottom).

5.2.3 Calculating the Index

Two examples showing how to calculate the FIBI are provided in Appendix 2. Metric scoring formulas and FIBI calculation instructions are listed in Table 5-9 and Appendix 2.1. Fish species classifications needed to calculate metrics are listed in Appendix A2.2.

The FIBI has a possible scoring range from 0-100. Table 5-10 provides qualitative scoring categories and guidelines for interpreting FIBI scores. The guidelines represent a general framework for relating FIBI scores to fish assemblage attributes. It is important to remember that the categories reflect contemporary biological conditions in Iowa's wadeable rivers and streams. Because of data limitations, it would be difficult, if not impossible, to quantify the natural, pre-European biological condition of Iowa's streams in comparable terms. A descriptive and qualitative analysis, however, would be useful to define an historic benchmark at the top of the biocondition scale to measure progress toward restoring the biological integrity of Iowa's rivers and streams.

Recently, the biological criteria program of the U.S. EPA has endorsed the adaptation of a multi-tiered biological condition gradient (Davies 2003; Jackson 2003). The gradient captures various levels of biological condition from natural (biological integrity) to highly impaired (i.e., not meeting Section 101(a)(2) CWA "fishable" interim use goal). The biocondition gradient establishes a consistent framework for conveying biological information to resource managers and the public, and it can also serve as a template for refining water quality standards and aquatic life use designations.

The conceptual biocondition gradient consists of six tiers that encompass changes in structural and functional biological attributes of the aquatic community along a gradient of human influence. Structural community attributes are mostly related to species composition, while functional attributes are more related to biological processes such as growth and reproduction of organisms, organic matter decomposition and primary production.

Table 5-9. FIBI metric scoring formulas and index calculation instructions.

#	Metric Definition	Metric Abbrv.	Stream Drainage Area Criterion	Metric Scoring Formula
1a	Native fish species richness - Mississippi Basin	NTVSP-MSP	LDA≤2.10 LDA>2.10	(NTVSP/(16.67*LDA))*10 (NTVSP/35)*10
1b	Native fish species richness - Missouri Basin	NTVSP-MO	LDA≤1.95 LDA>1.95	(NTVSP/(11.79*LDA))*10 (NTVSP/23)*10
2a	Sucker species richness- Mississippi Basin	SCKRSP-MSP	LDA≤2.45 LDA>2.45	(SKCRSP/(3.26*LDA))*10 (SCKRSP/8)*10
2b	Sucker species richness- Missouri Basin	SCKRSP-MO	LDA≤2.5 LDA>2.5	(SCRSP/(2.0*LDA))*10 (SCKRSP/5)*10
3a	Sensitive fish species richness - Mississippi Basin	SNSTVSP-MSP	LDA≤2.1 LDA>2.1	(SNSTVSP/(5.71*LDA))*10 (SNSTVSP/12)*10
3b	Sensitive fish species richness - Missouri Basin	SNSTVSP-MO	LDA≤2.1 LDA>2.1	(SNSTVSP/(1.43*LDA))*10 (SNSTVSP/3)*10
4a	Benthic invertivore fish species richness - Mississippi Basin	BINVSP-MSP	LDA≤2.0 LDA>2.0	(BINVSP/(6.0*LDA))*10 (BINVSP/12)*10
4b	Benthic invertivore fish species richness - Missouri Basin	BINVSP-MO	LDA≤2.25 LDA>2.25	(BINVSP/7)*10 (BINVSP/(3.11*LDA))*10
Metrics 5-10: IF total number of fish per 500 ft. stream length ≤ 100, THEN refer to scoring adjustment (SA) below.				
5	Percent abundance three dominant fish species	P3DOM	LDA≤1.65 LDA>1.65	((100-P3DOM)/(39*LDA))*10 ((100-P3DOM)/64.35)*10
6	Percent fish as benthic invertivores	PBINV	LDA≤2.55 LDA>2.55	(PBINV/(23.84*LDA))*10 (PBINV/60.8)*10
7	Percent fish in as omnivores	POMNV	LDA≤1.5 LDA>1.5	((80-POMNV)/(80-(50-30.5*LDA)))*10 ((80-POMNV)/75.75)*10
8	Percent fish in sample as top carnivores	PTOPC	LDA ≤2.4 LDA>2.4	(sq.rt.PTOPC/(2.67*LDA-1.4))*10 (sq.rt.PTOPC/5.0)*10
9	Percent fish as simple lithophilous spawners	PSLTH	LDA ≤2.5 LDA>2.5	(PSLTH/(12*LDA))*10 (PSLTH/30.0)*10
10	Fish assemblage tolerance index	TOLINDX	All streams	((10 - TOLINDX)/6.3)*10
SA	FIBI metrics 5-10 scoring adjustment for low fish abundance: -- IF total # fish / 500 ft. stream length < 25, THEN metric score is zero (0) -- IF total # fish / 500 ft. stream length ≥ 25 and ≤50, THEN maximum possible metric score is 2.5 -- IF total # fish / 500 ft. stream length >50 and ≤75, THEN maximum possible metric score is 5.0 -- IF total # fish / 500 ft. stream length >75 and ≤100, THEN maximum possible metric score is 7.5			
11	Adjusted catch per unit effort	ADJCPUE	All Streams	(ADJCPUE/100)*10
12	PDELT - All Streams. Scoring adjustments for abnormally high proportion of fish with DELTS (Deformaties, Eroded fins, Lesions, Tumors): IF % fish in sample with DELTS > 2.0 & < 4.0 THEN subtract 5 from total FIBI score (if total # fish / 500 ft. stream < 100, then subtract 2.5). IF % fish in sample with DELTS > 4.0 THEN subtract 10 from total FIBI score (if total # fish / 500 ft. stream < 100, then subtract 5).			

<u>FIBI Scoring Instructions:</u>

1. Calculate data metrics. Refer to metric descriptions (Section 5.2.1) and fish species classifications (Appendix 2.2).
2. Calculate metric scores. Apply appropriate metric scoring formula depending on drainage basin (metrics 1,2,3,4) and stream drainage area (metrics 1-9). If sample has low total number of fish, apply the scoring adjustment (SA) for metrics 5-10. Metric scoring ranges are continuous from 0–10. Minimum possible score = 0; maximum possible score = 10 (for certain metrics it is possible to calculate a score <0 or >10; these scores are automatically rounded to 0 and 10, respectively).
3. Calculate FIBI score. FIBI = (sum of metrics 1-11)*(10) /11. If applicable, adjust FIBI score for PDELT (#12) metric. Round score to nearest integer. FIBI scoring range is 0-100.

Table 5-10. Fish Index of Biotic Integrity (FIBI) qualitative scoring guidelines.

Biological Condition Rating	Characteristics of Fish Assemblage
71-100 (Excellent)	Fish (excluding tolerant species) are fairly abundant or abundant. A high number of native species are present, including many long-lived, habitat specialist, and sensitive species. Sensitive fish species and species of intermediate pollution tolerance are numerically dominant. The three most abundant fish species typically comprise 50% or less of the total number of fish. Top carnivores are usually present in appropriate numbers and multiple life stages. Habitat specialists, such as benthic invertivore and simple lithophilous spawning fish are present at near optimal levels. Fish condition is good; typically less than 1% of total fish exhibit external anomalies associated with disease or stress.
51-70 (Good)	Fish (excluding tolerant species) are fairly abundant to very abundant. If high numbers are present, intermediately tolerant species or tolerant species are usually dominant. A moderately high number of fish species belonging to several families are present. The three most abundant fish species typically comprise two-thirds or less of the total number of fish. Several long-lived species and benthic invertivore species are present. One or more sensitive species are usually present. Top carnivore species are usually present in low numbers; however, one or more life stages of each species are often missing. Species that require silt-free, rock substrate for spawning or feeding are present in low proportion to the total number of fish. Fish condition is good; typically less than 1% of the total number of fish exhibits external anomalies associated with disease or stress.
26-50 (Fair)	Fish abundance ranges from lower than average to very abundant. If fish are abundant, tolerant species are usually dominant. Native fish species usually equal ten or more species. The three most abundant species typically comprise two-thirds or more of the total number of fish. One or more sensitive species, long-lived fish species or benthic habitat specialists such as suckers (Catostomidae) are present. Top carnivore species are often, but not always, present in low abundance. Species that are able to utilize a wide range of food items including plant, animal and detritus are usually more common than specialized feeders, such as benthic invertivore fish. Species that require silt-free, rock substrate for spawning or feeding are typically rare or absent. Fish condition is usually good; however, elevated levels of fish exhibiting external anomalies associated with disease or stress are not unusual.
0-25 (Poor)	Fish abundance is usually lower than normal or, if fish are abundant, the assemblage is dominated by a few species. The number of native fish species present is low. Sensitive species and habitat specialists are absent or extremely rare. The fish assemblage is dominated by just a few ubiquitous species that are tolerant of wide-ranging water quality and habitat conditions. Pioneering, introduced and/or short-lived fish species are typically the most abundant types of fish. An unusually high number of fish with external physical anomalies is more likely to occur.

Although additional customization for Iowa might be needed, Figure 5-9 depicts how the FIBI qualitative categories might align within the tiered biocondition gradient (Davies 2003). The range of biological conditions that is measurable using the FIBI probably encompasses Tiers 3-6. In light of the widespread alterations of Iowa's landscape and historic losses of fish and mussel species described in Part 1 of this report, it is unlikely that any Iowa streams currently possess the biological attributes of Tiers 1 or 2. Tiers 3 and 4, which encompass gradually increasing losses of rare and sensitive native species and slight changes in biological functions, probably capture the biocondition in most of Iowa's rivers and streams.

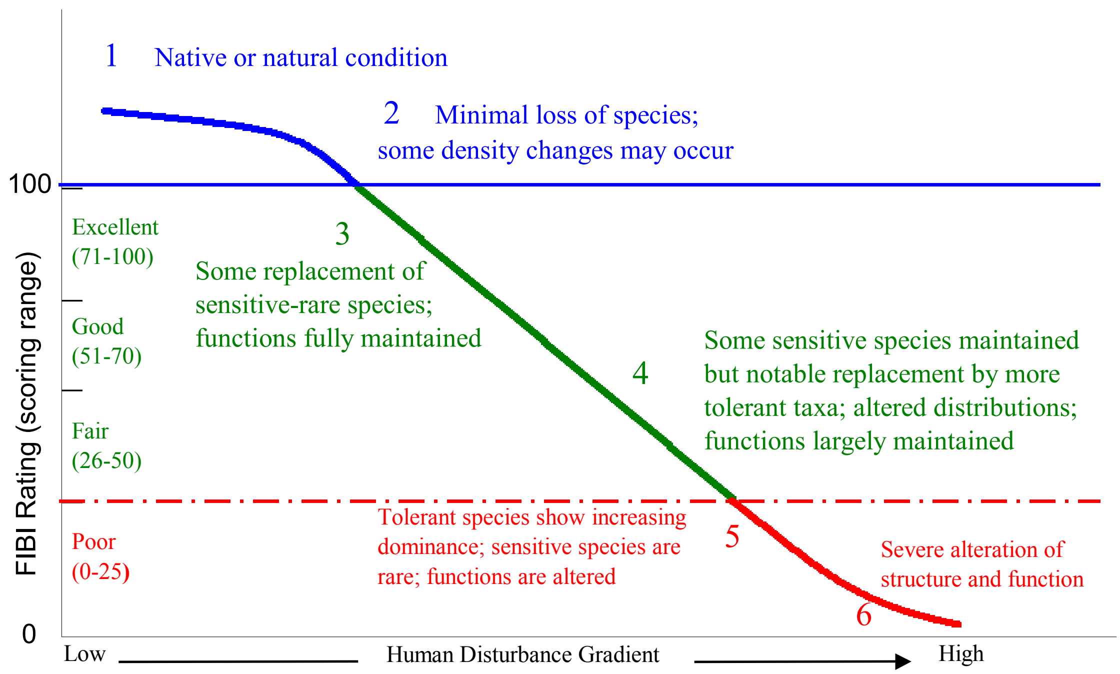


Figure 5-23. Fish Index of Biotic Integrity (FIBI) qualitative scoring ranges (excellent, good, fair, poor) in relation to a conceptual tiered biological condition gradient (after Davies 2003).

Tier 5 is the level at which biological structure and function is altered to the point where the interim CWA Section 101(a)(2) "fishable" use goal is not likely met. Tier 6 is a highly degraded biological condition that occurs at the highest levels of human disturbance. Sampling results presented below and in Part 6 indicate that a relatively small, but significant, proportion of Iowa streams probably belong in Tiers 5 or 6.

Sample Results

There was a substantial range in FIBI scores calculated from the 1994-1998 sample data used to calibrate and test the index. A high score of 85 (excellent) was attained in the Little Cedar River, Floyd County and the low score of 4 (poor) was measured in Keg Creek, Mills County (Appendix 3.3). The median score was 43 (fair). The majority of sites received either a "fair" rating (49%) or "good" rating (28%) for fish assemblage condition, while smaller proportions of sites were rated as either "poor" (13%) or "excellent" (10%). The distribution of scores was probably skewed toward good biological condition since two-thirds of the sites sampled between 1994-1998 were candidate reference sites. The 1994-1998 sample sites are listed in Appendix 3.1, and the metric and FIBI scores from each site are listed in Appendix 3.2

5.2.4 Ecoregion Patterns

.Analysis of the 1994-1998 candidate reference site data found that levels of the FIBI vary significantly (Kruskall-Wallis AOV; p<0.001) between ecoregions (Figure 5-24).

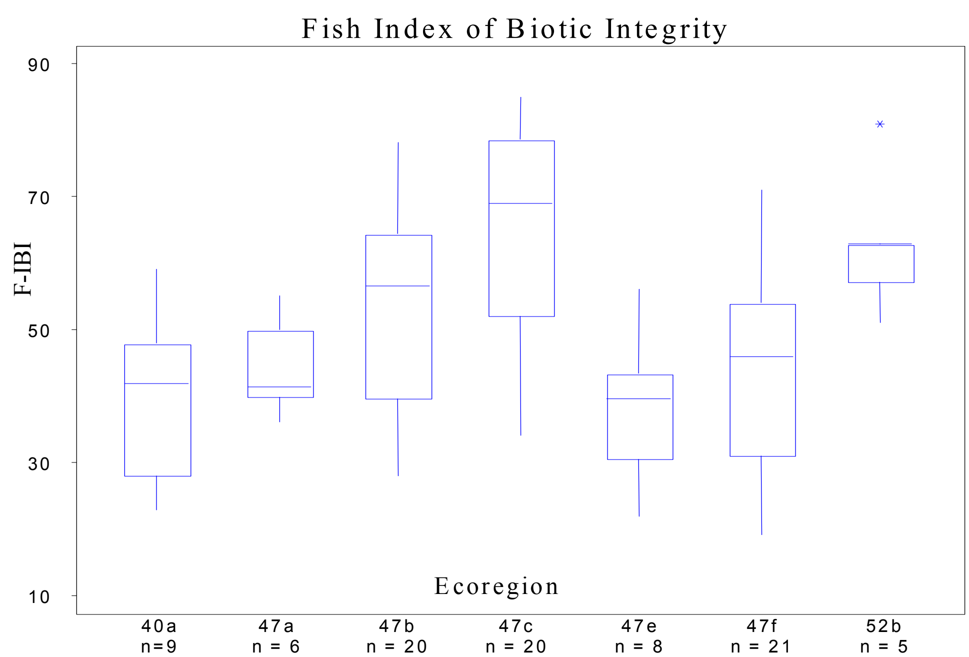


Figure 5-24. 1994-1998 candidate reference site FIBI scores by ecoregion.

In general, FIBI scores from northcentral and northeastern Iowa streams ranked higher than FIBI scores from southern and southwestern Iowa streams. The Iowan Surface (47c) ecoregion had the highest mean FIBI rank, which was significantly different ($p<0.05$) than mean FIBI ranks for the Steeply Rolling Loess Prairies (47e), Loess Flats and Till Plains (40a), and Rolling Loess Prairies (47f) (Figure 5-24). Many of the ecoregions encompass wide ranges in FIBI scores, which suggests there are other important factors that impact FIBI scores, such as physical habitat. The influence of certain physical habitat variables is discussed in greater detail later in this section.

5.2.5 Discrimination of Impacted Sites

To test the FIBI's discriminatory capability, a graphical and statistical analysis of FIBI scores was conducted using data from reference sites and impacted sites in two ecoregions. The ecoregions, Des Moines Lobe (47b) and Rolling Loess Prairies (47f), were among the few that had sufficient numbers of both types of sites to conduct the analysis (Figure 5-25).

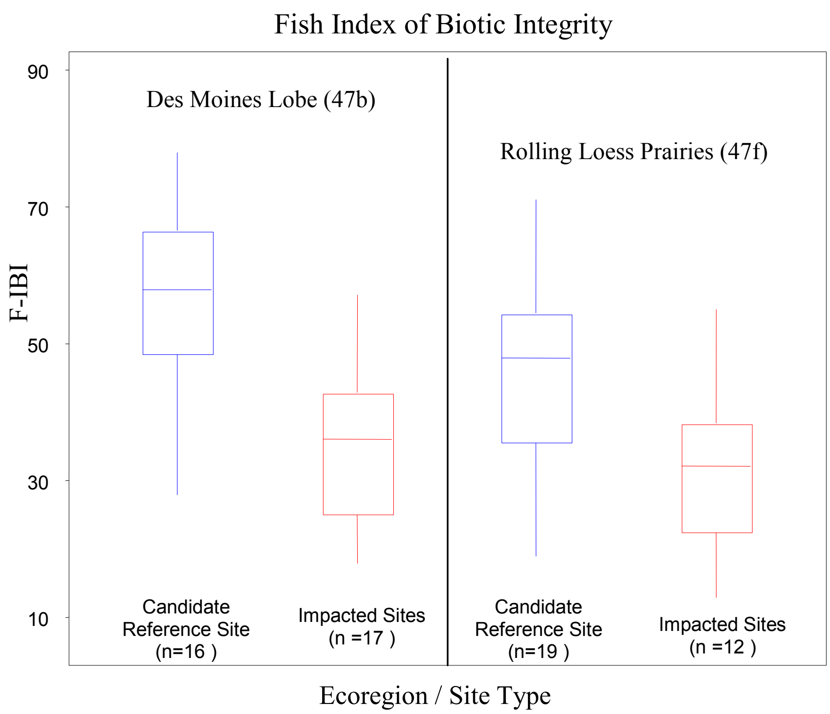


Figure 5-25. Box and whisker plot comparison of candidate reference site and impacted site FIBI scores from the Des Moines Lobe (47b) and Rolling Loess Prairies (47f) ecoregions.

Figure 5-25 shows reasonably good separation of FIBI box and whisker plots of the two site groupings from each ecoregion. The impacted group consisted of sites affected by common types of stream disturbance, including channelization, riparian livestock grazing, and wastewater discharges. The Mann Whitney Rank Sum test was used to statistically confirm the FIBI's ability to distinguish reference sites from impacted sites,. In both ecoregions, candidate reference site FIBI scores ranked significantly higher ($p<0.01$) than impacted site FIBI scores.

5.2.6 Season and Sample Month

Three candidate reference sites were sampled in spring, summer, and fall from 1994-1998 in order to evaluate the temporal variability of the FIBI and the appropriateness of the designated sample index period (Figure 5-26). Summer samples were taken within the normal sample index period (July 15 - October 15), while spring and fall samples were taken outside of the index period. It is important to evaluate seasonal variations in the FIBI because inconsistent or biased samples could lead to invalid bioassessment conclusions. Season-related variables that might influence biological assemblage sampling results include climate, life stage, migration, and stream flow.

Season effect on the FIBI was not as pronounced as with the BMIBI. Although, summer samples produced the highest individual FIBI scores at each site, the difference between season means was statistically significant for only one site. White Fox Creek FIBI scores from summer samples ranked significantly higher (Mann Whitney Rank Sum; $p<0.05$) than spring and fall FIBI scores. The average FIBI coefficient of variation was 0.08 for summer samples compared to 0.06 and 0.13 for spring and fall samples, respectively. From these limited data, it appears samples from the summer-early fall index period are comparable or better than spring or fall samples for producing optimal and consistent FIBI scores.

Reference sites sampled from 1994-2001 show no apparent trend or bias in FIBI score with respect to sampling time (month) within the July 15 - October 15 index period (Figure 5-27). The current sample index period appears to be providing satisfactory results from the perspectives of between and within sample-season comparisons.

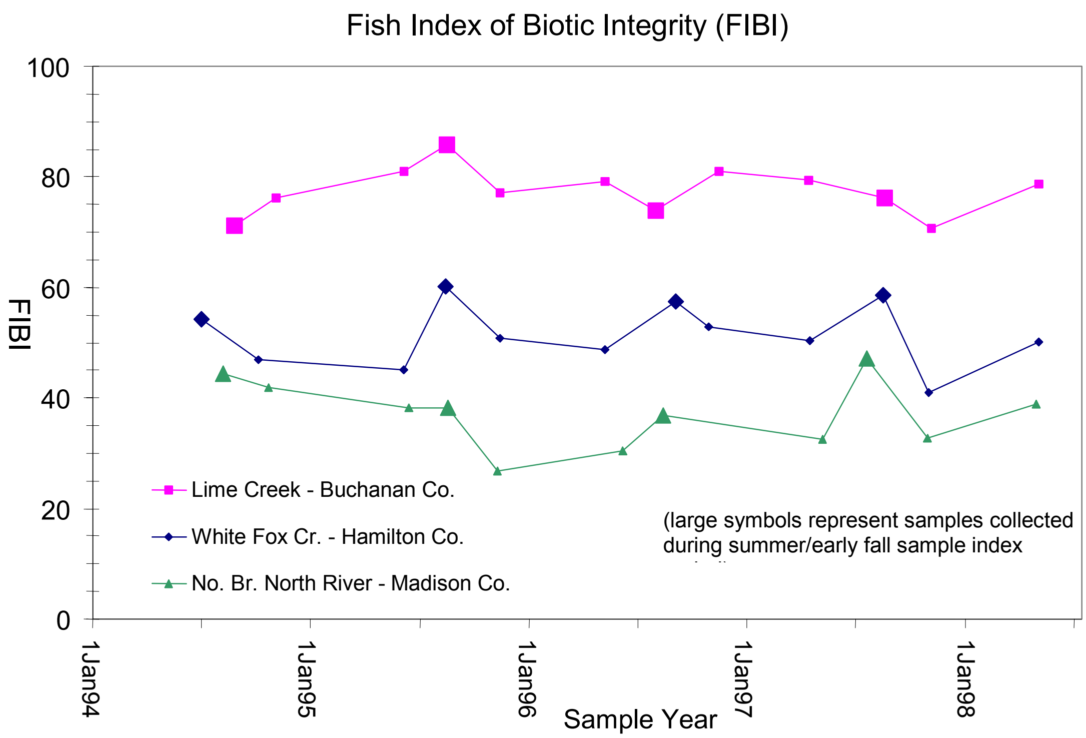


Figure 5-26. Fish Index of Biotic Integrity (FIBI) results from seasonal sampling sites: 1994-1998.

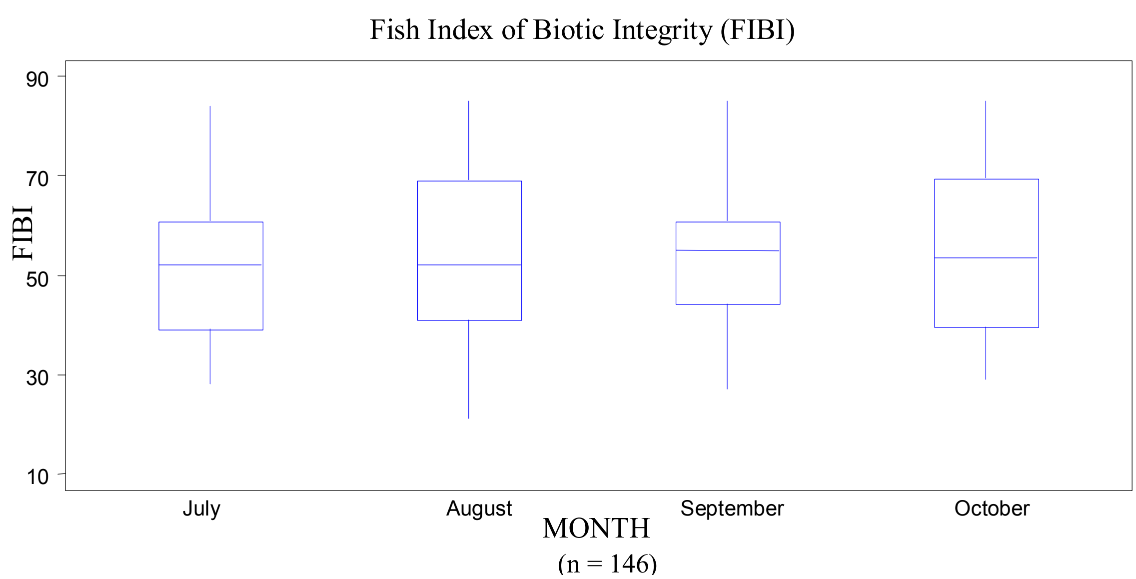


Figure 5-27. 1994-2001 FIBI sample results by month.

5.2.7 Physical Habitat

Multivariate analysis results (Part 4) and correlation analysis results demonstrate a relationship between stream physical habitat characteristics and FIBI levels. Among the habitat variables that were most strongly correlated with the FIBI are 1) cobble substrate; 2) total coarse substrate; 3) riffle habitat. These results suggest natural differences in substrate composition and macro-habitat might be important enough to merit consideration of separate FIBI reference criteria.

A statistical analysis was conducted to examine for significant differences in FIBI levels associated with different physical habitat classifications. To conduct the analysis, criteria for each habitat characteristic listed above were used to assign candidate reference sites from three ecoregions to one of two habitat classes:

- <u>Class 1 (Riffle) - streams having abundant coarse substrates and stable riffle habitat;</u>
  a) $\geq$ 10% stream reach area as cobble and/or boulder substrate;
  b) $\geq$ 30% stream reach area as coarse rock substrate (gravel+cobble+boulder+bedrock);
  c) $\geq$ 10% stream reach area classified as riffle habitat.
- <u>Class 2 (Non Riffle) - streams lacking abundant course substrates and stable riffle habitat.</u> Includes all candidate reference sites not meeting Class 1 criteria.

Figure 5-28 displays the ranges of FIBI scores for each ecoregion / habitat class. Within each ecoregion tested, FIBI scores from Class 1 candidate reference sites ranked significantly higher (Mann Whitney Rank Sum; $p<0.05$) than FIBI scores from Class 2 candidate reference sites. These results indicate that physical habitat-based FIBI reference criteria should be considered for the ecoregions tested. More sampling and data analysis are needed to determine whether separate criteria for other ecoregions are merited.

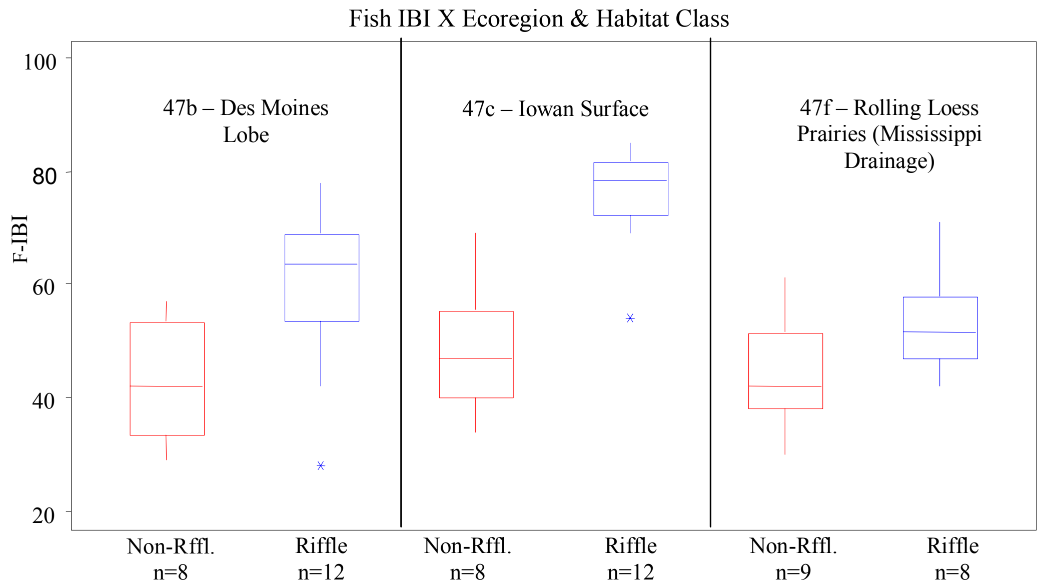


Figure 5-28. Ranges of FIBI scores for two habitat classes and three ecoregions.

5.2.8 Relationships with Physical Habitat and Water Quality Variables

For a biotic index like the FIBI to be useful, it should demonstrate relationships with abiotic indicators of stream quality. Multivariate statistical analyses described in Part 4 documented significant relationships between stream fish assemblages and several physical habitat and water quality variables. Perhaps not surprisingly, the FIBI is correlated with many of the same stream variables (Table 5-11). Scatter plots showing FIBI relationships with several habitat variables are displayed in Figure 5-29. Generally, good or excellent levels of the FIBI are associated with sites that have good instream and riparian habitat characteristics. More than 40% of the variability in 1994-1998 FIBI scores was explained by a qualitative habitat index (Barbour and Stribling 1991). The index is an assessment tool that combines visual observations of twelve variables that relate to channel morphology, instream habitat, and riparian habitat. It encompasses many of the same habitat variables that are individually correlated with the FIBI.

The FIBI was also correlated with nutrient and sediment-related water quality variables. FIBI levels generally decrease in relation to increasing levels of phosphorus, suspended solids, and water turbidity (Figure 5-30). Generally, FIBI correlations with water quality variables were fewer and weaker than physical habitat correlations (Table 5-11). Turbidity was the most strongly correlated water quality variable (r=-0.39). For most sites, water quality sampling consisted of a single grab sample taken during biological sampling. Without additional sampling, it would be hard to expect stronger correlations. It is likely that FIBI correlations with water quality, and also to some extent physical habitat, reflect broad regional patterns in stream characteristics and FIBI assemblages.

Table 5-11. Pearson correlation coefficients for physical habitat and water quality variables correlated with the Fish Index of Biotic Integrity (FIBI): 1994-1998 sample sites.

Physical Habitat Variable	Correlation Coefficient (r)	Water Quality Variable	Correlation Coefficient (r)
Habitat Index Score	**0.65**	Total Hardness	0.03
% Coarse Substrate	**0.58**	Water Temperature	0.03
%Cobble Substrate	**0.54**	Nitrate + Nitrite Nitrogen	0.00
Streambank Rating	**0.48**	Atrazine	0.00
%Riffle Habitat	**0.45**	Dissolved Oxygen	-0.01
Riparian Buffer Strip Rtg.	**0.41**	Specific Conductance	-0.04
%Gravel Substrate	**0.36**	pH	-0.15
%Boulder Substrate	**0.35**	Total Dissolved Solids	-0.16
Amount of Stream Shade Variation	**0.32**	**Total Phosphorus**	**-0.31**
Stream Channel Slope	**0.24**	**Total Suspended Solids**	**-0.36**
Avg. Stream Width	**0.23**	**Turbidity**	**-0.39**
Ave. Stream Shade Amount	0.16		
Stream Width:Depth Ratio	0.13		
Stream Maximum Depth	0.11		
Stream Segment Sinuousity	0.09		
Surface Watershed Area	0.05		
Streamflow	0.03		
Avg. Stream Thalweg Depth	-0.03		
Avg. Stream Depth	-0.05		
%Run Habitat	-0.08		
%Pool Habitat	-0.09		
%Frequency of Woody Debris	-0.15		
%Instream Cover	**-0.17**		
%Sand Substrate	**-0.30**		
%Silt Substrate	**-0.30**		
%Clay Substrate	**-0.40**		
%Bare Streambank	**-0.52**		
%Total Fine Substrates	**-0.55**		

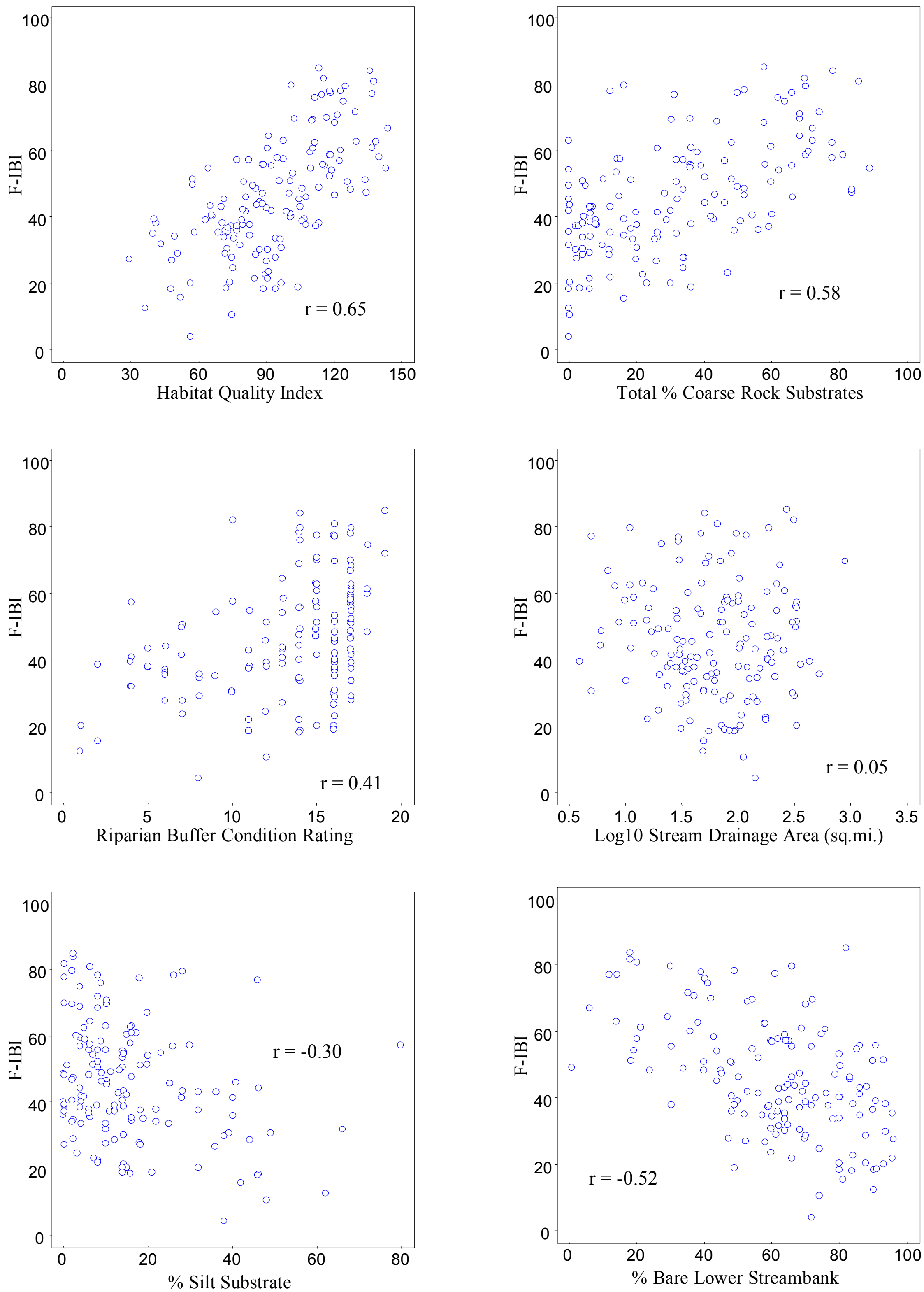


Figure 5-29. Relationships of the Fish Index of Biotic Integrity (FIBI) and selected stream physical habitat variables.

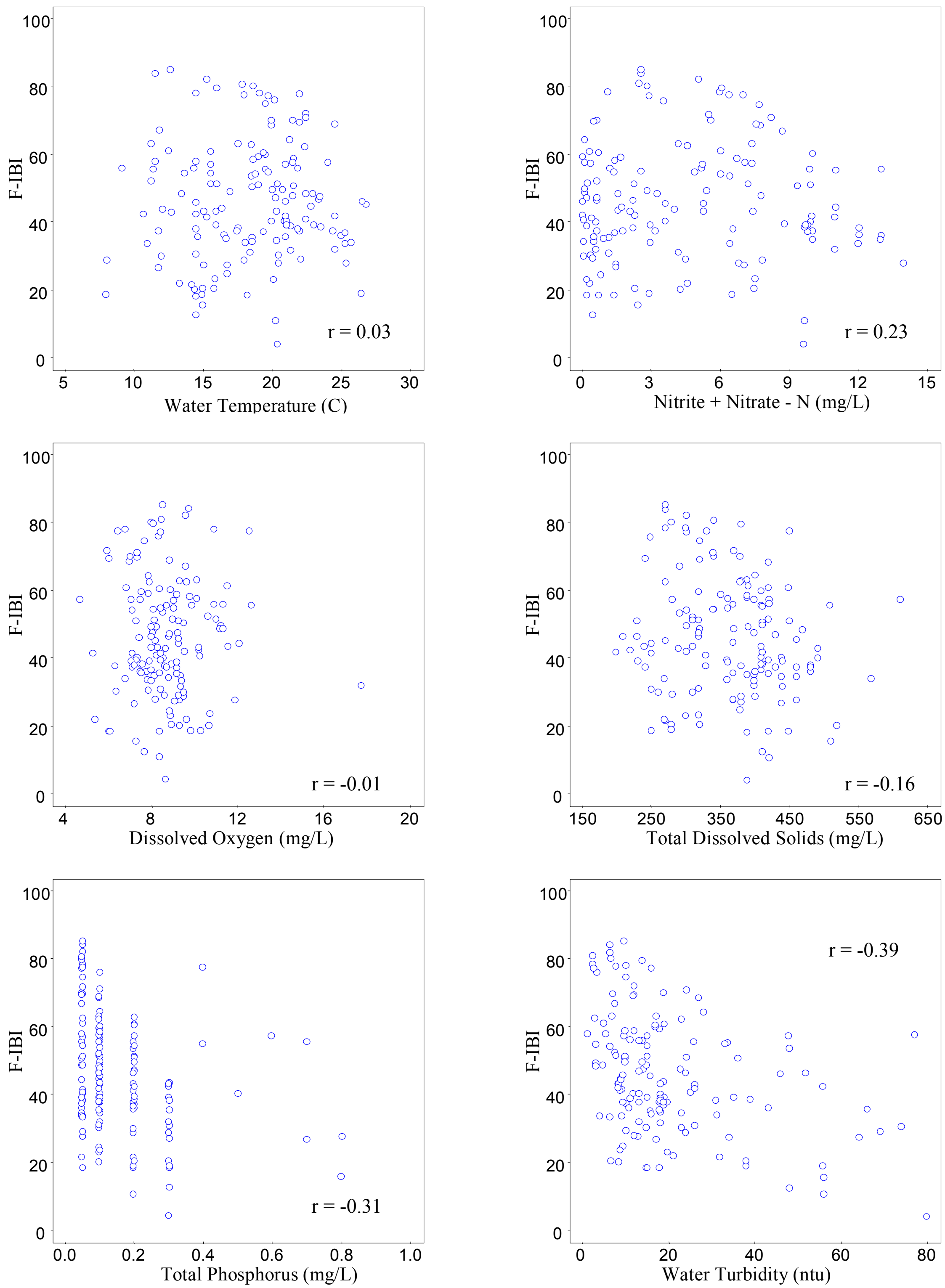


Figure 5-30. Relationships of the Fish Index of Biotic Integrity (FIBI) and selected stream water quality variables.

6 Applications

The stream biological assessment framework described in this report has helped meet several monitoring and assessment needs. Current uses of bioassessment information include problem investigation, project evaluation, status/trend monitoring, and TMDL development. Stream biological assessment has also become an important component of IDNR's water quality assessment and impaired waters listing process. Described below are several ways in which stream biological data are being used to monitor and assess the biological health of Iowa's wadeable rivers and streams.

6.1 Aquatic Life Use Support

A methodology to assess the status of warm water stream aquatic life uses based on biological sampling data has been developed (IDNR 2003). The assessment results are used to prepare Iowa's biennial [Section 305(b)] water quality report and [Section 303(d)] impaired waters list. To determine the level of aquatic life use support, the Benthic Macroinvertebrate Index of Biotic Integrity (BMIBI) and Fish Index of Biotic Integrity (FIBI) scores from a sample site are compared against index levels measured at reference stream sites located in the same ecological region. Using reference data from 1994-2001, a set of Biological Impairment Criteria (BIC) was specifically developed for the 2002 305(b) report (Table 6-1). A stream was considered biologically impaired if at least one of the index scores was significantly lower than reference levels.

The 25th percentile values for ecoregion reference site BMIBI and FIBI index scores were used to establish the BIC. Use of the reference 25th percentile as an impairment threshold is consistent with biocriteria development guidance (U.S. EPA 1996), and has demonstrated efficacy in state bioassessment programs (Yoder and Rankin 1995). Biotic index performance evaluation in Iowa found little or no overlap of index interquartile ranges between reference sites and test sites (see Figures 5-10, 5-23), which suggests that reference 25th percentile levels are appropriate for assessing biological impairment.

In three ecoregions (47b, 47c, 47f), reference sites are also grouped by habitat class (i.e., riffle streams vs. non-riffle streams) for comparison of FIBI scores. A comparison of reference site FIBI scores from these ecoregions, found the mean score from sites classified as riffle habitat was significantly higher than the mean score from sites classified as non-riffle habitat (see Figure 5-26). The mean difference was not significant for BMIBI scores (see Figure 5-13), therefore, separate BIC were not established.

Table 6-1. Biological Impairment Criteria (BIC) used to assess support of B(LR) and B(WW) aquatic life uses of Iowa's wadeable warm water streams for the 2002 Section 305b assessment.

Ecoregion:	**FIBI**	**BMIBI**
40(a) – Central Irregular Plains (CIR) / Loess Flats and Till Plains	33 (Fair)	46 (Fair)
47 – Western Corn Belt Plains (WCBP) Subregions:		
47(a) – WCBP / Northwest Iowa Loess Prairies	40 (Fair)	53 (Fair)
47(b) – WCBP / Des Moines Lobe		
(Stable Riffle Habitat)	55 (Good)	63 (Good)
(No Stable Riffle Habitat)	32 (Fair)	63 (Good)
47(c) – WCBP / Iowan Surface		
(Stable Riffle Habitat)	71 (Excellent)	59 (Good)
(No Stable Riffle Habitat)	43 (Fair)	59 (Good)
47(d) – WCBP / Missouri Alluvial Plain	na*	na
47(e) – WCBP / Steeply Rolling Loess Prairies	31 (Fair)	56 (Good)
47(f) – WCBP / Rolling Loess Prairies		
(Missouri Drainage System)	31 (Fair)	56 (Good)
(Mississippi Drainage System)		
(Stable Riffle Habitat)	41 (Fair)	53 (Fair)
(No Stable Riffle Habitat)	34 (Fair)	53 (Fair)
47(m) – WCBP / Western Loess Hills	na	na
52(b) – Driftless Area (DA) / Paleozoic Plateau	59 (Good)	61 (Good)
72(d) – Central Interior Lowland (CIL) / Upper Mississippi Alluvial Plain	na	na

* na (BIC not available)

Because the number of reference sites is insufficient, BIC are not available for ecoregions 47d, 47m, and 72d. Most streams flowing through these ecoregions originate in other ecoregions, which adds to the difficulty of establishing appropriate bioassessment thresholds. A relatively small number of stream sites in these ecoregions have been evaluated on a case-by-case basis. Typically, the BIC from adjacent ecoregions have been applied to determine aquatic life use support for these segments.

Similar to the assessment approach used by OEPA (Yoder and Rankin 1995), an uncertainty margin of ± 7 index points is applied when assessing stream sites based on a single bioassessment sample. When more than one bioassessment sample is available for a stream segment, the average index values are compared to the BIC to determine use support status, and the 7-point margin is not applied. Essentially, the margin is used to account for natural temporal variability and/or sampling error. Based on an analysis of repetitive sampling data obtained from three reference sites during 1994-1998, seven points was determined to be a typical variation in individual index scores during a four-year period. This amount of variation is similar to the 95% confidence interval of ± 8 points reported by Stribling et al. (1999) for a single sample of the Wyoming stream benthic IBI on a scale of 100.

The level of aquatic life use support is determined in the following manner: 1) If both the BMIBI score and the FIBI score exceed the applicable BIC by more than 7 points, the site is assessed as fully supporting aquatic life uses; 2) If either or both index scores are within 7 points of the BIC, and neither is more than 7 points below the BIC, the site is assessed as fully supporting/threatened; 3) If either index score, but not both are more than 7 points below the BIC, the site is assessed as partially supporting; 4) If both index scores are more than 7 points below the BIC, the site is assessed as not supporting uses.

Aquatic life use assessment results

Since 1994, 204 stream segments encompassing 2,412 miles of stream have been assessed. A combined total of 84 stream segments encompassing 972 stream miles (40%) have been assessed as biologically impaired (i.e. partially supporting or not supporting aquatic life uses.

Figure 6-1 shows the proportions of biological assessment sites in each status category of aquatic life use support. The proportion of stream sites that were assessed as impaired based on data from the 1994-1998 sampling period was smaller (31%) than the proportion of impaired sites (47%) sampled during the 1999-2001 period. Differences in sampling objectives are a likely cause. The sampling emphasis from 1994-1998 was mostly reference sites for development of biological indicators and reference conditions. From 1999-2001, the sampling emphasis changed to mostly test sites suspected of having physical habitat and/or water quality problems.

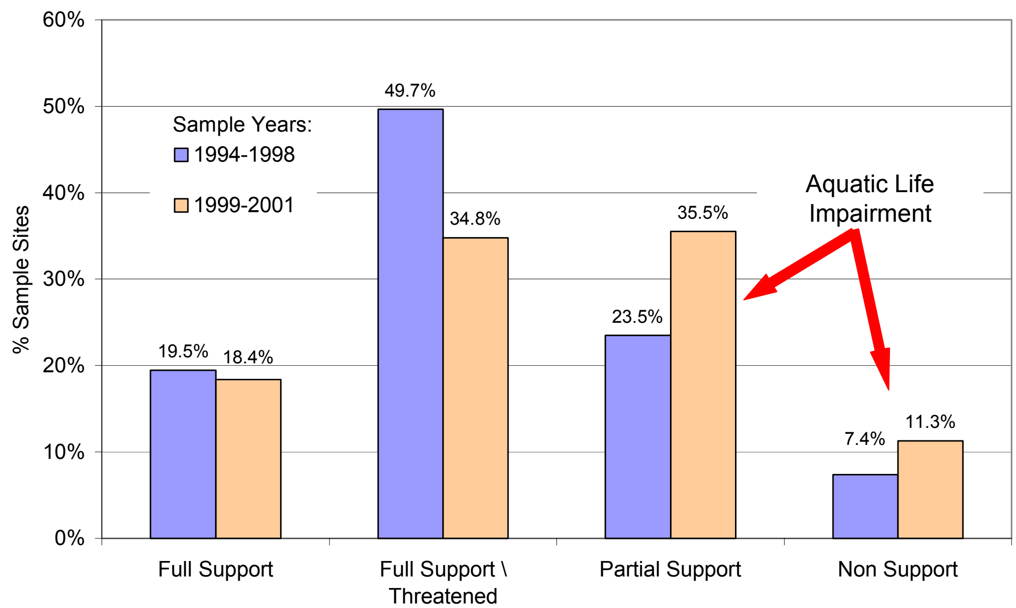


Figure 6-1. Status of stream aquatic life use support assessed at wadeable river and stream bioassessment sites: 1994-2001.

One unresolved issue is the length of stream that can be represented by results from a single bioassessment site. In Iowa's water body reporting system, segment boundaries are typically defined by confluences with tributary streams or changes in designated uses. Consequently, stream segments are not a uniform length. They range from less than one mile to more than twenty miles. From 1994-2002, the average 305(b) segment length assessed using biological assemblage data was approximately 12 miles (19 km). Often, entire segments are assessed based upon data from a single bioassessment site, which is typically a length of stream from 150-350 meters. This means the average bioassessment site would encompass approximately 1.2% of the length of an average 305(b) assessment segment. In Iowa, it is not clear whether this level of sample representation is adequate.

In Missouri, benthic macroinvertebrate metric data from multiple sites (sample reaches) located on reference stream segments were analyzed to determine the amount of between-reach variation, and the level of impairment discriminatory power gained by sampling multiple reaches compared to sampling a single reach (Rabeni et al. 1999). Variation between sample reaches on the same segment was small (coefficient of variation [CV] typically <10%), and there was only a modest gain in the ability to detect impairment from sampling one or two additional reaches (<15%). In terms of representation and cost effectiveness, the authors favored a single carefully selected and sampled reach to multiple sample reaches. A sample site for every 4-5 stream miles is currently preferred for bioassessment purposes (personal communication, Randy Sarver, MDNR).

Where multiple sites in the same stream segment were sampled in Iowa, varying results have been found. For example, there were only small variations in BMIBI and FIBI scores (CV=4% and 11%, respectively) among six Maple River sites (Sac County) spanning a 37-mile segment (IDNR 2001d). The riparian corridor, instream physical habitat and water quality characteristics of the Maple River are relatively homogenous. All sites received the same aquatic life use assessment of fully supporting / threatened. By comparison, BMIBI and FIBI scores were more variable (CV=13% and 21%, respectively) among nine sites sampled along 28 miles of the South Skunk River in Story and Hamilton counties (see Figure 6-5). Riparian land use, physical habitat and water quality conditions were more variable along the South Skunk River compared to the Maple River. Site assessments of aquatic life use status ranged from not supporting to fully supporting. In the Maple River, where physical habitat and stream morphology are relatively uniform, a single bioassessment site seemed adequate to represent a relatively long segment of stream that is comparable to the average 305(b) reporting unit. In the South Skunk River, that was clearly not the case.

Because of the variation in stream conditions, both locally and regionally, it would be difficult to define a standard segment length to which site-specific bioassessment can be extrapolated. Establishment of guidelines and procedures for choosing representative sampling reaches and determining the limits of representation can help, however, some degree of professional judgment applied on a case-by-case basis still may be required.

6.2 Problem Investigation

Stream bioassessment is used to investigate a variety of water quality impacts including animal waste runoff, chemical spills, and wastewater discharges. It has also been used as a tool to evaluate the environmental risks associated with hazardous waste. The information gained from bioassessment helps IDNR managers evaluate the severity of environmental impacts, need for management or regulatory actions, and recovery from pollution events. Bioassessment information is also used to establish benchmarks against which the effectiveness of control measures or mitigation is evaluated.

Wastewater Impacts

The bioassessment framework is useful for evaluating water quality impacts from wastewater discharges. Typically, an upstream (control) - downstream (impacted) sampling approach is used to isolate wastewater discharge effects. Ideally, the upstream (control) site will have similar physical habitat characteristics as the downstream (impacted) site, which makes it easier to discern stream biological differences that are attributable to the wastewater discharge. A comparison of control site and impacted site biological conditions to regional reference conditions is done to place bioassessment results within the context of reference expectations, and to evaluate the magnitude of impacts from other sources in the watershed.

Bioassessment results from Fourmile Creek are used to illustrate how the upstream-downstream wastewater-bracketing concept is applied (Figure 6-2). Fourmile Creek receives wastewater from the City of Ankeny's WWTP. The BMIBI score below the

WWTP outfall was 52 (fair) compared to a score of 72 (good) upstream from the outfall. The downstream BMIBI score is below the 25th percentile of regional reference sites, while the upstream BMIBI score is above the 25th percentile, thus suggesting a slight impairment of biological condition.

The physical habitat characteristics of both sites was very similar. Several metrics of the BMIBI that are sensitive to organic enrichment impacts showed an apparent decline in response to the wastewater discharge. The observed metric responses are indicative of a shift in benthic macroinvertebrate species composition and relative abundance that is consistent with increased inputs of fine particulate organic matter and oxygen-demanding waste products.

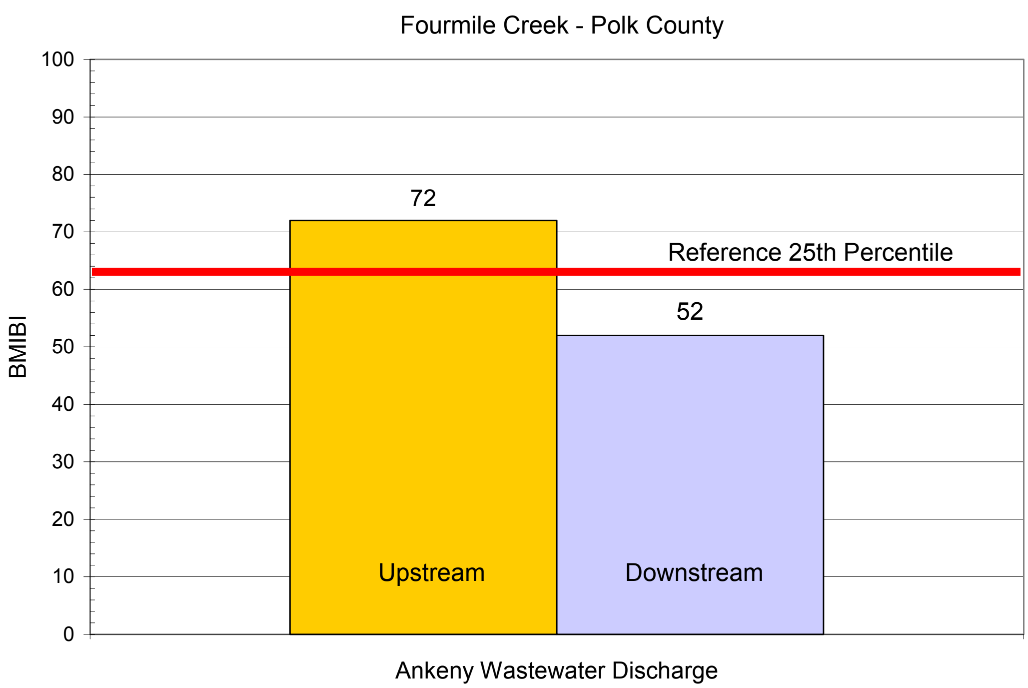


Figure 6-2. Benthic Macroinvertebrate Index of Biotic Integrity (BMIBI) scores from Fourmile Creek, Polk County. Sampling locations were upstream and downstream of the outfall for the Ankeny Wastewater Treatment Plant. The red line depicts the 25th percentile of BMIBI scores from ecoregional reference sites.

Fish Kills

A follow-up investigation of twenty stream fish kill events (Figure 6-3) was conducted from 1999-2001 (Wilton 2002). The primary goals of the project were to assess the biological condition status and recovery of fish populations in fish kill streams. The investigation encompassed a wide range in the lengths of time between the fish kill event and follow-up sampling (i.e., 5-60 months).

Follow-up sampling results were compared with data from fish kill reports and stream ecoregion reference sites. Data analysis focused on three aspects of the fish assemblage: abundance, biocondition (FIBI), and species composition. Levels of fish abundance and biocondition varied greatly among the follow-up stream sites. Fish abundance ranged from very low (17 fish/500ft.) to very high (2,506 fish/500ft.). FIBI scores ranged from 2 (very poor) to 73 (excellent). Levels of fish abundance and/or fish assemblage condition were lower than reference expectations in 52% of the follow-up stream segments (Table 6-2).

Several follow-up sample sites were missing fish species that were observed during the fish kill investigation. Alternatively, a number of follow-up sample sites also contained fish species that were not reported as part of the fish kill. Differences in sampling methods and data limitations make it difficult to form conclusions about the recovery of individual fish species. Sample results generally demonstrated that streams affected by fish kills are capable of significant recovery of fish abundance and composition within several months to a few years. Residual impacts, however, may exist for longer periods of time depending on the magnitude of the event and other factors affecting fish species re-colonization.

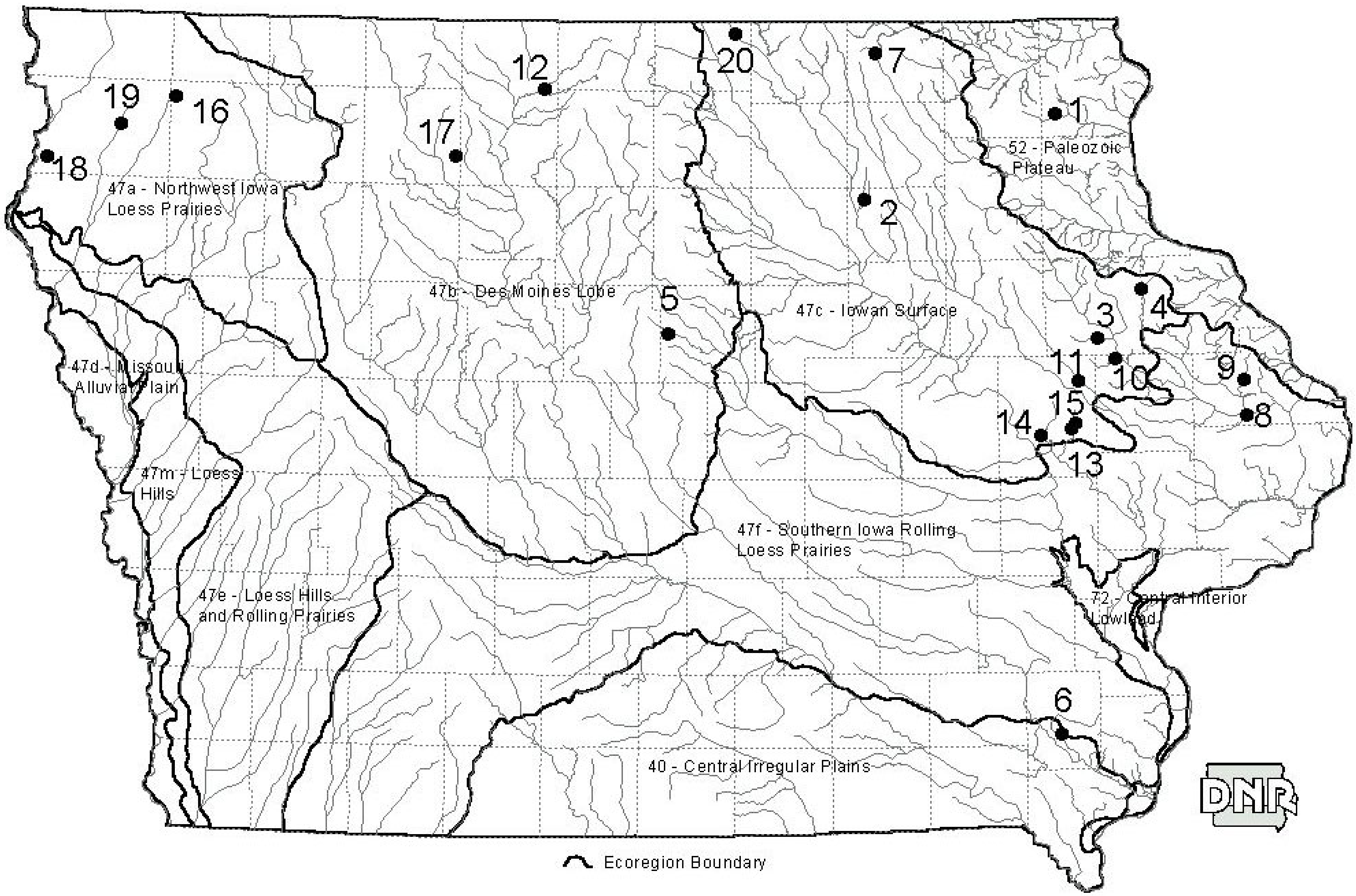


Figure 6-3. Locations of fish kill follow-up sample streams: 1999-2001 (numbers refer to Table 6-2).

Table 6-2. Summary of fish assemblage assessment results from 1999-2001 fish kill follow-up streams. (*Numbers in parentheses refer to Figure 6-3)

Comparable to Reference Conditions - No Apparent Loss of Fish Species	Potential Loss of Fish Species	Slightly - Moderately Impaired Fish Abundance and/or Biotic Condition	Severely Impaired Fish Abundance and Biotic Condition
Fish abundance and biotic condition are comparable to reference stream levels. Virtually all fish species observed in the fish kill investigation were present in follow-up sampling.	Fish abundance and biotic condition are comparable to reference stream levels. The majority of fish species reported in the fish kill investigation were present in follow-up sampling including one or more additional species; however, at least one fish species observed during the fish kill investigation was missing from follow-up sampling.	Fish abundance and/or biotic condition are slightly lower than reference stream thresholds. Most or all of the fish species observed during the fish kill investigation were present in follow-up sampling.	Fish abundance and biotic condition are not comparable to reference stream thresholds. At least one fish species observed in the fish kill investigation was not observed in follow-up sampling, or very low abundance and diversity of fish were reported in the fish kill investigation.
Big Creek – Linn Co. (15)* Buck Creek – Delaware Co. (3) Deer Creek – Worth/Mitchell Co. (20) East Big Creek – Linn Co. (15) Horton Cr. – Bremer Co. (2) Silver Creek – Jones Co. (10)	Crabapple Creek – Linn Co. (13) Tipton Cr. – Hamilton/Hardin Co. (5) Heather Branch – Henry Co. (6) Crane Creek – Worth Co. (7) Prairie Creek – Jackson Co. (8)	Buffalo Cr. – Jones Co. (11) Farmers Creek – Jackson Co. (9) Floyd River – O' Brien Co. (16) Indian Cr. – Linn Co. (14) N. F. Maquoketa R.–Dubuque Co. (4) Prairie Creek – Palo Alto Co. (17) W. Branch Floyd R. – Sioux Co. (19) Yellow River – Allamakee Co. (1)	Buffalo Cr. – Kossuth Co. (12) North Buffalo Cr. – Kossuth Co. (12) Sixmile Creek – Sioux Co. (18) Unn.Trib. Yellow R. – Allamakee (1)

6.3 Status and Trend Monitoring

Probabilistic Stream Survey

In 2002, IDNR initiated a statistical survey to objectively measure the status and trends of Iowa's perennial rivers and streams. The survey is partially supported by the U.S. EPA's Regional Environmental Monitoring and Assessment Program (REMAP). In accordance with REMAP specifications, a stratified-random design is being used to obtain an unbiased sample population from which accurate statements about the status of Iowa's perennial streams can be extrapolated. The survey measures several indicators of stream ecosystem health including biological assemblages; fish, sediment, and water contaminant levels; physical habitat structure; stream metabolism.

One of the primary questions the survey is attempting to answer is what is the true condition of biological assemblages inhabiting Iowa's perennial streams. From 1994-2001, sampling was done at targeted sites mostly for biological indicator and reference condition development. A smaller amount of sampling was done for problem investigation and TMDL watershed assessment purposes (see Figure 3-5).

Data from the first two years of the REMAP random (probabilistic) sampling project can be used to evaluate differences between random and non-random sample populations. The solid red and black curvilinear lines in Figure 6-4 represent the Cumulative Distribution Functions (CDF) of the random and non-random BMIBI sample data respectively. At any given point along a CDF, the proportion of the sample population having a BMIBI score less than or equal to the level corresponding to that point can be obtained by extending a horizontal line to the y-axis. For example, in Figure 6-4 the 50th percentile (median) BMIBI value from the random sample is 47 (fair) and the median value from the non-random sample population is 58 (good).

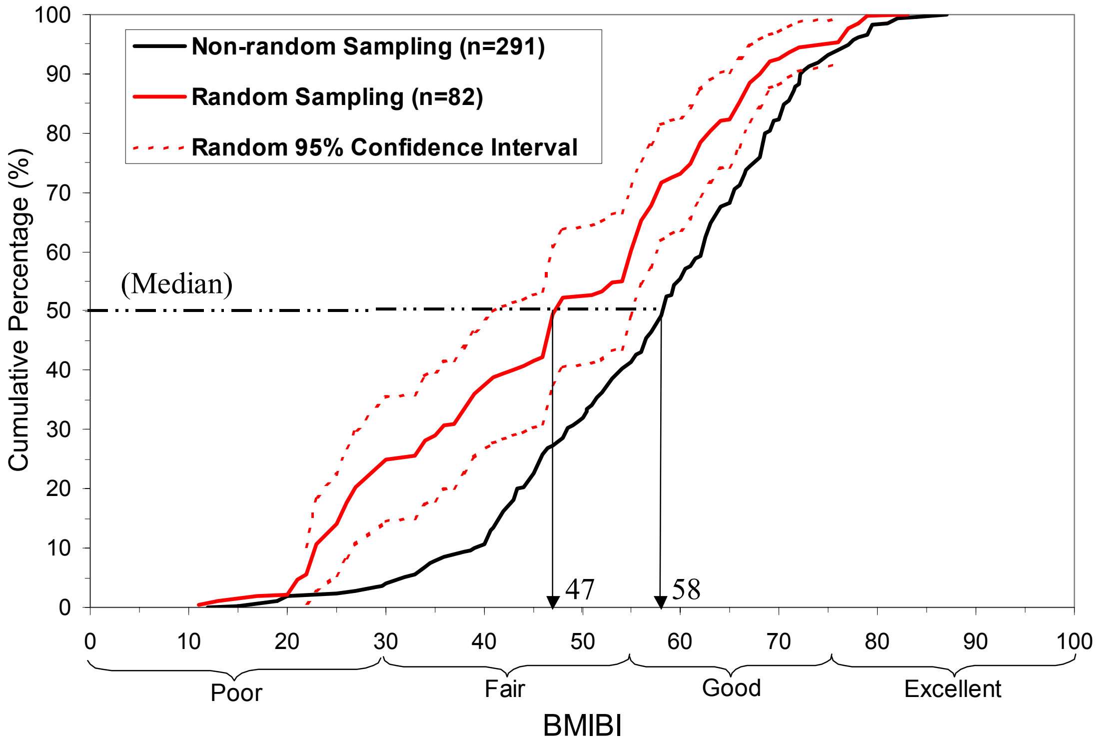


Figure 6-4. Cumulative distribution functions (CDF) of Benthic Macroinvertebrate Index of Biological Integrity (BMIBI) scores from 2002-2003 REMAP random sampling (median score = 47) and 1994-2002 non-random sampling (median score = 58). *(Note: non-random CDF represents cumulative % sample sites; random CDF represents cumulative % perennial stream miles.)*

One of the main benefits of the REMAP sample design is that each sample site has a known probability of being selected and represents a known proportion of the entire population. By combining each data value with its sample weight or probability factor, survey results can be extrapolated to the entire population of perennial streams. Furthermore, the statistical validity of the sample design allows confidence bounds to be obtained for the random sample CDF. The confidence bounds, depicted in Figure 6-4 as dashed red lines, make it possible to make statements about the entire population of perennial streams with statistical certainty. For example, there is 95% certainty the percentage of perennial stream miles in Iowa having "poor" benthic macroinvertebrate assemblage condition (i.e., BMIBI $\leq$ 30) during the 2002 and 2003 sampling period is

24.9% ± 10.5%. By comparison, only 5% of the non-random sites from 1994-2002 had BMIBI scores that were in the poor range.

Except for the tail ends, the fact that the non-random CDF remains outside and to the right of the 95% confidence bounds surrounding the random CDF strongly suggests the two sample populations differ with respect to BMIBI levels. The 2002-2003 random sample data indicate the condition of benthic macroinvertebrate assemblages is significantly worse than indicated by the non-random data from 1994-2002. This preliminary analysis emphasizes the value of conducting probabilistic sampling for obtaining accurate estimates of aquatic resource status. Other comparisons of aquatic resource condition estimates derived from probability-based sample data versus non-statistically derived sample data (Paulsen et al. 1998; Hughes et al. 2000) have found substantial disagreement and underestimated levels of impairment based upon non-statistical sample designs.

Reference Site Sampling

Reference sites are least disturbed stream habitats that serve as contemporary benchmarks of stream quality. Currently, reference sites are being sampled on a 5-year rotational cycle in order to keep the reference database current. One trend monitoring approach that might have merit involves comparing biological index scores from different sample cycles to see if a change in reference biological condition has occurred. Hopefully, stream biological condition will improve over time as land use practices and pollution control measures lead to improved stream conditions. Declining levels in biotic index levels at reference stream sites might be considered a warning sign that stream conditions are worsening. So far, BMIBI scores and FIBI scores from reference sites sampled in 1994-1996 have been compared to index scores sampled from the same sites in 1999-2001.

Figure 6-4 shows the ranges of FIBI scores from 33 reference sites sampled in 1994-1996 and again in 1999-2001. Twenty-three sites (70%) had a higher FIBI score in the 1994-

1996 period compared to the score from 1999-2001. The average difference of 3.5 points was close, but not quite significant at the 95% confidence level (paired t-test; p=0.08). The same statistical test was performed on BMBI scores from 1994-1996 versus 1999-2001. No significant trend in BMIBI levels was found. More statistical tests will be performed as the rotational sampling schedule progresses and more reference site data become available for trend analysis.

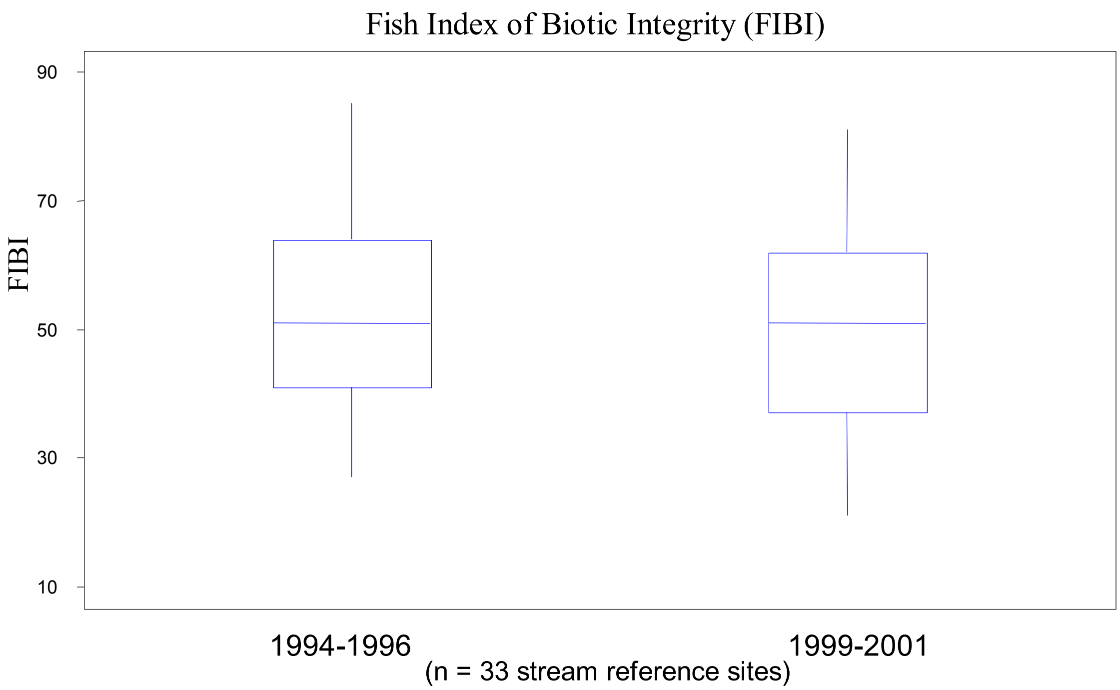


Figure 6-5. Box and whisker plot ranges of FIBI scores from 33 reference stream sites each sampled during two time periods.

6.4 Watershed Assessment and TMDL Development

Bioassessment is an integral part of stream watershed assessments that support TMDL development. A recently completed study (IDNR 2001d) documented a combined approach utilizing stream bioassessment and GIS-based watershed assessment methods to evaluate the extent, causes, and sources of aquatic life use impairment.

One of three watersheds included in the study was the upper South Skunk River Watershed. Levels of stream biological condition were highly variable across the watershed (Figure 6-5). Benthic macroinvertebrate index (BMIBI) scores ranged from 42 (fair) – 82 (excellent). Fish index (FIBI) scores ranged from 19 (poor) - 61 (good). Differences in biological condition were associated with differences in land cover/land use and stream habitat conditions. Localized biological impacts from point source discharges were also documented.

The highest level of biological condition in the watershed was found at a sampling site (SS4) in the Skunk River Greenbelt area between Story City and Ames. Stream habitat quality at this site was rated as "good." The greenbelt provides a riparian buffer that consists mostly of woody vegetation. The segment in which this site is located has the largest amount of forest cover (11%) in the watershed. Most of the forestland occurs on the steep valley slopes and the floodplain of the South Skunk River.

The primary causes of aquatic life impairment identified in the South Skunk River Watershed are organic enrichment and physical habitat alterations. Agriculture and municipal wastewater discharges were identified as the primary sources of impairment. Agricultural practices that appear to contribute to aquatic life impairment include channelization, hydrologic modification, and streamside livestock grazing. Land application of animal waste from confined animal feeding operations (CAFOs) is a potential source of stream nutrient and organic enrichment that needs further evaluation.

Stream bioassessment and GIS watershed assessment are complementary tools that enable resource managers to move beyond site-specific or program-specific solutions to holistic management of Iowa's stream resources. The tools will become even more effective as experience is gained from developing, implementing, and evaluating TMDLs and watershed plans.

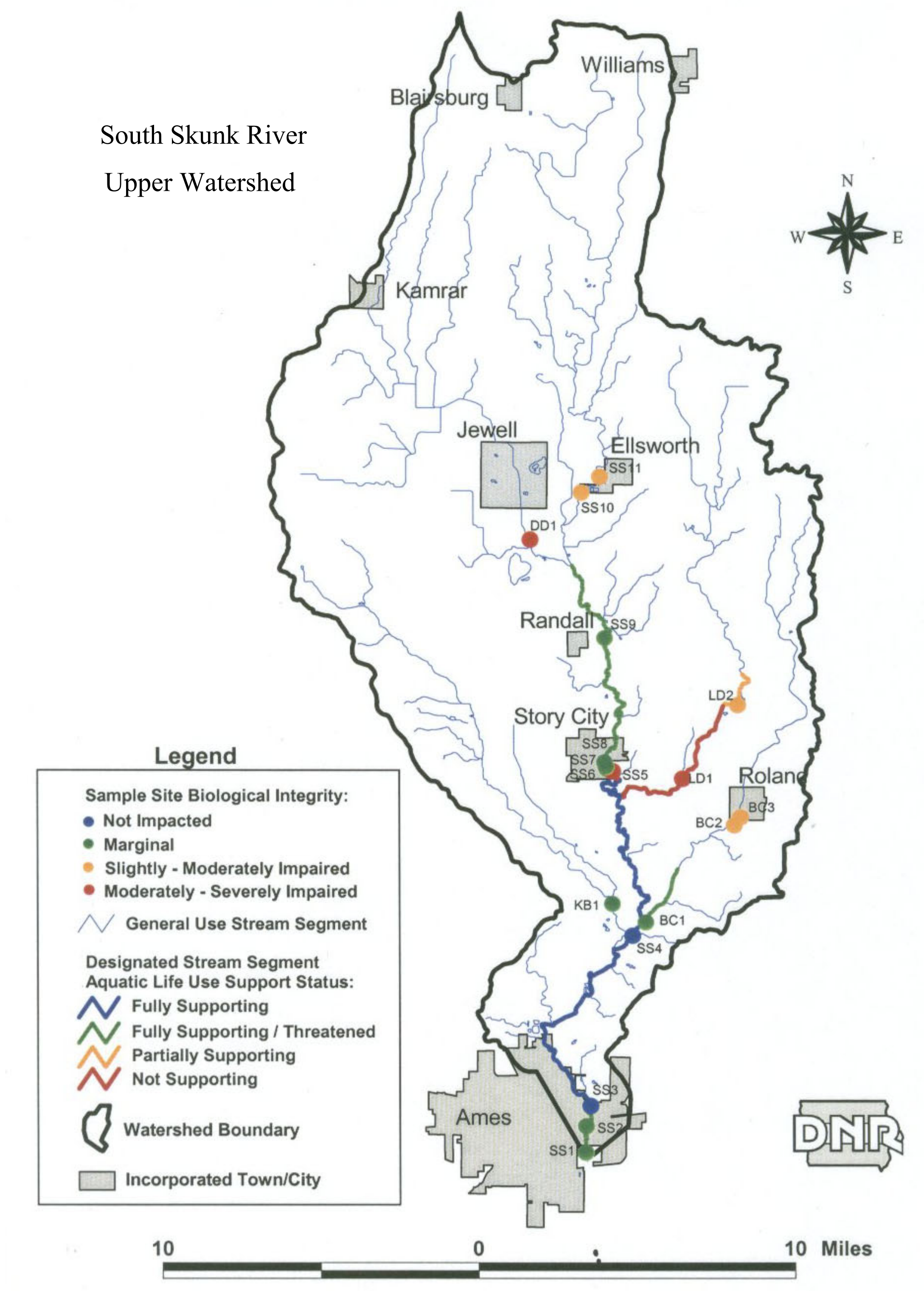


Figure 6-6. Stream biological condition and aquatic life use support status in the upper South Skunk River Watershed.

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8 Abbreviations and Acronyms

40	Central Irregular Plains
40a	Loess Flats and Till Plains
47	Western Corn Belt Plains
47a	Northwest Iowa Loess Prairies
47b	Des Moines Lobe
47c	Iowan Surface
47d	Missouri Alluvial Plain
47e	Steeply Rolling Loess Prairies
47f	Rolling Loess Prairies
47m	Western Loess Hills
52	Driftless Area
52b	Paleozoic Plateau/Coulee Section
72	Central Interior Lowland
72d	Upper Mississippi Alluvial Plain
ALUS	aquatic life use support
AOCV	Analysis of Covariance
AOV	Analysis of Variance
avg.	average
B(LR)	Limited Resource Warm Water
B(WW)	Significant Resource Warm Water
BIC	Biological Impairment Criteria
BINDX	Biotic Index
bldr.	boulder
BMIBI	Benthic Macroinvertebrate Index of Biotic Integrity
Bsim	between-class similarity
C	Celsius
CAFOs	confined animal feeding operations
CCA	Canonical Correspondance Analysis
cfs	cubic feet per second
Chrnmd.	Chironomidae
cm	centimeter
coll.	collector
CS	Classification Strength
CV	Coefficient of Variation
CWA	Clean Water Act
DC	direct current
DCA	Detrended Correspondance Analysis
diss.	dissolved
DML	Des Moines Lobe
dom.	dominant
dpth	depth
Drn.	drainage
Ecor.	ecoregion
EMAP	Environmental Monitoring and Assessment Program

embedd. or embd.	embedded
Ephmr.	Ephemeroptera
EPT	Ephemeroptera, Plecoptera, and Trichoptera
ffg	functional feeding group
FIBI	Fish Index of Biotic Integrity
fltrs.	filterers
FPOM	fine particulate organic matter
ft.	feet
GIS	Geographic Information System
gthrs.	gatherers
H'	Simpson's diversity index
herb. veg.	herbaceous vegetation
HUC	hydrologic unit code
hvy.	heavy
IAC	Iowa Administrative Code
IBI	Index of Biotic Integrity
ICFWRU	Iowa Cooperative Fisheries and Wildlife Research Unit
IDNR	Iowa Department of Natural Resources
IRIS	Iowa River Information System
IS	Iowan Surface
LDA	Log10 stream drainage area
LFTP	Loess Flats and Till Plains
lght	light
M or MH	multi-habitat
max.	maximum
mg/L	milligrams per liter
MHEPT	multi-habitat EPT richness
MHSTR	multi-habitat sensitive taxa richness
MHTR	multi-habitat taxa richness
mi.	mile
Mo.	Missouri
mod.	moderate
Msp.	Mississippi
NPDES	National Pollutant Discharge Elimination System
ntu	nephelometric turbidity units
NWILP	Northwest Iowa Loess Prairies
P3DOM	percent abundance of 3-dominant taxa
PCHR or %CHR	percent abundance of Chironomidae taxa
PDFFG	percent abundance of dominant functional feeding group
PEPHM	percent abundance of Ephemeroptera taxa
PEPT	percent abundance of EPT taxa
PP	Paleozoic Plateau
PSCR	percent abundance of scraper organisms
pts.	points
RDA	Redundancy Analysis
rip. veg.	riparian vegetation

RLP	Rolling Loess Prairies
S or SH	standard-habitat
scrprs.	scrapers
SHEPT	standard-habitat EPT richness
SHTR	standard-habitat taxa richness
SIDP	Southern Iowa Drift Plain
sq.	square
SRLP	Steeply Rolling Loess Prairies
str. bnk.	stream bank
substr.	substrate
susp.	suspended
TMDL	Total Maximum Daily Load
tot.	total
Tripchop.	Trichoptera
U.S. EPA	U.S. Environmental Protection Agency
UHL	University of Iowa Hygienic Laboratory
veg.	vegetation
WCBP	Western Corn Belt Plains
wdth	width
wdy.dbr.	woody debris
Wsim	within-class similarity
WWTP	Waste Water Treatment Plant

9 Glossary

(From U.S. EPA 1996, U.S. EPA 1998, U.S. EPA and Council of State Governments 2003)

Analysis of variance (AOV): a general statistical method for comparing the mean response to different treatments using the ratio of among-group to between-group variance. The method has also been applied to estimating precision and quantifying sources of variance.

Aquatic assemblage: an association of interacting populations of organisms in a given waterbody, for example, fish assemblage or a benthic macroinvertebrate assemblage.

Aquatic community: an association of interacting assemblages in a given waterbody, the biotic component of an ecosystem.

Aquatic life use: a beneficial use designation in which the waterbody provides suitable habitat for survival and reproduction of desirable fish, shellfish, and other aquatic organisms; classifications specified in state water quality standards relating to the level of protection afforded to the resident biological community by the state agency.

Benthic macroinvertebrates: animals without backbones, living in or on the sediments, of a size large enough to be seen by the unaided eye and which can be retained by a U.S. Standard No. 30 sieve. Also referred to as benthos, infauna, or macrobenthos.

Assemblage structure: the make-up or composition of the taxonomic grouping such as fish, algae, or macroinvertebrates relating primarily to the kinds and number of organisms in the group.

Biological assessment: an evaluation of the condition of a waterbody that uses biological surveys and other direct measurements of the resident biota in surface waters.

Biological criteria or biocriteria: numeric values or narrative expressions that describe the reference biological condition of aquatic communities inhabiting waters that have been given a designated aquatic life use.

Biological indicator or bioindicator: an organism, species, assemblage, or community characteristic of a particular habitat, or indicative of a particular set of environmental conditions.

Biological integrity: the ability of an aquatic ecosystem to support and maintain a balanced, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitats within a region.

Biological monitoring or biomonitoring: use of a biological entity as a detector and its response as a measure to determine environmental conditions. Ambient biological surveys and toxicity tests are common biological monitoring methods.

Biological survey or biosurvey: collecting, processing, and analyzing a representative portion of the resident biotic community to determine its structural and/or functional characteristics.

Biota: plants, animals and other living resources of a region.

Canonical correspondence analysis (CCA): a non-linear multi-variate ordination procedure.

Clean Water Act (CWA): an act passed by the U.S. Congress to control water pollution (formerly referred to as the Federal Water Pollution Control Act of 1972). Public Law 92-500, as amended 33 U.S.C. 1251 et seq.

Clean Water Act 303(d): This section of the Act requires states, territories, and authorized tribes to develop lists of impaired waters for which water quality standards are not being met, even after point sources of pollution have installed the minimum required levels of pollution control technology.

Clean Water Act 305(b): biennial reporting requires description of the quality of the Nation's surface waters, evaluation of progress made in maintaining and restoring water quality, and description of the extent of remaining problems.

Designated uses: those uses specified in water quality standards for each waterbody or segment whether or not they are being attained.

Ecological integrity: the condition of an unimpaired ecosystem as measured by combined chemical, physical (including physical habitat), and biological attributes. Ecosystems have integrity when they have their native components (plants, animals and other organisms) and processes (such as growth and reproduction) intact.

Ecoregions: a relatively homogenous area defined by similarity of climate, landform, soil, potential natural vegetation, hydrology, or other ecologically significant variables.

Habitat: a place where the physical and biological elements of ecosystems provide a suitable environment including the food, cover, and space resources needed for plant and animal livelihood.

Index of biological/biotic integrity (IBI): an integrative expression of site condition across multiple metrics. An index of biological integrity is often composed of at least seven metrics.

Metric: a calculated term of renumeration representing some aspect of biological assemblage structure, function, or other measurable aspect and is a characteristic of the biota that changes in some predictable way with increased human influence.

Multimetric index: an index that combines indicators, or metrics, into a single index value. Each metric is tested and calibrated to a scale and transformed into a unitless score prior to being aggregated into a multimetric index. Both the index and metrics are useful in assessing and diagnosing ecological condition.

Multivariate analysis: statistical methods (e.g., ordination, discriminant analysis) for analyzing physical and biological community data using multiple variables.

Narrative biocriteria: written statements describing the structure and function of aquatic communities in a waterbody necessary to protect a designated aquatic life use.

Nonpoint source pollution: pollution that occurs when rainfall, snowmelt, or irrigation water runs over land or through the ground, picks up pollutants, and deposits them into rivers, lakes, and coastal waters or introduces them into ground water.

Numeric biocrteria: specific quantitative measures of the structure and function of aquatic communities in a waterbody necessary to protect a designated aquatic life use.

Point source: an origin of pollutant discharge that is known and specific, usually thought of as effluent from the end of a pipe.

Reference condition: the condition that approximates natural, un-impacted conditions (biological, chemical, physical, etc.) for a waterbody. Reference condition (Biological Integrity) is best determined by collecting measurements at a number of sites in a similar waterbody class or region under undisturbed or minimally disturbed conditions (by human activity), if they exist. Since undisturbed or minimally disturbed conditions may be difficult or impossible to find, least disturbed conditions, combined with historical information, models or other methods may be used to approximate reference condition as long as the departure from natural or ideal is understood. Reference condition is used as a benchmark to determine how much other water bodies depart from this condition due to human disturbance.

Least Disturbed Condition: the best available existing conditions with regard to physical, chemical, and biological characteristics or attributes of a waterbody within a class or region. These waters have the least amount of human disturbance in comparison to others within the waterbody class, region or basin. Least disturbed conditions can be readily found, but may depart significantly from natural, undisturbed conditions or minimally disturbed conditions. Least disturbed condition may change significantly over time as human disturbances change.

Minimally Disturbed Condition: the physical, chemical, and biological conditions of a waterbody with very limited, or minimal, human disturbance in comparison to others within the waterbody class or region. Minimally disturbed conditions can change in time in response to natural processes.

Reference site: a specific locality on a waterbody that is undisturbed or minimally disturbed and is representative of the expected ecological integrity of other localities on the same waterbody or nearby waterbodies.

Regional Environmental Monitoring and Assessment Program (REMAP): the U.S. EPA program initiated to assess the applicability of the EMAP approach to answer questions about ecological conditions at regional and local scales. REMAP conducts projects at smaller geographic scales and in shorter time frames than the national EMAP program.

Taxa**:** a grouping of organisms given a formal taxonomic name such as species, genus, family, etc.

Test site: a location on a waterbody of which the condition is unknown and often suspected to be adversely affected by anthropogenic influence.

Total Maximum Daily Load (TMDL): calculation of the maximum amount of a pollutant a waterbody can receive and still meet water quality standards and an allocation of that amount to the pollutant's sources.

Water Quality Standards: a law or regulation that consists of the beneficial designated use or uses of a waterbody, the narrative or numerical water quality criteria (including biocriteria) that are necessary to protect the use or uses of that particular waterbody, and an antidegradation statement.

Appendix 1. Example Calculations of the Benthic Macroinvertebrate Index of Biotic Integrity (BMIBI).

Appendix 1.1. BMIBI Metric Scoring Formulas.

#	Metric	Abbreviation	Stream Drainage Area Criterion[1]	Metric Scoring Formula
1	Multi-habitat taxa richness	MHTR	LDA≤1.85 LDA>1.85	(#MH-taxa/(12 + 21.7*LDA))*10 (#MH-taxa/52)*10
2	Standardized-habitat taxa richness	SHTR	LDA≤2.06 LDA>2.06	(#SH-taxa/(4 + 9.08*LDA))*10 (#SH-taxa/22.7)*10
3	Multi-habitat EPT richness	MHEPT	LDA≤2.11 LDA>2.11	(#MH-EPT taxa/(6 + 9.93*LDA))*10 (#MH-EPT taxa/27)*10
4	Standardized-habitat EPT taxa richness	SHEPT	LDA≤1.93 LDA>1.93	(#SH-EPT taxa/(2.4 + 6.37*LDA))*10 (#SH-EPT taxa/14.7)*10
5	Multi-habitat sensitive taxa richness	MHSTR	LDA≤1.85 LDA>1.85	(#MH-snstv.taxa/(2.4 + 4.66*LDA))*10 (#MH-snstv.taxa/11)*10
Metrics 6-12 are calculated using standardized-habitat sampling data only				
6	% abundance 3-dominant taxa	P3DOM	LDA≤1.85 LDA>1.85	((100 - %3dom.taxa)/(100-(95-31.35*LDA))*10 ((100-%3domsp.)/63)*10
7	Biotic index	BINDX	All streams	((7-Bindx)/2.7)*10
8	% abundance EPT taxa	PEPT	All streams	(%EPT/95.5)*10
9	% abundance Chironomidae	PCHR	All streams	(100-%Chrnmd.)/98.98)*10
10	% abundance Ephemeroptera taxa	PEPHM	All streams	(%Ephmr./78.2)*10
11	% abundance scraper organisms	PSCR	All streams	(%scrpr./44.7)*10
12	% abundance dominant functional feeding group	PDFFG	All streams	((100-%dom.ffg.)/60)*10

[1]LDA = Log10 Stream Drainage Area (square miles)

<u>Benthic Macroinvertebrate Index of Biotic Integrity (BMIBI) Computation Steps</u>:
1) Obtain benthic macroinvertebrate taxa classifications and tolerance values from Appendix A1-1.
2) Calculate metrics (refer to metric descriptions in Section 5.1.3 and instructions in Appendix A1-4).
3) Compute the metric score for each of the twelve BMIBI metrics; apply the appropriate metric formula depending on the stream watershed drainage area. Each metric scoring range is continuous from 0 - 10 (round metric scores to one decimal place); minimum score = 0.0, maximum (optimum) score = 10.0. In computing metric scores, values less than zero or values exceeding ten may occur. Metric scores less than zero are rounded up to zero; metric scores greater than ten are rounded down to ten.
4) Calculate BMIBI score. BMIBI = ((Sum of metric scores 1 - 12)*10)/12. Round BMIBI score to nearest integer; possible scoring range is 0 - 100.

Appendix 1.2 Benthic Macroinvertebrate Taxa and Data Metric Classifications (2001).
(Note: taxonomic classifications are periodically reviewed. Contact IDNR stream bioassessment unit for updated information.)

Taxon	Life Stage	Biotic Index Value	Functional Feeding Group*	Filterer	Scraper	Collector / Gatherer	Sensitive Taxa
Annelida							
Hirudinea	adult	7.5					
	immature	7.5					
Pharyngobdellida							
Erpobdellidae	adult	8.0	pa				
	immature	8.0	pa				
Dina dubia	adult	8.0	pa				
D. parva	adult	8.0	pa				
	immature	8.0	pa				
Erpobdella punctata	adult	7.8	pa				
Helobdella stagnalis	adult	6.7	pa				
H. triserialis	adult	8.9	pa				
Mooreobdella fervida	adult	7.8	pa				
M. melanostoma	adult	7.8	pa				
M. microstoma	adult	7.8	pa				
M. tetragon	adult	7.8	pa				
Nephelopsis obscura	adult	8.0	pa				
Rhynchobdellida							
Glossiphoniidae	adult	7.0	pr				
	immature	7.0	pr				
Batracobdella picta	adult						
Glossiphonia complanata	adult	7.0	pr				
Placobdella	adult	7.0	pr				
	immature	7.0	pr				
P. montifera	adult	6.0	pr				
P. multilineata	adult	7.0	pr				
P. multilineata/papillifera	adult	7.0	pr				
P. nuchalis	adult	7.0	pr				
P. ornata	adult	7.0	pr				
P. papillifera	adult	9.0	pr				
P. parasitica	adult	6.6	pr				
Oligochaeta	adult	8.5	co			x	
	immature	8.5	co			x	
Haplotaxida	adult	8.5	co			x	
Lumbricidae	adult	8.0	co			x	
Eisenella tetredra	adult	8.0	co			x	
Naididae	adult	7.6	co			x	
Tubificidae	adult	10.0	co			x	
	immature	10.0	co			x	
Arthropoda							
Crustacea							
Amphipoda							
Gammaridae	adult	4.0					
	immature	4.0					
Gammarus	adult	4.0					
G. pseudolimnaeus	adult	4.0	co			x	
Talitridae		8.0	co			x	
Hyalella azteca	adult	8.0	co			x	
Decapoda	immature						
Cambaridae	immature	6.0	co			x	
Cambarus diogenes	adult	6.0	co			x	
Orconectes	adult	6.0	co			x	
	immature	6.0	co			x	
O. immunis	adult	6.0	co			x	
O. rusticus	adult	6.0	co			x	
O. virilis	adult	6.0	co			x	
	immature	6.0	co			x	

Taxon	Life Stage	Biotic Index Value	Functional Feeding Group*	Filterer	Scraper	Collector / Gatherer	Sensitive Taxa
Isopoda							
Asellidae							
Caecidotea	adult	8.0	co			x	
C. intermedia	adult	8.0	co			x	
Lirceus	adult	8.0	co			x	
Hydracarina	adult	5.7					
	larva						
Hydrachnida	adult						
Hydrachnidae	adult						
Insecta							
Coleoptera	adult						
	larva						
Carabidae	adult	4.0	pr				
Curculionidae	adult		he,sh				
Listronotus	adult		unk				
Lixus	adult		unk				
Dryopidae							
Helichus	adult	5.0	sc,co		x		
	larva	5.0	sh				
H. fastigiatus	adult	5.5	sc,co		x		
H. lithophilus	adult	5.0	sc,co		x		
H. striatus	adult	5.0	sc,co		x		
Dytiscidae	adult	5.0	pr				
	larva	5.0	pr				
Acilius sylvanus	larva		pr				
Agabetes acuductus	adult	5.0	pr				
Agabus	adult	5.0	pr				
	larva	5.0	pr				
Agabus/Ilybius	larva	5.0	pr				
A. gagetes	larva	5.0	pr				
A. semivittatus	adult	5.0	pr				
A. seriatus	adult	5.0	pr				
Celina	adult	5.0	pr				
Colymbetes	adult	5.0	pr				
Copelatus	adult		pr				
Copelatus chevrolati	adult		pr				
Copelatus glyphicus	adult	9.1	pr				
Coptotomus	adult	9.0	pr				
C. loticus	adult	9.0	pr				
Dytiscus	larva	3.7	pr				
Heterosternuta wichami	adult		pr				
Hydaticus	larva	5.0	pr				
Hydroporus	adult	8.9	pr				
H. dichorous	adult	8.9	pr				
Hydrovatus	adult	3.7	pr				
H. pustulatus	adult	3.7	pr				
Hygrotus dissimilis	adult	1.9	pr				x
H. sayi	adult	1.9	pr				x
Ilybius	larva	3.7	pr				
I. fraterculus	adult	3.7	pr				
Laccophilus	adult	5.0	pr				
	larva	5.0	pr				
L. fasciatus	adult	5.0	pr				
L. maculosus	adult	5.0	pr				
	larva	5.0	pr				
L. proximus	adult	5.0	pr				
L. undatus	adult	5.0	pr				
Liodessus	larva		pr				
L. affinis	adult		pr				
L. affinis/obsurellus	adult		pr				

Taxon	Life Stage	Biotic Index Value	Functional Feeding Group*	Filterer	Scraper	Collector / Gatherer	Sensitive Taxa
L. flavicollis	adult		pr				
Lioporeus triangularis	adult		pr				
Neoporus	adult		pr				
N. dimidiatus	adult		pr				
N. dimidiatus/solitarius	adult		pr				
N. solitarius	adult		pr				
N. undulatus	adult		pr				
N. vitiosus	adult		pr				
N. vittatus	adult		pr				
Oreodytes	larva		pr				
Sanfilippodytes	adult		pr				
Stictiotarsus griseostriatus	adult		pr				
Uvarus	adult	4.6	pr				
U. lacustris	adult	4.6	pr				
Elmidae	adult	4.0	co,ga,sc				
	larva	4.0	co,ga,sc				
Ancyronyx variegata	adult	6.0	co,sc			x	
	larva	6.0	co,sc				
Dubiraphia	adult	6.0	co,sc				
	larva	6.0	co,sc				
D. bivattata	larva	8.0	co,sc				
	adult	8.0	co,sc				
D. minima	adult	6.0	co,sc				
	larva	6.0	co,sc				
D. quadrinotata	adult	6.0	co,sc				
D. vittata	adult	6.0	co,sc				
Macronychus glabratus	adult	4.0	co,de			x	
	larva	4.0	co,de			x	
Optioservus	adult	4.0	sc,co		x		
	larva	4.0	sc,co		x		
O. fastiditus	adult	4.0	sc,co		x		
	larva	4.0	sc,co		x		
Stenelmis	adult	5.0	sc,co		x		
	larva	5.0	sc,co		x		
S. bicarinata	adult	5.0	sc,co		x		
S. cheryl	adult	5.0	sc,co		x		
S. crenata	adult	5.0	sc,co		x		
S. decorata	adult	5.0	sc,co		x		
S. grossa	adult	5.0	sc,co		x		
	larva	5.0	sc,co		x		
S. sexlineata	adult	5.0	sc,co		x		
Gyrinidae			pr				
Dineutus	adult	4.0	pr				
	larva	4.0	pr				
D. assimilis	adult	4.0	pr				
Gyrinus	adult	6.3	pr				
	larva	6.3	pr				
G. aeneolus	adult	6.3	pr				
G. marginellus	adult	6.3					
Haliplidae			he				
Haliplus	larva	5.0	mp,sh				
H. borealis	adult	5.0	mp,sh				
H. connexus	adult	5.0	mp,sh				
H. immaculicollis	adult	5.0	mp,sh				
H. triopsis	adult	5.0	mp,sh				
Peltodytes	adult	5.0	mp,sh,pr				
	larva	5.0	mp,sh,pr				
P. duodecimpuntatus	adult	5.0	mp,sh,pr				
	larva	5.0	mp,sh,pr				
P. edentulus	adult	5.0	mp,sh,pr				

Taxon	Life Stage	Biotic Index Value	Functional Feeding Group*	Filterer	Scraper	Collector / Gatherer	Sensitive Taxa
P. tortulosus	adult	5.0	mp,sh,pr				
Hydrochidae							
Hydrochus	adult	4.6	sh,he				
H. scabratus	adult	4.6	sh,he				
H. subcupreus	adult	4.6	sh,he				
Heteroceridae	adult						
	larva						
Hydrophilidae	adult	5.0	co,ga			x	
	larva	5.0	pr				
Anacaena	adult						
A. lutescens	adult						
Berosus	adult	5.0	he,co,mp,sh				
B. peregrinus	adult	5.0					
Cymbiodyta	adult	5.5					
C. chamberlaini	adult	5.5					
C. toddi	adult	5.5					
C. vindicata	adult	5.5					
Enochrus	adult	8.5	mp				
	larva	8.5	mp				
E. diffusus/hamiltoni	adult	8.5	mp				
E. ochraceus	adult	8.5	mp				
E. pygmaeus	adult	8.5	mp				
Helophorus	adult	5.0	sh, he				
H. lacustris	adult	5.0	sh, he				
Hydrobius	larva	5.0	pr				
	adult	5.0					
Hydrochara	adult						
H. soror	adult						
Hydrophilus	adult	4.6	mp,co				
	larva	4.6	pr				
Laccobius	adult	5.0	mp				
L. agilis	adult	5.0	mp				
L. spangleri	adult	5.0	mp				
Paracymus	adult	7.3					
P. subcupreus	adult	7.3					
Sperchopsis tessellatus	adult	6.5	unk				
	larva	6.5	unk				
Tropisternus	adult	9.8	co,mp				
	larva	9.8	pr				
T. lateralis	adult	9.8	co,mp				
T. natator	adult	9.8	co,mp				
Lampyridae	larva						
Noteridae	adult						
	larva						
Psephenidae							
Ectopria sp.1	larva	5.0	sc		x		
Ptilodactylidae	larva	5.0	sh,de,he				
Scirtidae							
Cyphon	adult	5.0	sc,co,ga,sh,mp,he				
	larva	5.0					
Scirtes	larva	5.0	sh				
Staphylinidae	adult						
Collembola	adult		co,ga			x	
Diptera	adult						
	immature						
	larva						
	pupa						
Athericidae		2.0	pr				x
Atherix	larva	2.0	pr				x
A. variegata	larva	2.0	pr				x

Taxon	Life Stage	Biotic Index Value	Functional Feeding Group*	Filterer	Scraper	Collector / Gatherer	Sensitive Taxa
Ceratopogonidae	larva	6.0	pr,co,ga				
Alluaudomyia	larva	6.0	pr				
Atrichopogon	larva	6.8	co,ga			x	
Bezzia	larva	6.0	pr				
Bezzia / Palpomyia	larva	6.0	pr				
Ceratopogon	larva	6.0					
Forcipomyia	larva	6.0					
Palpomyia	larva	6.0	pr,co,ga				
Probezzia	larva	6.0	pr				
Sphaeromias	larva	6.0	pr,co,ga				
Chironomidae	larva	6.0	co,pr			x	
	pupa	6.0					
Robackia demeijerei	larva	4.3	co,ga			x	
Culicidae	larva	8.0	co,fi,ga			x	
	pupa	8.0					
Aedes so	larva		co,ga, fi			x	
Anopheles	larva	9.1	fi	x			
	pupa						
Culex	larva	10.0	fi	x			
Cyclorrhaphous-Brachycera	larva						
Dixidae		1.0	co,ga				
Dixa	larva	1.0					
Dixella	larva	1.0	co			x	
Dolichopodidae	larva	4.0	pr				
Empididae	immature	6.0					
	larva	6.0	pr,co				
	pupa						
Chelifera	larva	6.0					
Clinocera	larva	6.0	pr				
Hemerodromia	larva	6.0	pr,co				
	pupa						
Wiedemannia	larva	6.0	pr				
Ephydridae	larva	6.0	co,ga,sh,sc,pr				
	pupa	6.0					
Notiphila	larva		co,ga,fi			x	
Parydra	larva		sc		x		
Scatella	larva		co,ga,sc			x	
Muscidae	larva	6.0	pr				
Psychodidae							
Pericoma	larva	4.0	co,ga			x	
Simuliidae	immature	6.0	fi	x			
	larva	6.0	fi	x			
	pupa	6.0					
Cnephia	larva	4.0	fi	x			
Prosimulium	larva	2.6	fi	x			x
Simulium	larva	6.0	fi	x			
	pupa	6.0					
S. aureum	larva	7.0	fi	x			
S. jenningsi/luggeri	larva	4.5	fi	x			
S. tuberosum	larva	5.0	fi	x			
S. vittatum							
Stratiomyidae	larva	8.0	co,ga			x	
Nemotelus	larva		co			x	
Odontomyia	larva	8.0	co,ga,sc			x	
Stratiomys	larva		co			x	
Syrphidae	larva	10.0					
Tabanidae	immature	6.0	pr				
	larva						
Chrysops	larva	6.0	pr				
Silvius	larva	5.0					

Taxon	Life Stage	Biotic Index Value	Functional Feeding Group*	Filterer	Scraper	Collector / Gatherer	Sensitive Taxa
Tabanus	larva	5.0	pr				
Tabanus/Atylotus	larva	5.0	pr				
Tipulidae	larva	4.0					
	immature	4.0					
	pupa						
Antocha	larva	3.0	co			x	x
Dicranota	larva	3.0	pr				x
Erioptera	larva	7.0	co			x	
Gonomyia	larva	5.5	co				
Helius	larva						
Hexatoma	larva	2.0	pr				x
Limonia	larva	6.0	sh				
Ormosia	larva		co			x	
Pedicia	larva	6.0	pr				
Pilaria	larva	7.0	pr				
Pseudolimnophilia	larva	2.0					x
Tipula	larva	4.0	sh,co				
Ephemeroptera	nymph						
	pupa						
	immature						
Baetidae	immature	6.0	co,sc			x	
	nymph	6.0	co,sc			x	
Acentrella	nymph	6.0	co			x	
A. ampla Prob	nymph		co			x	
A. ampla	nymph		co			x	
A. parvula	nymph	4.0	co			x	
A. turbida	nymph	6.0	co			x	
Baetis	immature	6.0	co,sc			x	
	nymph	6.0	co,sc			x	
B. armillatus	nymph	4.0	co			x	
B. brunneicolor	immature	4.0	co			x	
	nymph	4.0	co			x	
B. dubius	nymph	4.0	co			x	
B. dubius/punctiventris	nymph	4.5	co			x	
B. dubius/virile	nymph	6.0	co			x	
B. flavistriga	nymph	4.0	co			x	
B. intercalaris	immature	6.0	co			x	
	nymph	6.0	co			x	
B. pluto	nymph	6.0	co			x	
B. punctiventris	nymph	5.0	co			x	
B. tricaudatus	nymph	2.0	co			x	
B. virile	nymph	6.0	co			x	
Barbaetis cestus	nymph	6.0	co			x	
Callibaetis	nymph	9.0	co			x	
C. fluctuan	nymph	9.0	co			x	
C. pictus	nymph	9.0	co			x	
Centroptilum	nymph	2.0	co			x	x
C. victoriae	nymph	2.0	co			x	x
Fallceon sp.	nymph	6.0	co			x	
F. quilleri	nymph	6.0	co			x	
Labiobaetis	immature	6.0	co			x	
	nymph	6.0	co			x	
L. dardanus	nymph	6.0	co			x	
L. frondalis	nymph	5.0	co			x	
L. longipalpus	nymph	5.0	co			x	
L. propinquus	nymph	6.0	co			x	
Paracloeodes minutus	nymph	6.0	sc		x		
Plauditius	nymph	6.0	co			x	
P. cestus	nymph	6.0	co			x	
P. dubius	nymph	4.0	co			x	

Taxon	Life Stage	Biotic Index Value	Functional Feeding Group*	Filterer	Scraper	Collector / Gatherer	Sensitive Taxa
P. dubius/punctiventris	nymph	4.5	co			x	
P. dubius/virilis	nymph	5.0	co			x	
P. punctiventris	nymph	5.0	co			x	
P. virilis	nymph	6.0	co			x	
Procloeon	nymph	6.0	co			x	
P. irrubrum	nymph	6.0	co			x	
P. rufostrigatum	nymph	6.0	co			x	
P. viridocularis	nymph	6.0	co			x	
Pseudocloeon	nymph	4.0	co			x	
P. dardanum	nymph	6.0	co			x	
P. ephippiatum	nymph						
P. frondale	nymph	5.0	co			x	
P. longipalpus	nymph	5.0	co			x	
P. propinquum	nymph	6.0	co			x	
Baetiscidae		3.0	co,ga,sc				
Baetisca	nymph	4.0	co,ga,sc			x	
B. lacustris	nymph	5.0	co,ga,sc			x	
B. laurentina	nymph	3.0	co,ga,sc			x	x
Caenidae	immature	7.0					
Amercaenis ridens	nymph		co,fi			x	
Brachycercus	nymph	3.0	co			x	x
B. flavus	nymph	3.0	co			x	x
B. lacustris	nymph	3.0	co			x	x
B. nasutus	nymph	3.0	co			x	x
Caenis	immature						
	nymph	7.0	co,ga,sc			x	
C. anceps	nymph	7.0	co,ga,sc			x	
C. diminuta	nymph	7.0	co,ga,sc			x	
C. hilaris	nymph	7.0	co,ga,sc			x	
C. latipennis	nymph	7.0	co,ga,sc			x	
C. punctata	nymph	7.0	co,ga,sc			x	
C. tardata	nymph	7.0	co,ga,sc			x	
Cercobrachys	nymph		co			x	
C. serpentis	nymph		co			x	
Ephemeridae							
Hexagenia	immature	6.0	co			x	
H. atrocaudata	nymph	6.0	co			x	
H. bilineata	nymph	6.0	co			x	
H. limbata	nymph	6.0	co			x	
Pentagenia vittigera	nymph	6.0	co			x	
Ephemerellidae	immature						
	nymph	2.0					x
Ephemerella	nymph	2.0	co,ga,sc			x	x
E. inermis	nymph	2.0	co,ga,sc			x	x
E. needhami	nymph	2.0	co,ga,sc			x	x
Eurylophella	nymph	2.0	co,ga			x	x
Serratella	nymph	2.0	co			x	x
Heptageniidae	immature	4.0	sc,co		x		
	nymph	4.0	sc,co		x		
Heptagenia	immature	3.0	sc,co		x		x
	nymph	3.0	sc,co		x		x
H. diabasia	nymph	3.0	sc,co		x		x
H. flavescens	nymph	4.0	sc,co		x		
H. marginalis	nymph	4.0	sc,co		x		
H. pulla	nymph	4.0	sc,co		x		
Leucrocuta	nymph	1.0	sc,co		x		x
L. hebe	nymph	2.0	sc,co		x		x
L. maculipennis	nymph	2.0	sc,co		x		x
Nixe	nymph	2.0	sc,co		x		x
N. inconspicua	nymph	2.0	sc,co		x		x

Taxon	Life Stage	Biotic Index Value	Functional Feeding Group*	Filterer	Scraper	Collector / Gatherer	Sensitive Taxa
N. perfida	nymph	2.0	sc,co		x		x
Rhithrogena	nymph	0.0	co,sc			x	x
R. jejuna	nymph	0.0	co,sc			x	x
R. manifesta	nymph	0.0	co,sc			x	x
Stenacron	immature	7.0	co,sc			x	
	nymph	7.0	co,sc			x	
S. interpunctatum	nymph	7.0	co,sc			x	
Stenonema	immature	3.7	sc,co		x		
	nymph	3.7	sc,co		x		
S. exiguum	nymph	5.0	sc,co		x		
S. exiguum/pulchellum	nymph	4.0	sc,co		x		
S. femoratum	nymph	5.0	sc,co		x		
S. mediopunctatum	nymph	3.0	sc,co		x		x
S. meririvulanum	nymph	2.0	sc,co		x		x
S. mexicanum	nymph	4.0	sc,co		x		
S. pulchellum	nymph	3.0	sc,co		x		x
S. pulchellum/terminatum	nymph	3.5	sc,co		x		
S. terminatum	immature	4.0	sc,co		x		
	nymph	4.0	sc,co		x		
S. vicarium	nymph	2.0	sc,co		x		x
Isonychiidae							
Isonychia	nymph	3.8	fi	x			
Leptohyphidae							
Tricorythodes	nymph	4.0	co			x	
	immature						
Leptophlebiidae	nymph	4.0	co,sc				
	immature						
Leptophlebia	nymph	4.0	co			x	
Paraleptophlebia	nymph	1.0	co,sh				x
Metretopodidae		2.0					
Siphloplecton	nymph	2.0	co,ga			x	x
Oligoneuriidae		2.0					
Homoeoneuria ammophila	nymph		fi	x			
Polymitarcyidae		2.0					
Ephoron	nymph	2.0	co			x	x
E. album	nymph	2.0	co			x	x
Tortopus primus	nymph	4.5					
Potamanthidae							
Anthopotamus	immature	4.0	fi	x			
	nymph	4.0	fi	x			
A. myops	nymph	4.0	fi	x			
Hemiptera	immature						
Belostomatidae	immature						
Belostoma	adult	9.8	pr				
B. flumineum	adult	9.8	pr				
Lethocerus	adult	4.6	pr				
Corixidae	adult	5.0					
	immature	5.0					
Glaenocorisini	adult		unk				
Hesperocorixa	adult	5.0	mp				
H. vulgarius	adult	5.0	mp				
Palmacorixa	adult	5.5	unk				
P. gillettei	adult	5.5	unk				
P. nana	adult	5.5	unk				
Sigara	adult	4.6	pr,mp,he				
	larva	4.6	mp,co				
S. alternata	adult	4.6	mp,co				
S. bicoloripennis	adult	4.6	mp,co				
S. mathesoni	adult	4.6	mp,co				
S. trilineata	adult	4.6	mp,co				

Taxon	Life Stage	Biotic Index Value	Functional Feeding Group*	Filterer	Scraper	Collector / Gatherer	Sensitive Taxa
Trichocorixa	adult	5.5	pr				
T. borealis	adult	5.5	pr				
T. calva	adult	5.5	pr				
T. kanza	adult	5.5	pr				
T. naias	adult	5.5	pr				
Gerridae	immature		pr				
Aquarius	adult	6.4	pr				
A. remigis	adult	6.4	pr				
Gerris	adult	6.4	pr				
Limnoporus	adult		pr				
L. dissortis	adult		pr				
Metrobates	adult	6.4	pr				
M. hesperius	adult	6.4	pr				
Rheumatobates	adult	6.4	pr				
R. palosi	adult	6.4	pr				
Trepobates	adult	6.4	pr				
Hebridae	immature		pr				
Macroveliidae							
Macrovelia	adult		pr				
Mesoveliidae	immature		pr				
Mesovelia	adult	6.4	pr				
M. mulsanti	adult	6.4	pr				
Miridae	adult						
Nepidae							
Nepa	adult	4.6	pr				
Nepa apiculata	adult	4.6	pr				
Ranatra	adult	6.4	pr				
R. fusca	adult	7.3	pr				
Notonectidae							
Notonecta	adult	5.5	pr				
N. irrorata	adult	5.5	pr				
N. undulata	adult	5.5	pr				
Pleidae							
Neoplea	adult	5.5	pr				
N. striola	adult	5.5	pr				
Saldidae	immature		pr				
Veliidae	immature	6.4	pr				
Microvelia	adult	6.4	pr				
M. americana	adult	6.4	pr				
Rhagovelia	adult	6.4	pr				
	immature	6.4	pr				
R. oriander	adult	6.4	pr				
Lepidoptera							
Cosmopterigidae							
Pyroderces	larva						
Pyralidae							
Crambus	larva						
Petrophila	larva	5.0	sc,he		x		
Megaloptera							
Corydalidae							
Corydalus	larva	6.0	pr				
C. cornutus	larva	6.0	pr				
Chauliodes	larva	4.0	pr				
C. pectinicornis	larva	4.0	pr				
C. rastricornis	larva	4.0	pr				
Sialidae							
Sialis	larva	4.0	pr				
Neuroptera	larva						
Sisyridae							
Climacia	larva	6.5	pr				

Taxon	Life Stage	Biotic Index Value	Functional Feeding Group*	Filterer	Scraper	Collector / Gatherer	Sensitive Taxa
Odonata	immature						
Aeshnidae	immature	3.0	pr				
Aeshna	nymph	5.0	pr				
Aeshna/Anax	nymph	5.7	pr				
A. umbrosa	nymph	5.0	pr				
A. palmata	nymph	5.0	pr				
Anax	nymph	6.4	pr				
A. junius	nymph	8.0	pr				
Boyeria	nymph	2.0	pr				x
B. vinosa	nymph	2.0	pr				x
Calopterygidae	immature	6.0	pr				
Calopteryx	nymph	5.0	pr				
Hetaerina	nymph	6.0	pr				
Coenagrionidae	immature	8.0	pr				
	nymph	8.0	pr				
Amphiagrion	nymph	9.0	pr				
Argia	nymph	6.0	pr				
Coenagrion/Enallagma	nymph	8.0	pr				
Enallagma	nymph	8.0	pr				
Enallagma /Coenagrion	nymph	8.0	pr				
Hesperagrion	nymph	8.0	pr				
Corduliidae			pr				
Didymops	nymph	5.5	pr				
Macromia	nymph	2.0	pr				
M. illinoiensis	nymph	2.0	pr				x
Neurocordulia	nymph	5.0	pr				
N. molesta	nymph	5.0	pr				
N. xanthosoma	nymph	5.0	pr				
Somatochlora	nymph	1.0	pr				x
S. tenebrosa	nymph	1.0	pr				x
Gomphidae	immature	5.0	pr				
	nymph	5.0	pr				
Arigomphus	nymph	6.4	pr				
Dromogomphus	nymph	6.3	pr				
D. spinosus	nymph	6.3	pr				
Gomphurus	nymph	6.0	pr				
Gomphus	nymph	5.0	pr				
Ophiogomphus	nymph	1.0	pr				x
O. carolus	nymph	1.0	pr				x
O. rupinsulensis	nymph	1.0	pr				x
Phanogomphus	nymph		pr				
Progomphus	immature	8.7	pr				
	nymph	8.7	pr				
P. obscurus	nymph	8.7	pr				
Stylurus	nymph	4.0	pr				
S. amnicola	nymph	4.0	pr				
S. notatus	nymph	4.0	pr				
S. spiniceps	nymph	4.0	pr				
Libellulidae							
Erythemis	nymph	7.7	pr				
E. simplicicollis	nymph	7.7	pr				
Libellula	nymph	9.8	pr				
L. luctuosa	nymph	9.8	pr				
L. pulchella	nymph	9.0	pr				
Macrothemis	nymph	8.0	pr				
Pantala hymeanea	nymph	6.4	pr				
Perithemis	nymph	10.0	pr				
Plathemis	nymph	8.0	pr				
P. lydia	nymph	8.0	pr				
Plecoptera	immature						

Taxon	Life Stage	Biotic Index Value	Functional Feeding Group*	Filterer	Scraper	Collector / Gatherer	Sensitive Taxa
Capniidae							
Allocapnia	nymph	3.0	sh				x
Nemouridae							
Amphinemura	nymph	3.0	sh				x
Perlidae	immature	3.0	pr				
	nymph	3.0	pr				
Acroneuria sp.	nymph	0.0	pr				x
A. abnormis	nymph	0.0	pr				x
A. lycorias	nymph	0.0	pr				x
A. perplexa	nymph	0.0	pr				x
Agnetina	immature	2.0	pr				x
	nymph	2.0	pr				x
A. annulipes	nymph	2.0	pr				x
A. capitata	nymph	2.0	pr				x
A. flavescens	nymph	2.0	pr				x
Attaneuria ruralis	nymph	1.0	pr				x
Neoperla	nymph	3.0	pr				x
N. robisoni	nymph	3.0	pr				x
Paragnetina	nymph	1.0	pr				x
P. media	nymph	1.0	pr				x
Perlesta	nymph	5.0	pr				
P. decepiens	nymph	5.0	pr				
P. shubuta	nymph	5.0	pr				
Perlinella	immature	1.0	pr				x
	nymph	1.0	pr				x
P. drymo	nymph	1.0	pr				x
P. ephyre	nymph	1.0	pr				x
Perlodidae	immature	2.0	pr,sc,co,ga				x
Isoperla	nymph	2.0	pr,co,ga				x
I. bilineata	nymph	4.0	pr				
I. marlynia	nymph	4.0	pr				
I. signata	nymph	2.0	pr,co,ga				x
Pteronarcyidae			sh,de,sc				
Pteronarcys	nymph	0.0	sh				x
Taeniopterygidae	immature	2.0	sh,co				x
Taeniopteryx	immature	2.0	sh,co				x
	nymph	2.0	sh,co				x
Trichoptera	larva						
	immature						
	pupa						
Brachycentridae		1.0					
Brachycentrus	larva	1.0	fi,sc	x			x
B. americanus	larva	1.0	fi,sc	x			x
B. flavus	larva	2.2	fi,sc	x			x
B. lateralis	larva	1.0	fi,sc	x			x
B. numerosus	larva	1.0	fi,sc	x			x
B. occidentalis	larva	1.0	fi,sc	x			x
Micrasema	larva	2.0	sh				x
M. gelidum	larva	2.0	sh				x
M. kluane	larva	1.0	sh,co				x
Glossosomatidae		0.0					
Glossosoma	larva	0.0	sc		x		x
	pupa						
Helicopsychidae		3.0	sc				
Helicopsyche	pupa	3.0	sc				x
H. borealis	larva	3.0	sc		x		x
	immature	3.0	sc		x		x
Hydropsychidae	immature	5.0	fi	x			
	larva	5.0	fi	x			
	pupa						

Taxon	Life Stage	Biotic Index Value	Functional Feeding Group*	Filterer	Scraper	Collector / Gatherer	Sensitive Taxa
Ceratopsyche	immature	4.5	fi	x			
	larva	4.5	fi	x			
C. alhedra	larva	3.0	fi	x			x
C. alternans	larva	3.0	fi	x			x
C. bronta	larva	5.0	fi	x			
C. morosa (bifida)	larva	6.0	fi	x			
C. slossonae	larva	4.0	fi	x			
C. walkeri	larva	1.0	fi	x			x
Cheumatopsyche	larva	5.0	fi	x			
Hydropsyche	immature	4.0	fi	x			
	larva	4.0	fi	x			
H. arinale	larva	5.0	fi	x			
H. betteni	larva	6.0	fi	x			
H. bidens	larva	3.0	fi	x			x
H. dicantha	larva	2.0	fi	x			x
H. orris	larva	5.0	fi	x			
H. phalerata	larva	1.0	fi	x			x
H. placoda	larva	3.0	fi	x			x
H. simulans	larva	7.0	fi	x			
Potamyia flava	larva	2.0	fi	x			x
Hydroptilidae	immature	6.0	mp,sc,co				
	larva	6.0	mp,sc,co				
	pupa						
Hydroptila	larva	6.0	mp,sc				
Mayatrichia	larva	6.0	sc		x		
M. ayama	larva	6.0	sc		x		
Ochrotrichia	larva	6.0	mp				
Oxyethira	larva	3.0	mp,co				x
Stactobiella	larva	2.0	sh				x
Lepidostomatidae	larva	1.0	sh				
Lepidostoma	larva	1.0	sh				
Leptoceridae	immature	4.0					
	pupa						
Ceraclea	larva	3.0	co,sh,pr				x
C. cancellata	larva	3.0					x
C. flava	larva	3.0					x
C. neffi	larva	3.0					x
Leptocerus	larva	4.6	sh				
Nectopsyche	larva	3.0	sh,co				x
N. candida	larva	3.0	sh,co				x
N. diarina	larva	3.0	sh,co				x
	pupa	3.0					x
N. pavida	larva	3.0	sh,co				x
Oecetis	larva	8.0	pr,sh				
O. avara	larva	8.0	pr,sh				
O. avara/disjuncta	larva	8.0	pr,sh				
O. disjuncta	larva	8.0	pr,sh				
O. immobilis	larva	8.0	pr,sh				
O. inconspicua complex	larva						
O. nocturna	larva	8.0	pr,sh				
Limnephilidae	immature	4.0					
	larva	4.0					
	pupa						
Anabolia	larva	5.0	sh,co				
Grammotaulius/Limnephilu	larva	4.0					
Hesperophylax designatus	larva	3.0	sh				x
Ironoquia	larva	3.0	sh				x
Limnephilus	larva	3.0	sh,he,co				x
Pycnopsyche	larva	4.0	sh				
	pupa						

Taxon	Life Stage	Biotic Index Value	Functional Feeding Group*	Filterer	Scraper	Collector / Gatherer	Sensitive Taxa
Molannidae							
Molanna	larva	6.0	sc,co,pr				
Philopotamidae		4.0					
Chimarra	larva	4.0	fi	x			
C. aterrima	larva	4.0	fi	x			
C. obscura	larva	4.0	fi	x			
Phryganeidae							
Ptilostomis	larva	5.0	sh,pr				
Polycentropodidae	immature	6.0	fi,pr				
Cernotina	larva	4.6	pr				
Cyrnellus fraternus	larva	8.0	co,fi				
Neureclipsis	larva	7.0	fi,sh				
Nyctiophylax	larva	5.0	pr,fi,sh				
Paranyctiophylax	larva	5.0	pr,fi,sh				
Polycentropus	larva	6.0	pr,co,sh				
Psychomyiidae	immature	2.0	co,ga				
Psychomyia	larva	2.0	co,sh				x
P. flavida	larva	2.0	co,sh				x
Uenoidae							
Neopylax	larva	3.0	sc		x		x
Branchiobdellida	adult	6.0	cm,pa				
Coelenterata							
Hydrozoa							
Hydroida							
Hydridae							
Hydra	adult	5.0	pr				
Mollusca							
Gastropoda							
Basommatophora							
Ancylidae							
Ferrissia	adult	6.0	sc		x		
Hydrobiidae	adult	8.0	sc				
Lymnaeidae	adult	6.0	sc				
Fossaria	adult	2.6	sc		x		x
Pseudosuccinea columella	adult	6.0	sc		x		
Stagnicola	adult	6.0	sc		x		
Physidae	adult	8.0	sc		x		
Planorbidae	adult	8.0	sc				
Gyraulus	adult	8.0	sc		x		
Planorbella	adult	8.0	sc		x		
Pleuroceridae							
Elimia	adult	2.5	sc		x		x
Mesogastropoda							
Valvatidae							
Valvata	adult	8.0	sc		x		
Bivalvia	adult		fi	x			
Veneroida							
Corbiculidae							
Corbicula fluminea	adult	6.3	fi	x			
Sphaeriidae	adult	8.0	fi	x			
Unionidae		8.0	fi	x			
Anodontinae	adult	8.0	fi	x			
Lasmigona complanata	adult	8.0	fi	x			
Potamilus ohiensis	adult		fi	x			
Nematoda	adult						
Nematophora	adult						
Gordioidea	adult						
Chordodidae							
Pantachordodes	adult	6.0	pa				
Gordiidae	immature	6.0	pa				

Taxon	Life Stage	Biotic Index Value	Functional Feeding Group*	Filterer	Scraper	Collector / Gatherer	Sensitive Taxa
Gordius	adult		pa				
Parachordodidae							
Paragordius	adult		pa				
Platyhelminthes							
Turbellaria	adult	6.0					
	immature	6.0					
Tricladida							
Planariidae	adult	6.0	co			x	
Cura foremanii	adult	6.0	co			x	
Dugesia	adult	6.0	co			x	
D. tigrina	adult	6.0	co			x	

Functional feeding group abbreviations (Merritt and Cummins 1995; Penak 1989):

co, collector; **cm**, commensal; **de**, detrivore; **fi**, filterer; **ga**, gatherer; **he**, herbivore; **mp**, macrophyte piercer; **pa**, parasite; **pr**, predator; **sc**, scraper; **sh**, shredder; **unk**, unknown

Merritt, R.W. and K.W. Cummins. 1995. An Introduction to the Aquatic Insects of North America. Kendall/Hunt Publishing, Dubuque, Iowa

Pennak, R.W. 1989. Freshwater Invertebrates of the United States, Third Edition. John Wiley and Sons. New York, New York.

Biotic Index References:

The following literature sources were used to assign biotic index values for most of the benthic macroinvertebrate taxa.

Bode, R.W., M.A. Novak, and L.E. Abele, 1990. Biological impairment criteria for flowing waters in New York State. Stream Biomonitoring Unit, Bureau of Monitoring and Assessment, Division of Water, New York State Department of Environmental Conservation.

Hilsenhoff, W.L. 1988. Rapid field assessment of organic pollution with a family-level biotic index. J. N. Am. Benthol. Soc. 7(1):65-68.

Hilsenhoff, W.L. 1987. An improved biotic index of organic stream pollution. The Great Lakes Naturalist 20(1):31-39.

Lenat, D.R. 1993. A biotic index for the southeastern United States: derivation and list of tolerance values, with criteria for assigning water-quality ratings. J. N. Am. Benthol. Soc. 12(3):279-290.

Appendix 1.3. Benthic Macroinvertebrate Data and Taxa Classifications Used in BMIBI Example Calculation.

	South Skunk River - Story County				Sugar Creek - Cedar County										
Storet No.	472708	472708	472708	472708	476601	476601	476601	476601							
Sample Date	9/22/97	9/22/97	9/22/97	9/22/97	9/20/96	9/20/96	9/20/96	9/20/96							
Sample Type	SH	SH	SH	MH	SH	SH	SH	MH	Metric Classifications						
Sample No.	760740	760741	760742	760743	664068	664069	664070	664071	EPT Taxa	Snstv. Taxa	Biotic Value	Chironomidae	Ephemeroptera	Scraper Taxa	FFG
Annelida															
Oligochaeta	1						1				8.5				co
Arthropoda															
Crustacea															
Talitridae															
Hyalella azteca	1			4							8				co
Isopoda															
Ascellidae															
Caecidotea					1						8				co
Insecta															
Coleoptera															
Dryopidae															
Helichus lithophilus				8							5			X	sc
Helichus striatus				1				4			5			X	sc
Elmidae															
Dubiraphia					1						6				
Macronychus glabratus	3	2	3	5			1				4				co
Stenelmis			1								5			X	sc
S. crenata				7							5			X	sc
Gyrinidae															
Dineutus				2							4				pr
Scirtidae															
Cyphon								3							
Diptera															
Chironomidae	14	19	14	9	53	54	42	5			6	X			co
Culicidae				1				1							co
Anopheles								1			9.1				fi
Empididae															
Hemerodromia	1		3		1	1	1				6				pr
Ephydridae															
Parydra				1										X	sc
Ephemeroptera									X				X		
Baetidae									X				X		

Stream	South Skunk River - Story County				Sugar Creek - Cedar County										
Storet No.	472708	472708	472708	472708	476601	476601	476601	476601							
Sample Date	9/22/97	9/22/97	9/22/97	9/22/97	9/20/96	9/20/96	9/20/96	9/20/96							
Sample Type	SH	SH	SH	MH	SH	SH	SH	MH	Metric Classifications						
Sample No.	760740	760741	760742	760743	664068	664069	664070	664071	EPT Taxa	Snstv. Taxa	Biotic Value	Chironomidae	Ephemeroptera	Scraper Taxa	FFG
Baetis flavistriga							1	1	X		4		X		co
Baetis intercalaris	6	12	6	27			1	7	X		6		X		co
Fallceon quilleri	7	6	15	16				1	X		6		X		co
Labiobaetis propinquus				3				1	X		6		X		co
Paracloedes minutus				2					X		6		X	X	sc
Procloeon				8					X		6		X		co
Baetiscidae									X				X		
Baetisca				2					X		4		X		co
Caenidae									X				X		
Caenis				1	4	6		7	X		7		X		co
Ephemeridae									X				X		
Hexagenia limbata				4					X		6		X		co
Heptageniidae					2		1		X		4		X	X	sc
Heptagenia diabasia				1		5	11	4	X	X	3		X	X	sc
H. flavescens				2					X		4		X	X	sc
Stenacron interpunctatum				3	3	8	5	24	X		7		X		co
Stenonema mexicanum			1						X		4		X	X	sc
S. terminatum	24	17	22	13		2			X		4		X	X	sc
Isonychiidae									X				X		
Isonychia				3					X		3.8		X		fi
Leptohyphidae									X				X		
Tricorythodes	3	3		2	4	8	4	2	X		4		X		co
Hemiptera															
Belostomatidae															
Belostoma flumineum								1							pr
Gerridae															
Gerris				1											
Mesoveliidae								12							pr
Mesovelia								1							pr
Odonata															
Aeshnidae															
Boyeria				1				1		X	2				pr
Calopterygidae															
Calopteryx								2			5				pr
Hetaerina				8							6				pr
Coenagrionidae															
Argia				4				1			6				pr
Gomphidae															

Stream	South Skunk River - Story County				Sugar Creek - Cedar County										
Storet No.	472708	472708	472708	472708	476601	476601	476601	476601							
Sample Date	9/22/97	9/22/97	9/22/97	9/22/97	9/20/96	9/20/96	9/20/96	9/20/96							
Sample Type	SH	SH	SH	MH	SH	SH	SH	MH	Metric Classifications						
Sample No.	760740	760741	760742	760743	664068	664069	664070	664071	EPT Taxa	Snstv. Taxa	Biotic Value	Chironomidae	Ephemeroptera	Scraper Taxa	FFG
Gomphus				3							5				pr
Libellulidae															
Pantala hymenea				1											pr
Plecoptera									X						
Perlidae									X						
Acroneuria	1	1	1	7					X	X	0				pr
Pteronarcyidae									X						
Pteronarcys		1		2					X	X	0				sh
Trichoptera	1								X						
Hydropsychidae	2	5	3						X		5				fi
Ceratopsyche bronta		1	1	1		2	10	6	X		5				fi
C. morosa	5	1	1	2				4	X		6				fi
Cheumatopsyche	1	5	1	1	27	8	24	26	X		5				fi
Hydropsyche betteni							1		X		6				fi
H. bidens	8	7	6						X	X	3				fi
H. simulans	25	29	20	7					X		7				fi
Hydroptilidae			1						X		6				mp
Hydroptila	1								X		6				mp
Leptoceridae									X						
Nectopsyche candida				3					X	X	3				sh
Mollusca															
Gastropoda															
Basommatophora															
Physidae				1				1			8			X	sc
	104	109	99	167	96	94	103	116							

Appendix 1.4. BMIBI metric calculation instructions and metric values from example data sets.

Metric Instructions:

1. Multi-habitat Taxa Richness. Count the number of discrete taxa in the multi-habitat sample. Do not count taxa that are represented at lower (more precise) classification levels (e.g., Hydropsychidae is not counted as a distinct taxon when *Hydropsyche bettani* is present).
2. Standard-habitat taxa richness. Count the number of discrete taxa in each standard-habitat sample. Average the individual sample metric values.
3. Multi-habitat EPT richness. Count the number of discrete taxa in the multi-habitat sample that belong in either the Ephemeroptera (E), Plecoptera (P), or Trichoptera (T) aquatic insect orders.
4. Standard-habitat EPT taxa richness. Count the number of discrete taxa in each standard-habitat sample that belong in either the Ephemeroptera (E), Plecoptera (P), or Trichoptera (T) aquatic insect orders. Average the individual sample metric values.
5. Multi-habitat sensitive taxa richness. Count the number of discrete taxa in the multi-habitat sample that are classified as sensitive taxa.

Metrics 6-12 are calculated from standard-habitat sample data only.

6. % abundance 3-dominant taxa. Sum the three most-abundant taxa, divide by the total number of organisms in the sample and multiply by 100. Average the individual sample metric values.
7. Biotic index. The number of organisms in each taxon is multiplied by its biotic index value and divided by the total number of organisms in the sample; exclude any organisms that do not have an assigned biotic index value. Average the individual sample metric values.
8. % abundance EPT taxa. Sum all of the organisms classified as EPT taxa, divide by the total number of organisms in the sample and multiply by 100. Average the individual sample metric values.
9. % abundance Chironomidae. Divide the total number of organisms in the sample by the number of organisms classified as Chironomidae (aquatic midges) and multiply by 100. Average the individual sample metric values.
10. % abundance Ephemeroptera taxa. Divide the total number of organisms in the sample by the number of organisms classified as Ephemeroptera (mayflies) and multiply by 100. Average the individual sample metric values. Average the individual sample metric values.
11. % abundance scraper organisms. Divide the total number of organisms in the sample by the number of organisms belonging to the scraper functional feeding group, and multiply by 100. Average the individual sample metric values.
12. % abundance dominant functional feeding group. Calculate the percentage of the total number of organisms in the sample represented by each functional feeding group (ffg), and record the largest percentage (most dominant ffg). Average the individual sample metric values.

BMIBI metric values from example data sets

	South Skunk River - Story County				Sugar Creek - Cedar County			
Storet No.	472708	472708	472708	472708	476601	476601	476601	476601
Sample Date	9/22/97	9/22/97	9/22/97	9/22/97	9/20/96	9/20/96	9/20/96	9/20/96
Sample Type	Std. Hab.	Std. Hab.	Std. Hab.	Multi-Hab.	Std. Hab.	Std. Hab.	Std. Hab.	Multi-Hab.
Sample No.	760740	760741	760742	760743	664068	664069	664070	664071
1. Multi-habitat Taxa Richness				37				21
2. Standard-habitat taxa richness	15	13	15		8	9	12	
3. Multi-habitat EPT richness				21				11
4. Standard-habitat EPT taxa richness	10	11	11		4	7	8	
5. Multi-habitat sensitive taxa richness				5				2
Standard-habitat samples only:								
6. % abundance 3-dominant taxa	60.6	59.6	57.6		87.5	74.5	74.8	
7. Biotic index	5.38	5.46	5.37		5.69	5.66	5.24	
8. % abundance EPT taxa	80.8	80.7	78.8		41.7	41.5	56.3	
9. % abundance Chironomidae	13.5	17.4	14.1		55.2	57.4	40.8	
10. % abundance Ephemeroptera taxa	38.5	34.9	44.4		13.5	30.9	22.3	
11. % abundance scraper organisms	23.1	15.6	24.2		2.1	7.4	11.7	
12. % abundance dominant functional feeding group	39.4	44.0	38.4		67.7	80.9	53.4	

Appendix 1.5. Calculating the BMIBI.

South Skunk River - Story County			
Log10 Stream Drainage Area = 2.52	Storet No. 472708	Sample Date: 9/22/97	
Metric	Value[1]	Metric formula	Score
1. Multi-habitat Taxa Richness	37	(#MH-taxa/52)*10	7.1
2. Standard-habitat taxa richness	14.33	(#SH-taxa/22.7)*10	6.3
3. Multi-habitat EPT richness	21	(#MH-EPT taxa/27)*10	7.8
4. Standard-habitat EPT taxa richness	10.67	(#SH-EPT taxa/14.7)*10	7.3
5. Multi-habitat sensitive taxa richness	5	(#MH-snstv.taxa/11)*10	4.5
Standard-habitat samples:			
6. % abundance 3-dominant taxa	59.27	((100 - %3dom.taxa)/52)*10	7.8
7. Biotic index	5.40	((7-Bindx)/2.65)*10	6.0
8. % abundance EPT taxa	80.10	(%EPT/95.5)*10	8.3
9. % abundance Chironomidae	15.01	(100-%Chrnmd.)/98.5)*10	8.6
10. % abundance Ephemeroptera taxa	39.26	(%Ephmr./77.7)*10	5.0
11. % abundance scraper organisms	20.97	(%scrpr./44.7)*10	4.7
12. % abundance dominant functional feeding group	40.62	((100-%dom.ffg.)/60)*10	9.9
[1] standard-habitat metric values are the average of 3 replicate samples.		(83.3 / 12)10 = 69.4 (sum of metric scores / 12) x 10	
		BM-IBI Score (rounded to nearest integer)	69

Sugar Creek - Cedar County			
Log10 Stream Drainage Area = 1.49	Storet No. 476601	Sample Date: 9/20/96	
Metric	Value[1]	Metric formula	Score
1. Multi-habitat Taxa Richness	21	(#MH-taxa/(10.5 + 21.8*LDA))*10	4.9
2. Standard-habitat taxa richness	9.67	(#SH-taxa/(4 + 8.7*LDA))*10	5.7
3. Multi-habitat EPT richness	11	(#MH-EPT taxa/(1.5 + 12.5*LDA))*10	5.5
4. Standard-habitat EPT taxa richness	6.33	(#SH-EPT taxa/(1.2 + 7.30*LDA))*10	5.2
5. Multi-habitat sensitive taxa richness	2	(#MH-snstv.taxa/4.4*LDA)*10	3.0
Standard-habitat samples:			
6. % abundance 3-dominant taxa	78.93	((100 - %3dom.taxa)/52)*10	4.0
7. Biotic index	5.53	((7-Bindx)/2.65)*10	5.5
8. % abundance EPT taxa	46.50	(%EPT/95.5)*10	4.9
9. % abundance Chironomidae	51.14	(100-%Chrnmd.)/98.5)*10	5.0
10. % abundance Ephemeroptera taxa	22.24	(%Ephmr./77.7)*10	2.9
11. % abundance scraper organisms	7.06	(%scrpr./44.7)*10	1.6
12. % abundance dominant functional feeding group	67.32	((100-%dom.ffg.)/60)*10	5.4
[1] standard-habitat metric values are the average of 3 replicate samples.		(53.6 / 12)10 = 44.7 (sum of metric scores / 12) x 10	
		BM-IBI Score (rounded to nearest integer)	45

Appendix 2. Example Calculations of the Fish Index of Biotic Integrity (FIBI).

Appendix 2.1 Fish Index of Biotic Integrity (FIBI) Metric Scoring Instructions and Formulas.

#	Metric Definition	Metric Abbrv.	Stream Drainage Area Criterion	Metric Scoring Formula
1a	Native fish species richness - Mississippi Basin	NTVSP-MSP	LDA≤2.10 LDA>2.10	(NTVSP/(16.67*LDA))*10 (NTVSP/35)*10
1b	Native fish species richness - Missouri Basin	NTVSP-MO	LDA≤1.95 LDA>1.95	(NTVSP/(11.79*LDA))*10 (NTVSP/23)*10
2a	Sucker species richness- Mississippi Basin	SCKRSP-MSP	LDA≤2.45 LDA>2.45	(SKCRSP/(3.26*LDA))*10 (SCKRSP/8)*10
2b	Sucker species richness- Missouri Basin	SCKRSP-MO	LDA≤2.5 LDA>2.5	(SCRSP/(2.0*LDA))*10 (SCKRSP/5)*10
3a	Sensitive fish species richness - Mississippi Basin	SNSTVSP-MSP	LDA≤2.1 LDA>2.1	(SNSTVSP/(5.71*LDA))*10 (SNSTVSP/12)*10
3b	Sensitive fish species richness - Missouri Basin	SNSTVSP-MO	LDA≤2.1 LDA>2.1	(SNSTVSP/(1.43*LDA))*10 (SNSTVSP/3)*10
4a	Benthic invertivore fish species richness - Mississippi Basin	BINVSP-MSP	LDA≤2.0 LDA>2.0	(BINVSP/(6.0*LDA))*10 (BINVSP/12)*10
4b	Benthic invertivore fish species richness - Missouri Basin	BINVSP-MO	LDA≤2.25 LDA>2.25	(BINVSP/7)*10 (BINVSP/(3.11*LDA))*10
Metrics 5-10: IF total number of fish per 500 ft. stream length ≤ 100, THEN refer to scoring adjustment (SA) below.				
5	Percent abundance three dominant fish species	P3DOM	LDA≤1.65 LDA>1.65	((100-P3DOM)/(39*LDA))*10 ((100-P3DOM)/64.35)*10
6	Percent fish as benthic invertivores	PBINV	LDA≤2.55 LDA>2.55	(PBINV/(23.84*LDA))*10 (PBINV/60.8)*10
7	Percent fish in as omnivores	POMNV	LDA≤1.5 LDA>1.5	((80-POMNV)/(80-(50-30.5*LDA)))*10 ((80-POMNV)/75.75)*10
8	Percent fish in sample as top carnivores	PTOPC	LDA ≤2.4 LDA>2.4	(sq.rt.PTOPC/(2.67*LDA-1.4))*10 (sq.rt.PTOPC/5.0)*10
9	Percent fish as simple lithophilous spawners	PSLTH	LDA ≤2.5 LDA>2.5	(PSLTH/(12*LDA))*10 (PSLTH/30.0)*10
10	Fish assemblage tolerance index	TOLINDX	All streams	((10 - TOLINDX)/6.3)*10
SA	FIBI metrics 5-10 scoring adjustment for low fish abundance: -- IF total # fish / 500 ft. stream length < 25, THEN metric score is zero (0) -- IF total # fish / 500 ft. stream length ≥ 25 and ≤50, THEN maximum possible metric score is 2.5 -- IF total # fish / 500 ft. stream length >50 and ≤75, THEN maximum possible metric score is 5.0 -- IF total # fish / 500 ft. stream length >75 and ≤100, THEN maximum possible metric score is 7.5			
11	Adjusted catch per unit effort	ADJCPUE	All Streams	(ADJCPUE/100)*10
12	PDELT - All Streams. Scoring adjustments for abnormally high proportion of fish with DELTS (Deformaties, Eroded fins, Lesions, Tumors): IF % fish in sample with DELTS > 2.0 & < 4.0 THEN subtract 5 from total FIBI score (if total # fish / 500 ft. stream < 100, then subtract 2.5). IF % fish in sample with DELTS > 4.0 THEN subtract 10 from total FIBI score (if total # fish / 500 ft. stream < 100, then subtract 5).			

<u>FIBI Scoring Instructions:</u>

3. Calculate data metrics. Refer to metric descriptions (Section 5.2.1) and fish species classifications (Appendix 2.2).
4. Calculate metric scores. Apply appropriate metric scoring formula depending on drainage basin (metrics 1,2,3,4) and stream drainage area (metrics 1-9). If sample has low total number of fish, apply the scoring adjustment (SA) for metrics 5-10. Metric scoring ranges are continuous from 0–10. Minimum possible score = 0; maximum possible score = 10 (for certain metrics it is possible to calculate a score <0 or >10; these scores are automatically rounded to 0 and 10, respectively).

3. Calculate FIBI score. FIBI = (sum of metrics 1-11)*(10) /11. If applicable, adjust FIBI score for PDELT (#12) metric. Round score to nearest integer. FIBI scoring range is 0-100.

Appendix 2.2. FIBI Metric Classifications for Fish Species Sampled in IDNR/UHL Stream Biocriteria Project.

Fish Species		Trophic metric classif-ication*	Simple Lithophilous Spawner	Tolerance Rating**	Exotic or Introduced Species	Sucker Sp.
Petromyzontidae - lampreys						
am. brook lamprey (ammocoete)	*Lampetra appendix*	fi		S		
am. brook lamprey (adult)	*Lampetra appendix*			S		
Lepisosteidae - gars						
longnose gar	*Lepisosteus osseus*	tc		I		
shortnose gar	*Lepisosteus platostomus*	tc		I		
Amiidae - bowfins						
bowfin	*Amia calva*	tc		I		
Hiodontidae - mooneyes						
goldeye	*Hiodon alosoides*	inv		I		
Clupeidae - herrings						
gizzard shad	*Dorosoma cepedianum*	om		T		
Salmonidae - trouts						
rainbow trout	*Oncorhynchus mykiss*	tc		S	x	
brown trout	*Salmo trutta*	tc		S	x	
brook trout	*Salvelinus fontinalis*	tc		S		
Umbridae- mudminnows						
central mudminnow	*Umbra limi*	inv		T		
Esocidae - pikes						
grass pickerel	*Esox americanus*	tc		I		
northern pike	*Esox lucius*	tc		S		
Aphredoderidae - pirate perches						
pirate perch	*Aphredoderus sayanus*	inv		I		
Cyprinidae - minnows						
central stoneroller	*Campostoma anomalum*	he		I		
largescale stoneroller	*Campostoma oligolepsis*	he		S		
goldfish	*Carassius auratus*	om		I	x	
grass carp	*Ctenopharyngodon idella*	he		I	x	
red shiner	*Cyprinella lutrensis*	om		T		
spotfin shiner	*Cyprinella spilopterus*	inv		I		
common carp	*Cyprinus carpio*	om		T	x	
gravel chub	*Erimystax x-punctata*	binv	x	S		
brassy minnow	*Hybognathus hankinsoni*	he		I		
central silvery minnow	*Hybognathus nuchalis*	om		S		
plains minnow	*Hybognathus placitus*	he		I		
common shiner	*Luxilus cornutus*	inv		I		
redfin shiner	*Lythrurus umbratilis*	inv	x	I		
silver chub	*Macrhybopsis storeriana*	inv		I		
hornyhead chub	*Nocomis biguttatus*	inv		S		
golden shiner	*Notemigonus crysoleucas*	om		T		
emerald shiner	*Notropis atherinoides*	inv		I		
river shiner	*Notropis blennius*	binv		I		
bigmouth shiner	*Notropis dorsalis*	inv		T		
ozark minnow	*Notropis nubilus*	he		S		
rosyface shiner	*Notropis rubellus*	inv		S		
sand shiner	*Notropis stramineus*	inv		I		

Fish Species		Trophic metric classif-ication*	Simple Lithophilous Spawner	Tolerance Rating**	Exotic or Introduced Species	Sucker Sp.
northern mimic shiner	*Notropis volucellus*	inv		I		
suckermouth minnow	*Phenacobius mirabilis*	binv	x	I		
s. redbelly dace	*Phoxinus erythrogaster*	he		S		
bluntnose minnow	*Pimephales notatus*	om		T		
fathead minnow	*Pimephales promelas*	om		T		
bullhead minnow	*Pimephales vigilax*	om		I		
flathead chub	*Platygobio gracilis*	inv		I		
blacknose dace	*Rhinichthys atratulus*	inv		I		
longnose dace	*Rhinichthys cataractae*	binv		S		
creek chub	*Semotilus atromaculatus*	ge		T		
Catostomidae - suckers						
river carpsucker	*Carpiodes carpio*	om		I		x
quillback carpsucker	*Carpiodes cyprinus*	om		I		x
highfin carpsucker	*Carpiodes velifer*	om		I		x
white sucker	*Catostomus commersoni*	om		I		x
northern hog sucker	*Hypentelium nigricans*	binv	x	S		x
smallmouth buffalo	*Ictiobus bubalus*	om		I		x
bigmouth buffalo	*Ictiobus cyprinellus*	inv		I		x
silver redhorse	*Moxostoma anisurum*	binv	x	I		x
black redhorse	*Moxostoma duquesnei*	binv	x	S		x
golden redhorse	*Moxostoma erythrurum*	binv	x	I		x
shorthead redhorse	*Moxostoma macrolepidotum*	binv	x	I		x
Ictaluridae - freshwater catfishes						
black bullhead	*Ameicrus melas*	ge		T		
yellow bullhead	*Ameicrus natalis*	binv		I		
channel catfish	*Ictalurus punctatus*	tc		I		
slender madtom	*Noturus exilis*	binv		S		
stonecat	*Noturus flavus*	binv		I		
tadpole madtom	*Noturus gyrinus*	binv		S		
freckled madtom	*Noturus nocturnus*	binv		I		
flathead catfish	*Pylodictus olivaris*	tc		I		
Percopsidae - trout-perches						
trout-perch	*Percopsis omiscomaycus*	binv	x	S		
Gadidae - codfishes						
burbot	*Lota lota*	tc		I		
Cyprinodontidae - killifishes						
blackstripe topminnow	*Fundulus notatus*	inv		I		
Atherinidae - silversides						
brook silverside	*Labidesthes sicculus*	inv		I		
Gasterosteidae - sticklebacks						
brook stickleback	*Culaea inconstans*	inv		S		
Percichthyidae - temperate basses						
white bass	*Morone chrysops*	tc		I		
Centrarchidae - sunfishes						
northern rock bass	*Ambioplites rupestris*	tc		S		
green sunfish	*Lepomis cyanellus*	ge		T		
pumkinseed	*Lepomis gibbosus*	inv		I		
orangespotted sunfish	*Lepomis humilus*	inv		I		
bluegill	*Lepomis macrochirus*	inv		I	x	
green sunf. X bluegill hybrid	*Lepomis sp.*	ge				
smallmouth bass	*Micropterus dolomieu*	tc		S		

Fish Species		Trophic metric classif-ication*	Simple Lithophilous Spawner	Tolerance Rating**	Exotic or Introduced Species	Sucker Sp.
largemouth bass	*Micropterus salmoides*	na		I	x	
white crappie	*Poxomis annularis*	tc		I		
black crappie	*Poxomis nigromaculatus*	tc		I		
Percidae - perches						
mud darter	*Etheostoma asprigene*	binv		I		
rainbow darter	*Etheostoma caeruleum*	binv		S		
iowa darter	*Etheostoma exile*	binv		S		
fantail darter	*Etheostoma flabellare*	binv		I		
johnny darter	*Etheostoma nigrum*	binv		I		
orangethroat darter	*Etheostoma spectabile*	binv		S		
banded darter	*Etheostoma zonale*	binv		S		
yellow perch	*Perca flavescens*	inv		I		
northern logperch	*Percina caprodes*	binv		S		
blackside darter	*Percina maculata*	binv		S		
slenderhead darter	*Percina phoxocephala*	binv		S		
sauger	*Stizostedion canadense*	tc		I		
walleye	*Stizostedion vitreum*	tc		I		
Sciaenidae - drums						
freshwater drum	*Apodinotus grunniens*	binv		I		
Cottidae - sculpins						
mottled sculpin	*Cottus bairdi*	binv		S		
slimy sculpin	*Cottus cognatus*	binv		S		

* Fish Species Trophic Feeding Classification: fi = filter feeder; ge = generalist invertivore/carnivore; he = herbivore; in = insectivore/invertivore; na = not applicable; om = omnivore; tc = top carnivore.

Trophic feeding classifications are based on Lyons (1992) and Goldstein and Simon (1999). Species accounts of feeding preferences and diet studies from Becker (1983), Harlan et al. (1987), and Pflieger (1997) were also reviewed. A literature review and diet analysis of five common stream fishes was conducted by Luzier (2000), and the information from this study was used in support of trophic classifications.

** Fish Species Tolerance Rating: S = Sensitive species; I = Intermediate Tolerance; T = Tolerant species.

The following literature resources were reviewed to assign tolerance classifications: Bailey et al.; Barbour et al. 1999; Bertrand et al. 1996; Karr et al. 1986; Lyons 1992; Muncy et al. 1980; NDEC 1991; Niemala et al. 1999; OEPA 1989; Plafkin et al. 1989; Whittier et al. 1987; U.S. EPA Region 7;

Determination of simple lithophilous spawners was based primarily on Simon (1999). Lyons (1992) was used as a secondary source.

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U.S. EPA Region VII. REMAP Fish species list and autecological information. Lyle Cowles, Region 7 R-EMAP coordinator, Kansas City, KS.

Appendix 2.3. Example Data and FIBI Metric Classifications.

	Major Drainage Basin	Mississippi	Missouri	
	Log10 Stream Watershed Drainage Area (LDA)	1.48	2.17	
	Stream Reach Length (ft.)	1070	710	
	Fish Species	Lime Creek - 8/31/94	West Nishnabotna R. - 8/15/94	Applicable Metric Classifications *
Cyprinidae - minnows				
cental stoneroller	*Campostoma anomalum*	93		he, I
spotfin shiner	*Cyprinella spilopterus*	3		inv, I
common carp	*Cyprinus carpio*		1	om, T, ex
common shiner	*Luxilus cornutus*	23		inv, I
plains minnow	*Hybognathus placitus*		2	he, I
hornyhead chub	*Nocomis biguttatus*	5		inv, S
bigmouth shiner	*Notropis dorsalis*	4	37	inv, T
ozark minnow	*Notropis nubilus*	1		he, S
rosyface shiner	*Notropis rubellus*	1		inv, S
sand shiner	*Notropis stramineus*		4	inv, I
suckermouth minnow	*Phenacobius mirabilis*	2	7	binv, sl, I
bluntnose minnow	*Pimephales notatus*	7		om, T
fathead minnow	*Pimephales promelas*		11	om, T
flathead chub	*Platygobio gracilis*		19	inv, I
blacknose dace	*Rhinichthys atratulus*	11		inv, I
creek chub	*Semotilus atromaculatus*	90	3	ge, T
Catostomidae - suckers				
river carpsucker	*Carpiodes carpio*		3	om, I, sckr
white sucker	*Catostomus commersoni*	47		om, I, sckr
northern hog sucker	*Hypentelium nigricans*	2		binv, sl, S, sckr
golden redhorse	*Moxostoma erythrurum*	1		binv, sl, I, sckr
shorthead redhorse	*Moxostoma macrolepidotum*	1		binv, sl, I, sckr
Ictaluridae - freshwater catfishes				
channel catfish	*Ictalurus punctatus*		5	tc, I
slender madtom	*Noturus exilis*	4		binv, S
Centrarchidae - sunfishes				
northern rock bass	*Ambioplites rupestris*	3		tc, S
green sunfish	*Lepomis cyanellus*	5		ge, T
smallmouth bass	*Micropterus dolomieu*	13		tc, S
Percidae - perches				
fantail darter	*Etheostoma flabellare*	142		binv, I
johnny darter	*Etheostoma nigrum*	33		binv, I
	total # fish	491	92	
	total # fish w/ DELTs	0	0	

* Fish metric classification abbreviations:
Trophic guild: fi = filter feeder; ge = generalist invertivore/carnivore; he = herbivore; in = insectivore/invertivore; om = omnivore; tc = top carnivore. **Simple Lithophilous Spawner** = sl. **Tolerance Rating**: S = Sensitive species; I = Intermediate Tolerance; T = Tolerant species. **Exotic or Introduced Species** =ex. **Sucker sp.** (Catostomidae) = sckr.

Appendix 2.4. FIBI Metric Values from Example Data.

	Lime Creek - 8/31/94	West Nishnabotna R. - 8/15/94
Major Drainage Basin	Mississippi	Missouri
Log10 Stream Watershed Drainage Area (LDA)	1.48	2.17
Stream Reach Length (ft.)	1070	710
Metric:	Value	Value
1. ntvsp	21	9
2. sckrsp	4	1
3. senstvsp	7	0
4. bnthcinv	7	1
5. %3domsp.	66.2	72.8
6. %bnthcinv	37.7	7.6
7. %omnv	11	16.3
8. %topc	3.2	5.4
9. %slitho	1.2	7.6
10. tolindx	5.78	7.83
11. adjcpue	36	5.6
12. %DELTs	0	0
Total No. Fish / 500 ft.	229.4	64.8

FIBI Metric Definitions:

1. ntvsp - # native fish species excluding exotic species and commonly stocked farm pond species (i.e., largemouth bass and bluegill)
2. sckrsp - # fish species belonging to sucker family (Catostomidae)
3. senstvsp - # fish species classified as sensitive to stream degradation
4. bnthcinv - # benthic invertivore fish species
5. %3domsp. = % abundance of three most abundant fish species
6. %bnthcinv = % abundance of fish as benthic invertivores
7. %omnv = % abundance of fish as omnivores
8. %topc = % abundance top carnivore fish **(*note*:** largemouth bass are not classified as top carnivores in this metric but are included in the total fish count)
9. %slitho = % fish in sample as simple lithophilous spawners
10. tolindx = fish assemblage tolerance index
11. adjcpue = adjusted catch per unit effort (total # fish - # tolerant fish / 100 ft. stream)
12. %DELTs = % abundance of fish with DELTS (**D**eformaties, **E**roded fins, **L**esions, **T**umors):

Appendix 2.5. Calculating the FIBI.

Lime Creek - 8/31/94

Major Drainage Basin: Mississippi Log10 Drainage Area (LDA): 1.48 Stream Reach Length (ft.): 1070

Metrics:	raw metric value	applicable metric formula (Appendix 2.1)	metric score (adjusted score)
1. ntvsp	21	(#sp/(16.67*LDA))*10	8.5
2. sckrsp	4	(#sp/(3.26*LDA))*10	8.3
3. senstvsp	7	(#sp/(5.71*LDA))*10	8.3
4. bnthcinv	7	(#sp/(6.0*LDA))*10	7.9
5. %3domsp.	66.2	((100-%3domsp.)/(39*LDA))*10	5.9
6. %bnthcinv	37.7	(%binv/(23.84*LDA))*10	10.7 (10)
7. %omnv	11	((80-%omnv)/(80-(50-30.5*LDA)))*10	9.2
8. %topc	3.2	(sq.root%topc/(2.67*LDA-1.4))*10	7.0
9. %slitho	1.2	(%slitho/(12*LDA))*10	0.7
10. tolindx	5.78	((10 - tolindx)/6.3)*10	6.7
11. adjcpue	36	(adjcpue/100)*10	3.6
12. %DELTs	0	not applicable	
Low fish abundance scoring adjustment	229.4 / 500 ft.	not applicable	
		***FIBI**	**69**

West Nishnabotna R. - 8/15/94

Major Drainage Basin: Missouri Log10 Drainage Area (LDA): 2.17 Stream Reach Length (ft.): 710

Metrics:	raw metric value	applicable metric formula (Appendix 2.1)	metric score (adjusted score)
1. ntvsp	9	(#sp/23)*10	3.9
2. sckrsp	1	(#sp/(2.0*LDA))*10	2.3
3. senstvsp	0	(#sp/3)*10	0
4. bnthcinv	1	(#sp/(3.11*LDA))*10	1.5
5. %3domsp.	72.8	((100-%3domsp.)/64.35)*10	4.2
6. %bnthcinv	7.6	(%binv/(23.84*LDA))*10	1.5
7. %omnv	16.3	((80-%omnv)/75.75)*10	8.4 (5.0)
8. %topc	5.4	(sq.root%topc/(2.67*LDA-1.4))*10	5.3 (5.0)
9. %slitho	7.6	(%slitho/(12*LDA))*10	2.9
10. tolindx	7.83	((10 - tolindx)/6.3)*10	3.4
11. adjcpue	5.6	(adjcpue/100)*10	0.6
12. %DELTs	0	not applicable	
Low fish abundance scoring adjustment	64.8 / 500 ft.	metrics 5-10, maximum poss. score = 5.0	
		***FIBI**	**28**

* FIBI calculation steps: (1) sum metrics 1-11 (use adjusted scores when applicable); (2) subtract %DELT scoring adjustment (when applicable); (3) divide by 11, then multiply by 10 and round to nearest integer.

Appendix 3. 1994-1998 Data Used in the Development and Calibration of the BMIBI and FIBI.

Appendix 3.1. 1994–1998 Sample Sites.

SITE NUM.	STREAM	LOCATION DESCRIPTION	COUNTY	ECO-REGION	SITE TYPE*
400501	SOUTH WHITEBREAST CREEK	APPROXIMATELY 4.5 MILES NORTH AND 6 MILES EAST OF WELDON	CLARKE	40A-LFTP	CRS
400502	LONG CREEK	DECATUR STATE WILDLIFE AREA-- APPROXIMATELY 3 MILES WEST & 2.5 MILES SOUTH OF VAN WERT	DECATUR	40A-LFTP	CRS
400601	SOAP CREEK	APPROXIMATELY 3 MILES SOUTHWEST OF ELDON-- ADJACENT TO ELDON SWMA	DAVIS	40A-LFTP	CRS
400602	LOTTS CREEK	RINGOLD SWMA-- 11 MILES WEST OF LAMONI	RINGGOLD	40A-LFTP	CRS
400701	LICK CREEK	SHIMEK SF-- LICK CREEK UNIT-- APPROXIMATELY 2 MILES SOUTH & 3 MILES EAST OF FARMINGTON	LEE	40A-LFTP	CRS
400702	CHEQUEST CREEK	APPROXIMATELY 1.5 MILES WEST & 1 MILE NORTH OF PITTSBURG	VAN BUREN	40A-LFTP	CRS
400703	WHITE BREAST CREEK	COUNTY ROAD H20-- APPROXIMATELY 6 MILES SOUTH OF LACONA	LUCAS	40A-LFTP	CRS
400801	NORTH CEDAR CREEK	APPROXIMATELY 2 MILES WEST & 1/2 MILE NORTH OF BUSSEY	MARION	40A-LFTP	TEST
400802	SAUNDERS BRANCH	IMMEDIATELY DOWNSTREAM MT. PLEASANT SE WWTP MIXING ZONE	HENRY	40A-LFTP	TEST
400803	SAUNDERS BRANCH	SAUNDERS PARK-- DOWNSTREAM APPROXIMATELY 0.3 MILES FROM MT. PLEASANT MGP SITE	HENRY	40A-LFTP	TEST
400804	SAUNDERS BRANCH	ADJACENT TO MT. PLEASANT MGP SITE-- WEST HIGHWAY 34	HENRY	40A-LFTP	TEST
400805	SAUNDERS BRANCH	UPSTREAM MT. PLEASANT MGP SITE APPROXIMATELY 1/4 MILES	HENRY	40A-LFTP	TEST
400806	HEATHER BRANCH	APPROXIMATELY 1.5 MILES SOUTH OF MT. PLEASANT	HENRY	40A-LFTP	TEST
471501	WILLOW CREEK	APPROXIMATELY 5 MILES WEST & 1/2 MILES NORTH FROM QUIMBY	CHEROKEE	47A-NWILP	CRS
471502	FLOYD RIVER	SHELDON WELL FIELD-- APPROXIMATELY 1.5 MILES NORTHEAST OF SHELDON	O'BRIEN	47A-NWILP	CRS
471503	WATERMAN CREEK	WHITROCK INDIAN VILLAGE-- APPROXIMATELY 1/2 MILE NORTH & 3 MILES EAST OF SUTHERLAND	O'BRIEN	47A-NWILP	CRS
471601	LITTLE ROCK CREEK	LITTLE ROCK COUNTY WILDLIFE AREA-- APPROXIMATELY 1.5 MILES EAST OF GEORGE	LYON	47A-NWILP	CRS
471602	LITTLE WATERMAN CREEK	WATERMAN CREEK SWMA-- APPROXIMATELY 7 MILES SOUTH OF HARTLEY	O'BRIEN	47A-NWILP	CRS
471701	HALFWAY CREEK	IMMEDIATELY DOWNSTREAM OF GALVA WWTP MIXING ZONE	IDA	47A-NWILP	WSHD
471702	HALFWAY CREEK	CITY OF GALVA STP MIXING ZONE	IDA	47A-NWILP	WSHD
471703	HALFWAY CREEK	IMMEDIATELY UPSTREAM OF GALVA WWTP MIXING ZONE	IDA	47A-NWILP	WSHD
471704	SILVER CREEK	APPROXIMATELY 6 MILES NORTH & 2 MILES EAST OF IDA GROVE	IDA	47A-NWILP	WSHD
471705	MAPLE RIVER	APPROXIMATELY 4.5 MILES SOUTH & 1.5 MILES WEST OF AURELIA	CHEROKEE	47A-NWILP	WSHD
471706	MAPLE RIVER	APPROXIMATELY 1.5 MILES WEST & 1 MILE NORTH OF GALVA	IDA	47A-NWILP	WSHD

SITE NUM.	STREAM	LOCATION DESCRIPTION	COUNTY	ECO REGION	SITE TYPE
471707	MAPLE RIVER	APPROXIMATELY 2.5 MILES NORTH & 1 MILE WEST OF AURELIA	CHEROKEE	47A-NWILP	WSHD
471708	LITTLE MAPLE RIVER	APPROXIMATELY 4.5 MILES NORTH OF GALVA	CHEROKEE	47A-NWILP	WSHD
471709	MAPLE CREEK	APPROXIMATELY 1 MILE N/NE OF AURELIA	CHEROKEE	47A-NWILP	WSHD
471710	ELK CREEK	APPROXIMATELY 3 MILES EAST & 2 MILES NORTH OF IDA GROVE	IDA	47A-NWILP	WSHD
471711	MAPLE RIVER	APPROX 4 MI NORTH OF IDA GROVE	IDA	47A-NWILP	WSHD
471712	MAPLE RIVER	APPROX 1 MI SW OF GALVA	IDA	47A-NWILP	WSHD
471801	MILL CREEK	APPROXIMATELY 3.5 MILES WEST & 1/2 MILE SOUTH OF LARRABEE	CHEROKEE	47A-NWILP	CRS
472401	LITTLE BEAVER CREEK	APPROXIMATELY 3 MILES SW OF WOODWARD-- APPROXIMATELY 0.6 MILES UPSTREAM OF CONFLUENCE WITH BEAVER CREEK	DALLAS	47B-DML	CRS
472402	BEAVER CREEK	ADJACENT TO THE CITY OF BEAVER	BOONE	47B-DML	TEST
472403	WHITE FOX CREEK	APPROXIMATELY 5.5 MILES N/NE OF WEBSTER CITY	HAMILTON	47B-DML	CRS
472501	WILLOW CREEK	WILLOW CREEK WILDLIFE AREA (WORTH CO)-- APPROXIMATELY 2 MILES E/SE OF HANLONTOWN	WORTH	47B-DML	CRS
472502	MAYNES CREEK	MALLORY COUNTY PARK-- APPROXIMATELY 5 MILES SOUTH OF HAMPTON	FRANKLIN	47B-DML	CRS
472503	BIG MUDDY CREEK	APPROXIMATELY 3 MILES EAST & 3 MILES NORTH OF SPENCER	CLAY	47B-DML	CRS
472504	WEST BUTTRICK CREEK	ADJACENT TO SPRING LAKE PARK (GREENE COUNTY)	GREENE	47B-DML	CRS
472505	SOUTH FORK IOWA RIVER	LOGSDON COUNTY PARK-- APPROXIMATELY 8.5 MILES SOUTH OF IOWA FALLS	HARDIN	47B-DML	CRS
472506	WINNEBAGO RIVER	LANDE ACCESS-- APPROXIMATELY 3 MILES WEST & 1.5 MILES NORTH OF LAKE MILLS	WINNEBAGO	47B-DML	CRS
472507	BUTTRICK CREEK	WATERS COUNTY WILDLIFE AREA-- APPROXIMATELY 3 MILES WEST OF GRAND JUNCTION	GREENE	47B-DML	CRS
472508	SOUTH SKUNK RIVER	APPROXIMATELY 3 MILES NORTH & 2 MILES EAST OF AMES	STORY	47B-DML	CRS
472601	MOSQUITO CREEK	UPSTREAM OF HIGHWAY 44 BRIDGE-- 5 MILES EAST OF PANORA	DALLAS	47B-DML	CRS
472602	LITTLE SIOUX RIVER	APPROXIMATELY 1 MILE WEST OF DIAMOND LAKE-- NE OF LAKE PARK	DICKINSON	47B-DML	CRS
472603	LITTLE SIOUX RIVER	HORSHOE BEND COUNTY PARK-- APPROXIMATELY 1.5 MILES SOUTH & 2 MILES WEST OF MILFORD	DICKINSON	47B-DML	CRS
472604	LIZARD CREEK	APPROXIMATELY 3.5 MILES SOUTH OF CLARE	WEBSTER	47B-DML	CRS
472605	PRAIRIE CREEK	DOLLIVER STATE PARK-- APPROXIMATELY 2 MILES WEST & 2 MILES NORTH OF LEHIGH	WEBSTER	47B-DML	CRS
472701	PLUM CREEK	APPROXIMATELY 3.5 MILES EAST & 3.5 MILES NORTH OF ALGONA	KOSSUTH	47B-DML	CRS
472702	BLACK CAT CREEK	COUNTY ROAD P30-- APPROXIMATELY 2 MILES WEST & 5 MILES NORTH OF ALGONA	KOSSUTH	47B-DML	CRS
472703	BEAR CREEK	IMMEDIATELY DOWNSTREAM FROM ROLAND WWTP MIXING ZONE	STORY	47B-DML	WSHD
472704	BEAR CREEK	CITY OF ROLAND STP MIXING ZONE	STORY	47B-DML	WSHD
472705	BEAR CREEK	APPROXIMATELY 1/4 MILE UPSTREAM FROM ROLAND WWTP OUTFALL	STORY	47B-DML	WSHD

SITE NUM.	STREAM	LOCATION DESCRIPTION	COUNTY	ECO REGION	SITE TYPE
472706	SOUTH SKUNK RIVER	RIVER VALLEY PARK-- APPROXIMATELY 1/8 MILE SOUTH OF 13TH STREET-- AMES	STORY	47B-DML	WSHD
472707	KEIGLEY BRANCH	APPROXIMATELY 1 MILE NORTH & 3 MILES EAST OF GILBERT	STORY	47B-DML	WSHD
472708	SOUTH SKUNK RIVER	IMMEDIATELY UPSTREAM FROM CONFLUENCE WITH SQUAW CREEK-- SOUTHEAST OF AMES	STORY	47B-DML	WSHD
472709	BEAR CREEK	SKUNK RIVER GREENBELT AREA-- NE OF AMES-- APPROXIMATELY 1/8 MILE UPSTREAM FROM MOUTH	STORY	47B-DML	WSHD
472710	LONG DICK CREEK	APPROXIMATELY 2 MILES WEST & 3/4 MILES NORTH OF ROLAND	STORY	47B-DML	WSHD
472711	LONG DICK CREEK	APPROXIMATELY 3 MILES NORTH & 1/4 MILE WEST OF ROLAND	HAMILTON	47B-DML	WSHD
472712	SOUTH SKUNK RIVER	IMMEDIATELY UPSTREAM OF LINCOLNWAY BRIDGE IN AMES	STORY	47B-DML	WSHD
472714	SOUTH SKUNK RIVER	1 MILE EAST OF RANDALL-- UPSTREAM OF COUNTY ROAD D65 BRIDGE	HAMILTON	47B-DML	WSHD
472715	SOUTH SKUNK RIVER	APPROXIMATELY 1 MILE WEST & 1/2 MILE SOUTH OF ELLSWORTH	HAMILTON	47B-DML	WSHD
472716	DRAINAGE DITCH #71	APPROXIMATELY 1.5 MILE SOUTH & 1/2 MILE EAST OF JEWELL	HAMILTON	47B-DML	WSHD
472717	SOUTH SKUNK RIVER	APPROXIMATELY 1/4 MILE UPSTREAM STORY CITY WWTP & DOWNSTREAM CITY STORM SEWER OUTFALL	STORY	47B-DML	WSHD
472718	SOUTH SKUNK RIVER	APPROX. 300 FT. UPSTR. CONCRETE STORM SEWER OUTFALL IN STORY CITY	STORY	47B-DML	WSHD
472719	SOUTH SKUNK RIVER	IMMEDIATELY DOWNSTREAM OF STORY CITY WWTP EFFLUENT MIXING ZONE	STORY	47B-DML	WSHD
472720	SOUTH SKUNK RIVER	APPROXIMATELY 200' UPSTREAM STORY CITY WWTP OUTFALL	STORY	47B-DML	WSHD
472721	E. FRK. DES MOINES RIVER	SENECA SWMA-- APPROXIMATELY 5 MILES EAST & 1 MILE NORTH OF RINGSTEAD	KOSSUTH	47B-DML	CRS
472722	SOUTH SKUNK RIVER	APPROX. 1/4 MILE WEST OF ELLSWORTH DWNSTR. OF HWY 175 BRIDGE	HAMILTON	47B-DML	WSHD
472801	WALNUT CREEK	8TH STREET GREENBELT-- WINDSOR HEIGHTS	POLK	47B-DML	TEST
472802	NORTH RACCOON RIVER	RACCOON RIVER GREENBELT-- APPROXIMATELY 2.75 MILES NORTH OF SAC CITY	SAC	47B-DML	CRS
472803	BOONE RIVER	BELLS MILL PARK-- APPROXIMATELY 3.5 MILES NORTH & 1/2 MILE EAST OF STRATFORD	HAMILTON	47B-DML	CRS
472804	SKILLET CREEK	DOWNSTREAM APPROXIMATELY 175' FROM DAYTON WWTP OUTFALL	WEBSTER	47B-DML	TEST
472805	SKILLET CREEK	UPSTREAM APPROXIMATELY 120' FROM DAYTON WWTP OUTFALL	WEBSTER	47B-DML	TEST
473401	LIME CREEK	LIME CREEK PARK-- APPROXIMATELY 1.5 MILES NE OF BRANDON	BUCHANAN	47C-IS	CRS
473402	CRANE CREEK	APPROXIMATELY 1 MILE WEST OF LOURDES	HOWARD	47C-IS	CRS
473403	CRANE CREEK	HOWARD/CHICKASAW CO LINE-- APPROX 0.9 MI. DOWNSTREAM CONFLUENCE W/ SPRING CREEK & 3 MILES N/NW OF JERICO	CHICKASAW	47C-IS	TEST
473404	WAPSIPINICON RIVER	TWIN PONDS CHICKASAW COUNTY PARK-- APPROXIMATELY 5 MILES SOUTHEAST OF IONIA	CHICKASAW	47C-IS	CRS

SITE NUM.	STREAM	LOCATION DESCRIPTION	COUNTY	ECO REGION	SITE TYPE
473501	E FRK WAPSIPINICON RIVER	APPROXIMATELY 5 MILES NORTH & 3 MILES WEST OF NEW HAMPTON	CHICKASAW	47C-IS	CRS
473502	BURR OAK CREEK	APPROXIMATELY 2 MILES NORTH & 4 MILES EAST OF OSAGE	MITCHELL	47C-IS	CRS
473503	VOLGA RIVER	APPROXIMATELY 3 MILES NORTH FROM MAYNARD-- IMMEDIATELY UPSTREAM FROM TWIN BRIDGES COUNTY PARK	FAYETTE	47C-IS	CRS
473504	BEAR CREEK	APPROXIMATELY 2 MILES WEST & 1 MILE NORTH OF SHELLSBURG	BENTON	47C-IS	CRS
473505	DEER CREEK	APPROXIMATELY 1 MILE N/NW FROM CARPENTER	MITCHELL	47C-IS	CRS
473506	LITTLE CEDAR RIVER	COLWELL COUNTY PARK-- APPROXIMATELY 2.5 MILES WEST OF COLWELL	FLOYD	47C-IS	CRS
473601	BLACK HAWK CREEK	POPP COUNTY ACCESS-- APPROXIMATELY 2.5 MILES SW OF HUDSON	BLACK HAWK	47C-IS	CRS
473602	BEAR CREEK	BUCHANAN COUNTY PARK-- APPROXIMATELY 2 MILES EAST & 1/2 MILE SOUTH OF BRANDON	BUCHANAN	47C-IS	CRS
473603	COLDWATER CREEK	APPROXIMATELY 3 MILES SOUTH & 1 MILE EAST OF GREENE	BUTLER	47C-IS	CRS
473604	BAILEY CREEK	INGREBRETSEN COUNTY PARK-- APPROXIMATELY 4 MILES WEST & 1.5 MILES NORTH OF SHEFFIELD	FRANKLIN	47C-IS	CRS
473605	SOUTH BEAVER CREEK	APPROXIMATELY 1 MILE SOUTH & 1.25 MILES WEST OF PARKERSBURG	GRUNDY	47C-IS	CRS
473606	BUFFALO CREEK	TMDL SITE #13 / APPROXIMATELY 4 MILES EAST OF CENTRAL CITY	LINN	47C-IS	CRS
473607	WAPSIPINICON RIVER	WAPSIPINICON SWMA-- APPROXIMATELY 2 MILES NORTH & 2 MILES WEST OF MCINTYRE	MITCHELL	47C-IS	CRS
473608	ROCK CREEK	APPROXIMATELY 1/4 MILE EAST OF ROCK CREEK (TOWN)	MITCHELL	47C-IS	CRS
473701	E. BR. WAPSIPINICON RIVER	SWEET MARSH SWMA-- HIGHWAY 93-- APPROXIMATELY 2 MILES NORTH & 1 MILE EAST OF TRIPOLI	BREMER	47C-IS	CRS
473702	PINE CREEK	APPROXIMATELY 3.5 MILES NORTH & 2 MILES WEST OF QUASQUETON	BUCHANAN	47C-IS	CRS
473703	PLUM CREEK	APPROXIMATELY 2.5 MILES NORTH OF HOPKINTON	DELAWARE	47C-IS	CRS
473704	LITTLE TURKEY RIVER	GOULDSBURG COUNTY PARK-- APPROXIMATELY 500' DOWNSTREAM OF CONFLUENCE WITH CRANE CREEK	FAYETTE	47C-IS	CRS
475401	JORDAN CREEK	APPROXIMATELY 1.5 MILES UPSTREAM FROM CONFLUENCE WITH FARM CREEK	POTTAWATTA MIE	47E-SRLP	CRS
475402	WEST NISHNABOTNA RIVER	APPROXIMATELY 1 MILE NE OF IRWIN-- SHELBY COUNTY UPPER NISHNABOTNA HABITAT AREA	SHELBY	47E-SRLP	CRS
475403	WEST NISHNABOTNA RIVER	APPROXIMATELY 2.5 MILES N/NE OF KIRKMAN-- APPROXIMATELY 150' UPSTREAM FROM E/W COUNTY ROAD BRIDGE	SHELBY	47E-SRLP	TEST
475404	EAST BRANCH WEST NISHNABOTNA RIVER	APPROXIMATELY 4.5 MILES NE OF AVOCA	SHELBY	47E-SRLP	CRS
475501	WEST TARKIO CREEK	APPROXIMATELY 6 MILES E/SE OF SHENANDOAH	PAGE	47E-SRLP	CRS
475601	INDIAN CREEK	UPSTREAM HIGHWAY 6 BRIDGE-- APPROXIMATELY 2 MILES WEST & 1/2 MILE NORTH OF LEWIS	CASS	47E-SRLP	CRS
475602	PILOT BRANCH	APPROXIMATELY 1/2 MILE NORTHEAST OF STENNETT	MONTGOMERY	47E-SRLP	CRS

SITE NUM.	STREAM	LOCATION DESCRIPTION	COUNTY	ECO REGION	SITE TYPE
475603	WALNUT CREEK	APPROXIMATELY 3 MILES WEST & 1 MILE NORTH OF RED OAK-- DOWNSTREAM FROM BRIDGE	MONTGOMERY	47E-SRLP	TEST
475604	WALNUT CREEK	APPROXIMATELY 3 MILES WEST & 1 MILE NORTH OF RED OAK-- UPSTREAM FROM BRIDGE	MONTGOMERY	47E-SRLP	TEST
475701	PIDGEON CREEK	APPROXIMATELY 7 MILES WEST OF NEOLA	POTTAWATTAMIE	47E-SRLP	CRS
475702	KEG CREEK	APPROXIMATELY 1/4 MILE WEST OF MINEOLA	MILLS	47E-SRLP	CRS
475703	MAPLE RIVER	APPROXIMATELY 1 MILE N/NE OF IDA GROVE	IDA	47E-SRLP	WSHD
475704	ODEBOLT CREEK	APPROXIMATELY 1/4 MILE UPSTREAM FROM MOUTH-- NEXT TO AMERICAN LEGION PARK-- IDA GROVE	IDA	47E-SRLP	WSHD
475705	ODEBOLT CREEK	APPROXIMATELY 2 MILES EAST AND 1/2 MILE SOUTH OF IDA GROVE	IDA	47E-SRLP	WSHD
475706	MAPLE RIVER	APPROXIMATELY 1/8 MILE DOWNSTREAM IDA GROVE WWTP OUTFALL	IDA	47E-SRLP	WSHD
475801	OTTER CREEK	APPROXIMATELY 3/4 MILES NORTHWEST OF DELOIT	CRAWFORD	47E-SRLP	CRS
475802	BIG CREEK	APPROXIMATELY 4 MILES NORTH & 1/2 MILE WEST OF DENISON	CRAWFORD	47E-SRLP	CRS
476401	BUCK CREEK	APPROXIMATELY 8 MILES WEST OF BARNES CITY-- POWESHIEK/MAHASKA COUNTY LINE	POWESHIEK	47F-RLP	CRS
476402	NORTH BRANCH NORTH RIVER	ADJ. TO GOELDNER WOODS-- MADISON CO. PARK-- LOW. REACH BNDRY IS APPROX. 150' UPST. FROM N/S CO. RD BRIDGE	MADISON	47F-RLP	CRS
476403	OLD MANS CREEK	APPROXIMATELY 1 MILE UPSTREAM CONFLUENCE WITH N. BRANCH OLD MAN'S CREEK-- 3.5 MILES NE OF WILLIAMSTOWN	JOHNSON	47F-RLP	CRS
476501	HOWERDON CREEK	APPROXIMATELY 4 MILES WEST AND 2 MILES NORTH OF WINTERSET	MADISON	47F-RLP	CRS
476502	BIG SLOUGH CREEK	SPRING RUN SPEEDWAY-- APPROXIMATELY 4 MILES SOUTH OF COLUMBUS CITY	LOUISA	47F-RLP	CRS
476503	ROCK CREEK	APPROXIMATELY 2 MILES SOUTH AND 1 MILE WEST OF TIPTON	CEDAR	47F-RLP	CRS
476504	RICHLAND CREEK	APPROXIMATELY 1/2 MILE NORTH OF HAVEN	TAMA	47F-RLP	CRS
476505	LYTLE CREEK	APPROXIMATELY 1.5 MILES NORTH & 4 MILES WEST OF ZWINGLE	DUBUQUE	47F-RLP	CRS
476506	WEST BRANCH 102 RIVER	APPROXIMATELY 3 MILES EAST OF NEW MARKET	TAYLOR	47F-RLP	TEST
476507	LONG CREEK	APPROXIMATELY 3 MILES SOUTH OF COLUMBUS JUNCTION	LOUISA	47F-RLP	CRS
476601	SUGAR CREEK	DOWNSTREAM OF UNNAMED TRIBUTARY-- STREAM CARRYING TIPTON EAST WWTP EFFLUENT	CEDAR	47F-RLP	WSHD
476602	SUGAR CREEK	UPSTREAM OF UNNAMED TRIBUTARY-- STREAM CARRYING TIPTON EAST WWTP EFFLUENT	CEDAR	47F-RLP	WSHD
476603	SUGAR CREEK	APPROXIMATELY 2.5 MILES SOUTH & 1 MILE EAST OF TIPTON-- PASTURE SITE	CEDAR	47F-RLP	WSHD
476604	SUGAR CREEK	APPROXIMATELY 1 MILE NORTH & 2.5 MILES WEST OF WILTON-- BEDROCK SITE	CEDAR	47F-RLP	WSHD
476605	MUD CREEK	DOWNSTREAM OF NORTHSTAR STEEL OUTFALL-- WILTON	MUSCATINE	47F-RLP	WSHD
476606	MUD CREEK	UPSTREAM OF NORTHSTAR STEEL OUTFALL-- WILTON	MUSCATINE	47F-RLP	WSHD

SITE NUM.	STREAM	LOCATION DESCRIPTION	COUNTY	ECO REGION	SITE TYPE
476607	MUD CREEK	DOWNSTREAM OF DURANT WWTP OUTFALL	MUSCATINE	47F-RLP	WSHD
476608	MUD CREEK	UPSTREAM OF DURANT WWTP OUTFALL	MUSCATINE	47F-RLP	WSHD
476609	MUD CREEK	DOWNSTREAM OF WILTON WWTP OUTFALL	MUSCATINE	47F-RLP	WSHD
476610	MUD CREEK	UPSTREAM OF WILTON WWTP OUTFALL	MUSCATINE	47F-RLP	WSHD
476611	SUGAR CREEK	DOWNSTREAM OF HIGHWAY 6 BRIDGE-- APPROXIMATELY 1 MILE SOUTHEAST OF MOSCOW	MUSCATINE	47F-RLP	WSHD
476612	NORTH SKUNK RIVER	APPROXIMATELY 3.5 MILES NORTH & 1/2 MILE EAST OF ROSE HILL	MAHASKA	47F-RLP	CRS
476613	MUD CREEK	CITY OF DURANT STP MIXING ZONE	MUSCATINE	47F-RLP	WSHD
476701	BEAR CREEK	EDEN VALLEY COUNTY PARK-- APPROXIMATELY 2 MILES SOUTH & 1/2 MILE WEST OF BALDWIN	JACKSON	47F-RLP	CRS
476801	SILVER CREEK	APPROXIMATELY 1.25 MILES NORTH & 1.5 MILES WEST OF DEWITT	CLINTON	47F-RLP	CRS
476802	BARBER CREEK	BARBER CREEK SWMA-- APPROXIMATELY 3 MILES SOUTH & 1.5 MILES EAST OF GRAND MOUND	CLINTON	47F-RLP	CRS
476803	DEER CREEK	APPROXIMATELY 2 MILES NORTH OF STUART	GUTHRIE	47F-RLP	CRS
476804	WEST NODAWAY RIVER	APPROXIMATELY 1 MILE NORTH & 3 MILES EAST OF GRANT	CASS	47F-RLP	CRS
476806	LOST CREEK	APPROXIMATELY 2.5 MILES NORTH & 3.5 MILES WEST OF PRINCETON	SCOTT	47F-RLP	CRS
476807	NORTH RIVER	APPROXIMATELY 1.5 MILES SOUTH & 1/2 MILE WEST OF NORWALK	WARREN	47F-RLP	CRS
476808	EAST NODAWAY RIVER	HAWLEYVILLE-- APPROXIMATELY 3 MILES NORTH & 2 MILES WEST OF NEW MARKET	PAGE	47F-RLP	CRS
476809	MIDDLE NODAWAY RIVER	APPROXIMATELY 5 MILES SOUTH & 2 MILES EAST OF BRIDGEWATER	ADAIR	47F-RLP	CRS
476810	MUD CREEK	APPROXIMATELY 4.5 MILES WEST & 1.5 MILES NORTH OF BAXTER	JASPER	47F-RLP	CRS
476811	HONEY CREEK	APPROXIMATELY 3 MILES EAST OF BEDFORD	TAYLOR	47F-RLP	CRS
476812	MIDDLE RIVER	PAMMEL STATE PARK-- APPROXIMATELY 2 MILES SOUTH & 2.5 MILES WEST OF WINTERSET	MADISON	47F-RLP	CRS
520401	NORTH CEDAR CREEK	PUBLIC ACCESS AREA AT CO. RD X60 BRIDGE-- APPROX 1/2 MILE UPSTREAM FROM CONFL WITH SNY MAGILL CREEK	CLAYTON	52B-PP	CRS
520402	NORTH BEAR CREEK	NORTH BEAR CREEK PUBLIC ACCESS NEAR HIGHLANDVILLE	WINNESHIEK	52B-PP	CRS
520403	PAINT CREEK	YELLOW RIVER STATE FOREST APPROXIMATELY 0.60 MILES DOWNSTREAM FROM CONFLUENCE WITH LITTLE PAINT CREEK	ALLAMAKEE	52B-PP	CRS
520501	MIDDLE BEAR CREEK	APPROXIMATELY 2.5 MILES NORTH & 1.5 MILES EAST OF HIGHLANDVILLE	WINNESHIEK	52B-PP	CRS
520502	CATFISH CREEK	SWISS VALLEY DUBUQUE COUNTY PARK	DUBUQUE	52B-PP	CRS
520503	COLDWATER CREEK	COLDWATER SPRING SWMA-- APPROXIMATELY 2 MILES NORTH & 2 MILES WEST OF BLUFFTON	WINNESHIEK	52B-PP	CRS
520504	LITTLE MAQUOKETA RIVER	APPROXIMATELY 1/4 MILE DOWNSTREAM FROM TWIN SPRINGS ROAD CROSSING-- 6 MILES WEST OF DUBUQUE	DUBUQUE	52B-PP	CRS

SITE NUM.	STREAM	LOCATION DESCRIPTION	COUNTY	ECO REGION	SITE TYPE
520601	FRENCH CREEK	FRENCH CREEK SWMA-- APPROXIMATELY 7 MILES NORTH & 4 MILES EAST OF WAUKON	ALLAMAKEE	52B-PP	CRS
520602	TROUT RIVER	TROUT RIVER PUBLIC AREA-- APPROXIMATELY 7 MILES SOUTH & EAST OF DECORAH	WINNESHIEK	52B-PP	CRS
520701	CANOE CREEK	CANOE CREEK SWMA-- APPROXIMATELY 1/8 MILE UPSTREAM FROM MOUTH-- NE OF DECORAH	WINNESHIEK	52B-PP	CRS
520801	DIBBLE CREEK	APPROXIMATELY 1.5 MILES NORTHEAST OF CLERMONT	FAYETTE	52B-PP	CRS
520802	YELLOW RIVER	YELLOW RIVER UNIT/YRSF-- APPROXIMATELY 1.5 MILES EAST OF ION	ALLAMAKEE	52B-PP	CRS
720801	PIKE RUN	APPROXIMATELY 5 MILES EAST & 1/2 MILE NORTH OF NICHOLS	MUSCATINE	72A-UMRAP	CRS
720802	HONEY CREEK	APPROXIMATELY 3 MILES SOUTH & 1/4 MILES WEST OF CONESVILLE	LOUISA	72A-UMRAP	CRS

* Site Type: CRS = Candidate Reference Site; TEST = Test (impacted) Site; WSHD = Watershed Assessment Site.

Appendix 3-2. Metric Values and BMIBI Scores from 1994-1998 Sample Sites.

SITE NUMBER	SH SAMPLE TYPE*	SITE TYPE	ECOREGION	MHTR	MHTR SCORE	MHEPT	MHEPT SCORE	MHSNTR	MHSNSTR SCORE	SHTR	SHTR SCORE	SHEPT	SHEPT SCORE	P3DOM	P3DOM SCORE	PEPT	PEPT SCORE	PSCR	PSCR SCORE	PCHR	PCHR SCORE	BINDX	BINDX SCORE	PDFFG	PDFFG SCORE	PEPHM	PEPHM SCORE	BMIBI
400501	M	CRS	40A-LFTP	25	5.4	4	1.9	1	1.0																			
400502	HS	CRS	40A-LFTP	35	6.7	12	4.6	1	0.9	12.3	5.6	8.3	5.7	48.0	8.3	69.1	7.2	23.2	5.2	13.7	8.7	4.86	7.9	60.5	6.6	65.3	8.3	63
400601	HS	CRS	40A-LFTP	32	6.2	11	4.1	1	0.9	12.3	5.4	8.0	5.4	73.3	4.2	82.1	8.6	6.0	1.3	4.3	9.7	5.09	7.1	45.7	9.0	37.1	4.7	56
400602	HS	CRS	40A-LFTP	32	6.3	13	5.4	1	0.9	9.7	4.8	7.7	5.5	83.9	2.6	82.2	8.6	3.3	0.7	16.9	8.4	5.24	6.5	60.2	6.6	26.2	3.3	50
400701	HS	CRS	40A-LFTP	17	4.4	5	2.7	0	0.0	10.5	6.9	4.0	3.9	83.9	3.7	35.9	3.8	19.2	4.3	38.4	6.2	5.72	4.7	45.0	9.2	3.0	0.4	42
400702	HS	CRS	40A-LFTP	38	7.3	20	7.5	8	7.3	16.7	7.3	11.0	7.5	50.6	7.8	80.2	8.4	9.2	2.1	0.3	10.0	4.85	8.0	43.1	9.5	58.5	7.5	75
400703	HD	CRS	40A-LFTP	29	5.6	13	4.8	4	3.6	10.7	4.7	8.3	5.7	77.9	3.5	95.7	10.0	18.4	4.1	2.3	9.9	4.90	7.8	70.3	5.0	29.1	3.7	57
400801	SB	TEST	40A-LFTP	28	5.4	12	4.5	4	3.6	11.0	4.8	9.0	6.1	75.4	3.9	85.1	8.9	2.1	0.5	13.2	8.8	5.42	5.8	55.1	7.5	29.1	3.7	53
400802	M	TEST	40A-LFTP	6	2.2	0	0.0	0	0.0																			
400803	M	TEST	40A-LFTP	16	6.4	3	2.5	0	0.0																			
400804	M	TEST	40A-LFTP	19	8.5	2	1.9	0	0.0																			
400805	M	TEST	40A-LFTP	14	7.6	0	0.0	0	0.0																			
400806	M	TEST	40A-LFTP	24	7.6	7	4.7	1	1.5																			
471501	HS	CRS	47A-NWILP	18	4.0	12	5.7	2	2.1	13.7	7.7	8.3	6.9	82.5	3.3	48.4	5.1	2.2	0.5	45.9	5.5	5.34	6.1	67.9	5.4	23.3	3.0	46
471502	HD	CRS	47A-NWILP	18	3.5	10	4.2	3	2.8	13.7	6.7	10.7	7.7	50.5	8.0	91.4	9.6	17.7	4.0	6.8	9.4	4.90	7.8	42.0	9.7	61.3	7.8	68
471503	HS	CRS	47A-NWILP	27	5.2	19	7.0	5	4.5	14.7	6.5	12.3	8.4	51.1	7.8	63.2	6.6	1.4	0.3	9.9	9.1	5.20	6.7	50.6	8.2	34.6	4.4	62
471601	M	CRS	47A-NWILP	36	6.9	17	6.3	5	4.5																			
471602	HS	CRS	47A-NWILP	24	6.3	13	7.3	1	1.3	12.7	8.5	8.3	8.3	68.4	7.4	47.3	5.0	1.4	0.3	41.0	6.0	5.78	4.5	58.6	6.9	10.5	1.3	53
471701	HD	WSHD	47A-NWILP	24	5.7	13	6.6	3	3.4	11.0	6.7	9.3	8.3	64.1	7.4	91.7	9.6	9.3	2.1	7.7	9.3	4.83	8.0	44.6	9.2	45.4	5.8	69
471702	HD	WSHD	47A-NWILP							10.0	6.0	8.7	7.7	63.4	7.6	80.8	8.5	22.2	5.0	18.5	8.2	4.68	8.6	44.4	9.3	50.2	6.4	
471703	HD	WSHD	47A-NWILP	16	3.8	11	5.6	2	2.3	13.3	8.1	10.0	8.9	67.6	6.7	90.6	9.5	6.0	1.4	5.4	9.6	4.95	7.6	50.5	8.3	38.7	5.0	64
471704	HD	WSHD	47A-NWILP	25	5.9	15	7.5	3	3.3	12.3	7.3	10.3	9.1	66.7	6.8	93.6	9.8	19.3	4.3	5.0	9.6	4.92	7.7	59.9	6.7	36.1	4.6	69
471705	M	WSHD	47A-NWILP	27	5.2	21	8.1	5	4.5																			
471706	HD	WSHD	47A-NWILP	22	4.2	12	4.4	3	2.7	11.7	5.1	10.3	7.0	65.9	5.4	96.0	10.0	12.1	2.7	3.0	9.8	4.75	8.3	57.6	7.1	67.9	8.7	63
471707	HD	WSHD	47A-NWILP	27	6.0	10	4.7	1	1.0	9.7	5.4	6.0	4.9	74.5	4.8	94.6	9.9	30.1	6.7	2.1	9.9	4.67	8.6	46.6	8.9	74.3	9.5	67
471708	HD	WSHD	47A-NWILP	22	4.8	13	6.0	3	3.1	13.7	7.5	10.7	8.6	50.6	9.2	84.7	8.9	13.0	2.9	13.0	8.8	4.95	7.6	43.2	9.5	44.0	5.6	69
471709	HD	WSHD	47A-NWILP	27	5.8	14	6.4	2	2.0	9.5	5.1	8.0	6.4	82.2	3.2	98.6	10.0	31.4	7.0	1.0	10.0	3.92	10.0	55.2	7.5	87.0	10.0	70
471710	HD	WSHD	47A-NWILP	21	4.7	16	7.6	3	3.2	12.0	6.7	11.0	9.1	67.3	6.2	92.7	9.7	16.1	3.6	7.3	9.4	5.05	7.2	53.8	7.7	40.9	5.2	67
471711	HD	WSHD	47A-NWILP	26	5.0	12	4.4	3	2.7	14.0	6.2	10.0	6.8	62.2	6.0	90.7	9.5	17.4	3.9	3.5	9.8	4.70	8.5	48.2	8.6	62.0	7.9	66

SITE NUMBER	SH SAMPLE TYPE*	SITE TYPE	ECOREGION	MHTR	MHTR SCORE	MHEPT	MHEPT SCORE	MHSNTR	MHSNSTR SCORE	SHTR	SHTR SCORE	SHEPT	SHEPT SCORE	P3DOM	P3DOM SCORE	PEPT	PEPT SCORE	PSCR	PSCR SCORE	PCHR	PCHR SCORE	BINDX	BINDX SCORE	PDFFG	PDFFG SCORE	PEPHM	PEPHM SCORE	BMIBI
471712	HD	WSHD	47A-NWILP	29	5.6	15	5.6	3	2.7	12.7	5.6	10.0	6.8	69.1	4.9	95.4	10.0	25.8	5.8	3.0	9.8	4.40	9.6	50.8	8.2	75.2	9.6	70
471801	HS	CRS	47A-NWILP	52	10.0	24	8.9	6	5.5	14.0	6.2	10.3	7.0	68.0	5.1	64.8	6.8	43.1	9.7	19.6	8.1	5.30	6.3	43.1	9.5	50.6	6.5	75
472401	HS	CRS	47B-DML	20	4.4	15	7.1	4	4.2	14.7	8.2	12.3	10.0	58.7	7.8	92.8	9.7	17.4	3.9	0.0	10.0	4.66	8.7	60.4	6.6	68.3	8.7	74
472402	HS	TEST	47B-DML	15	3.2	12	5.5	3	3.1	12.3	6.7	9.3	7.5	81.2	3.4	85.2	8.9	6.1	1.4	11.2	9.0	5.26	6.4	80.2	3.3	78.9	10.0	57
472403	HS	CRS	47B-DML	45	8.7	17	6.8	5	4.5	14.3	6.7	11.0	7.6	68.5	5.0	93.5	9.8	11.4	2.5	2.3	9.9	4.82	8.1	73.7	4.4	84.4	10.0	70
472501	HS	CRS	47B-DML	42	10.0	21	10.0	10	10.0	13.3	8.1	7.3	6.6	56.9	8.9	49.7	5.2	40.0	9.0	11.2	9.0	4.96	7.6	40.0	10.0	20.8	2.7	81
472502	HS	CRS	47B-DML	25	5.5	13	6.0	4	4.1	17.7	9.7	11.7	9.5	53.3	8.7	75.9	7.9	9.6	2.1	10.3	9.1	4.98	7.5	65.0	5.8	62.4	8.0	70
472503	HD	CRS	47B-DML	24	4.8	13	5.5	4	3.8	16.3	8.1	12.3	9.0	65.9	5.6	89.0	9.3	44.3	9.9	5.7	9.5	4.28	10.0	44.3	9.3	75.9	9.7	79
472504	HS	CRS	47B-DML	31	6.0	16	6.1	2	1.8	14.0	6.3	11.0	7.5	58.0	6.7	56.4	5.9	45.1	10.0	6.3	9.5	4.80	8.1	45.1	9.1	46.0	5.9	69
472505	HS	CRS	47B-DML	24	4.6	16	6.0	7	6.4	11.0	4.8	8.3	5.7	61.6	6.1	89.6	9.4	17.3	3.9	2.6	9.8	4.85	8.0	58.6	6.9	52.3	6.7	65
472506	HD	CRS	47B-DML	39	7.5	12	4.5	3	2.7	12.0	5.3	8.7	5.9	59.1	6.5	83.6	8.8	27.6	6.2	13.5	8.7	4.66	8.7	46.4	8.9	31.2	4.0	65
472507	HS	CRS	47B-DML	31	6.0	22	8.1	7	6.4	14.0	6.2	10.0	6.8	52.1	7.6	54.7	5.7	35.0	7.8	20.5	8.0	4.58	9.0	46.2	9.0	43.6	5.6	72
472508	HS	CRS	47B-DML	36	6.9	20	7.4	5	4.5	13.3	5.9	10.7	7.3	60.0	6.4	80.0	8.4	29.0	6.5	5.0	9.6	5.33	6.2	42.2	9.6	54.8	7.0	71
472601	HS	CRS	47B-DML	23	4.4	16	6.5	4	3.6	12.7	6.0	10.3	7.2	69.3	4.9	75.4	7.9	29.4	6.6	0.6	10.0	4.42	9.6	56.8	7.2	49.3	6.3	67
472602	HD	CRS	47B-DML	30	5.8	12	4.6	2	1.8	11.3	5.1	8.3	5.7	76.6	3.7	42.4	4.4	10.7	2.4	53.1	4.7	5.76	4.6	57.9	7.0	16.2	2.1	43
472603	HS	CRS	47B-DML	42	8.1	21	7.8	8	7.3	13.7	6.0	10.0	6.8	50.6	7.8	83.9	8.8	11.3	2.5	8.7	9.2	4.49	9.3	60.5	6.6	22.5	2.9	69
472604	HS	CRS	47B-DML	33	6.3	20	7.4	4	3.6	18.0	7.9	14.7	10.0	51.0	7.8	83.7	8.8	16.0	3.6	5.0	9.6	4.83	8.0	44.8	9.2	49.2	6.3	74
472605	HS	CRS	47B-DML	31	7.0	17	8.2	3	3.2	14.3	8.2	11.0	9.3	65.7	6.7	87.9	9.2	10.5	2.4	4.9	9.6	5.47	5.7	62.7	6.2	65.2	8.3	70
472701	HD	CRS	47B-DML	31	6.3	15	6.6	5	4.8	9.7	5.0	8.3	6.3	73.5	4.6	96.3	10.0	63.7	10.0	3.0	9.8	3.88	10.0	63.7	6.1	92.0	10.0	75
472702	HD	CRS	47B-DML	30	5.8	18	7.4	5	4.5	14.3	6.9	12.3	8.7	71.1	4.6	97.1	10.0	17.5	3.9	1.6	9.9	4.16	10.0	56.9	7.2	78.2	10.0	74
472703	HD	WSHD	47B-DML	23	5.7	10	5.3	1	1.2	10.7	6.8	5.7	5.3	82.9	3.7	41.1	4.3	7.8	1.7	46.2	5.4	5.86	4.2	47.4	8.8	3.6	0.5	44
472704	SB	WSHD	47B-DML							7.3	4.6	4.3	4.1	89.3	2.3	90.0	9.4	1.0	0.2	5.8	9.5	5.85	4.3	89.4	1.8	0.7	0.1	
472705	HD	WSHD	47B-DML	24	6.0	10	5.3	3	3.5	14.0	8.9	9.0	8.4	67.1	7.2	56.3	5.9	10.5	2.3	30.2	7.1	5.82	4.4	73.1	4.5	48.3	6.2	58
472706	HD	WSHD	47B-DML	41	7.9	26	9.6	8	7.3	15.0	6.6	11.3	7.7	62.9	5.9	89.0	9.3	36.6	8.2	6.3	9.5	4.55	9.1	36.6	10.0	50.1	6.4	81
472707	HD	WSHD	47B-DML	41	8.7	17	7.7	6	6.0	12.5	6.6	8.5	6.6	73.7	4.7	83.7	8.8	63.6	10.0	0.5	10.0	3.79	10.0	63.6	6.1	79.1	10.0	79
472708	HD	WSHD	47B-DML	36	6.9	21	7.8	5	4.5	14.0	6.2	10.3	7.0	59.3	6.5	80.1	8.4	21.0	4.7	15.0	8.6	5.37	6.0	38.6	10.0	39.3	5.0	68
472709	HD	WSHD	47B-DML	39	8.7	17	8.1	5	5.3	14.0	7.9	9.3	7.8	69.6	5.8	90.4	9.5	45.8	10.0	2.8	9.8	5.08	7.1	45.8	9.0	73.4	9.4	82
472710	HD	WSHD	47B-DML	39	8.8	15	7.2	3	3.2	14.7	8.4	5.7	4.8	76.2	4.6	24.0	2.5	13.8	3.1	55.1	4.5	6.05	3.5	69.5	5.1	21.1	2.7	49
472711	SB	WSHD	47B-DML	22	5.2	8	4.0	1	1.1	13.0	7.8	7.0	6.2	54.1	9.4	55.9	5.8	19.4	4.3	10.0	9.1	5.68	4.9	42.0	9.7	13.8	1.8	58
472712	HD	WSHD	47B-DML	35	6.7	17	6.3	4	3.6	14.7	6.5	10.7	7.3	48.5	8.2	86.0	9.0	29.5	6.6	5.4	9.6	4.76	8.3	48.3	8.6	35.7	4.6	71
472714	HD	WSHD	47B-DML	39	7.5	15	5.6	4	3.6	16.0	7.0	11.3	7.7	61.7	6.1	85.4	8.9	33.1	7.4	7.6	9.3	5.32	6.2	38.9	10.0	48.5	6.2	71
472715	HD	WSHD	47B-DML	34	6.8	13	5.6	4	3.8																			

SITE NUMBER	SH SAMPLE TYPE*	SITE TYPE	ECOREGION	MHTR	MHTR SCORE	MHEPT	MHEPT SCORE	MHSNTR	MHSNSTR SCORE	SHTR	SHTR SCORE	SHEPT	SHEPT SCORE	P3DOM	P3DOM SCORE	PEPT	PEPT SCORE	PSCR	PSCR SCORE	PCHR	PCHR SCORE	BINDX	BINDX SCORE	PDFFG	PDFFG SCORE	PEPHM	PEPHM SCORE	BMIBI
472716	HD	WSHD	47B-DML	30	5.8	10	4.1	3	2.7	10.3	4.9	7.7	5.4	82.7	2.7	39.5	4.1	11.5	2.6	58.5	4.2	5.46	5.7	79.6	3.4	39.2	5.0	42
472717	HD	WSHD	47B-DML	30	5.8	14	5.2	7	6.4	7.3	3.2	3.7	2.5	92.8	1.1	10.3	1.1	3.5	0.8	84.2	1.6	5.66	5.0	67.7	5.4	1.7	0.2	32
472718	HD	WSHD	47B-DML	30	5.8	13	4.8	6	5.5	11.5	5.1	7.0	4.8	80.2	3.1	57.9	6.1	42.5	9.5	32.4	6.8	4.79	8.2	43.5	9.4	49.3	6.3	63
472719	SB	WSHD	47B-DML	34	6.5	18	6.7	5	4.5	13.0	5.7	8.3	5.7	81.2	3.0	82.2	8.6	5.9	1.3	8.7	9.2	5.48	5.6	75.3	4.1	7.8	1.0	52
472720	SB	WSHD	47B-DML	33	6.3	13	4.8	6	5.5	14.0	6.2	9.7	6.6	61.1	6.2	77.5	8.1	17.0	3.8	6.1	9.5	4.89	7.8	55.7	7.4	19.6	2.5	62
472721	HD	CRS	47B-DML	19	3.7	8	3.0	2	1.8	10.7	4.7	7.0	4.8	79.1	3.3	47.5	5.0	19.9	4.4	46.1	5.4	4.83	8.0	50.5	8.3	19.9	2.5	46
472722	SB	WSHD	47B-DML	44	9.1	18	8.0	5	4.9	17.3	9.0	10.7	8.2	48.2	9.0	67.6	7.1	16.3	3.7	9.9	9.1	5.82	4.4	43.9	9.4	33.9	4.3	72
472801	HS	TEST	47B-DML	24	4.6	12	4.8	2	1.8	9.3	4.4	8.0	5.5	68.8	5.0	78.9	8.3	6.0	1.3	20.4	8.0	5.17	6.8	58.5	6.9	45.2	5.8	53
472802	HS	CRS	47B-DML	42	8.1	26	9.6	6	5.5	14.0	6.2	10.0	6.8	64.5	5.6	77.9	8.2	7.8	1.7	12.5	8.8	5.70	4.8	65.6	5.7	11.4	1.5	60
472803	HS	CRS	47B-DML	47	9.0	27	10.0	11	10.0	12.7	5.6	10.0	6.8	70.6	4.7	64.1	6.7	9.7	2.2	33.3	6.7	4.81	8.1	44.3	9.3	23.7	3.0	68
472804	SB	TEST	47B-DML	10	2.6	0	0.0	0	0.0	4.0	2.7	0.0	0.0	93.0	1.6	0.0	0.0	15.0	3.4	83.0	1.7	6.05	3.5	85.0	2.5	0.0	0.0	15
472805	SB	TEST	47B-DML	25	6.7	7	4.0	3	3.8	11.7	7.9	5.7	5.7	74.0	6.2	31.3	3.3	63.2	10.0	1.0	10.0	5.41	5.9	63.2	6.1	4.1	0.5	58
473401	HS	CRS	47C-IS	41	9.3	16	7.7	5	5.4	15.0	8.6	9.0	7.6	54.9	8.8	51.3	5.4	18.0	4.0	26.3	7.4	5.24	6.5	44.6	9.2	11.9	1.5	68
473402	HS	CRS	47C-IS	24	4.6	13	5.3	5	4.5	22.0	10.0	15.5	10.0	43.4	9.0	75.0	7.9	25.1	5.6	7.4	9.4	4.32	9.9	42.9	9.5	15.7	2.0	73
473403	HD	TEST	47C-IS	33	6.3	20	7.9	4	3.6	14.3	6.6	12.7	8.6	57.2	6.8	78.4	8.2	13.8	3.1	21.0	8.0	5.00	7.4	58.6	6.9	27.7	3.5	64
473404	HD	CRS	47C-IS	22	4.2	9	3.3	3	2.7	16.7	7.4	13.7	9.3	62.3	6.0	88.2	9.2	53.5	10.0	1.2	10.0	4.01	10.0	53.5	7.7	66.8	8.5	74
473501	HD	CRS	47C-IS	18	5.2	6	3.7	0	0.0	10.0	7.4	5.0	5.5	75.5	6.5	58.5	6.1	1.1	0.2	17.0	8.4	6.28	2.7	72.3	4.6	58.5	7.5	48
473502	HS	CRS	47C-IS	42	10.0	14	7.3	4	4.7	14.3	9.0	8.0	7.4	62.9	8.0	74.9	7.8	5.3	1.2	3.3	9.8	3.84	10.0	47.3	8.8	46.2	5.9	75
473503	HS	CRS	47C-IS	51	10.0	24	10.0	11	10.0	22.7	10.0	13.7	10.0	36.9	10.0	72.4	7.6	28.0	6.3	3.2	9.8	4.69	8.6	44.5	9.3	54.8	7.0	90
473504	HS	CRS	47C-IS	28	5.7	15	6.5	3	2.9	13.0	6.6	9.7	7.2	74.1	4.4	94.4	9.9	1.1	0.2	3.3	9.8	5.50	5.6	62.1	6.3	60.9	7.8	61
473505	HS	CRS	47C-IS	50	9.6	17	6.8	4	3.6	20.3	9.4	10.7	7.3	48.2	8.2	31.1	3.3	21.2	4.7	21.4	7.9	4.81	8.1	49.4	8.4	27.4	3.5	67
473506	HS	CRS	47C-IS	35	6.7	21	7.8	9	8.2	18.3	8.1	13.3	9.1	46.1	8.6	77.3	8.1	23.3	5.2	7.9	9.3	4.93	7.7	38.3	10.0	51.3	6.6	79
473601	HD	CRS	47C-IS	28	5.4	13	4.8	3	2.7	10.7	4.7	8.3	5.7	80.6	3.1	47.4	5.0	24.9	5.6	50.5	5.0	5.37	6.0	58.6	6.9	37.2	4.8	50
473602	HS	CRS	47C-IS	50	10.0	21	9.3	8	7.9	17.0	8.9	10.3	8.0	44.2	9.8	68.2	7.1	10.6	2.4	18.0	8.3	5.18	6.7	48.1	8.6	33.0	4.2	76
473603	HD	CRS	47C-IS	39	7.6	24	10.0	8	7.4	17.0	8.4	11.3	8.2	65.0	5.7	70.4	7.4	33.7	7.5	22.7	7.8	4.45	9.4	35.4	10.0	59.5	7.6	81
473604	HS	CRS	47C-IS	43	8.3	24	9.7	7	6.4	14.0	6.6	10.7	7.4	60.7	6.2	84.7	8.9	24.7	5.5	9.2	9.2	4.39	9.7	48.4	8.6	78.7	10.0	80
473605	HD	CRS	47C-IS	37	7.1	15	5.7	5	4.5	10.3	4.5	7.7	5.2	79.6	3.2	93.2	9.8	17.3	3.9	4.9	9.6	4.46	9.4	69.7	5.1	83.0	10.0	65
473606	HS	CRS	47C-IS	42	8.1	21	7.8	7	6.4	17.3	7.6	13.3	9.1	53.7	7.3	83.1	8.7	7.2	1.6	12.6	8.8	5.31	6.3	43.7	9.4	40.3	5.2	72
473607	HD	CRS	47C-IS	29	6.6	5	2.4	1	1.1	4.3	2.5	1.0	0.8	98.2	0.4	3.1	0.3	0.6	0.1	93.6	0.6	6.07	3.4	95.1	0.8	3.1	0.4	16
473608	HS	CRS	47C-IS	23	4.8	6	2.7	3	3.0	14.3	7.5	6.0	4.6	69.3	5.4	11.3	1.2	48.9	10.0	19.1	8.2	4.19	10.0	48.9	8.5	5.5	0.7	55
473701	HD	CRS	47C-IS	37	7.1	16	5.9	7	6.4	15.5	6.8	12.5	8.5	66.9	5.3	69.1	7.2	34.5	7.7	26.0	7.5	4.80	8.1	44.2	9.3	57.8	7.4	73
473702	SB	CRS	47C-IS	41	9.3	16	7.7	6	6.5	11.3	6.5	8.3	7.0	76.4	4.6	72.4	7.6	4.7	1.0	25.2	7.6	5.30	6.3	61.3	6.5	11.1	1.4	60

SITE NUMBER	SH SAMPLE TYPE*	SITE TYPE	ECOREGION	MHTR	MHTR SCORE	MHEPT	MHEPT SCORE	MHSNTR	MHSNSTR SCORE	SHTR	SHTR SCORE	SHEPT	SHEPT SCORE	P3DOM	P3DOM SCORE	PEPT	PEPT SCORE	PSCR	PSCR SCORE	PCHR	PCHR SCORE	BINDX	BINDX SCORE	PDFFG	PDFFG SCORE	PEPHM	PEPHM SCORE	BMIBI
473703	HD	CRS	47C-IS	32	6.2	17	6.8	4	3.6	20.7	9.7	14.3	9.8	48.1	8.2	52.6	5.5	13.8	3.1	28.1	7.3	5.39	6.0	44.9	9.2	24.5	3.1	65
473704	HS	CRS	47C-IS	50	9.6	25	9.3	11	10.0	14.7	6.5	8.7	5.9	53.9	7.3	70.7	7.4	8.1	1.8	12.5	8.8	5.20	6.7	45.0	9.2	38.0	4.9	73
475401	HD	CRS	47E-SRLP	15	3.4	5	2.4	1	1.1	9.3	5.3	6.7	5.6	61.4	7.5	94.5	9.9	38.6	8.6	1.0	10.0	4.82	8.1	40.1	10.0	50.4	6.4	65
475402	HD	CRS	47E-SRLP	13	2.5	10	4.0	3	2.7	13.0	6.0	10.7	7.3	53.0	7.5	93.3	9.8	27.6	6.2	4.7	9.6	4.76	8.3	38.1	10.0	52.9	6.8	67
475403	HD	TEST	47E-SRLP	21	4.0	12	4.4	3	2.7	12.3	5.4	10.7	7.3	67.8	5.1	95.1	10.0	13.4	3.0	3.5	9.7	4.99	7.4	68.5	5.2	46.2	5.9	59
475404	HD	CRS	47E-SRLP	18	3.5	8	3.0	0	0.0																			
475501	HD	CRS	47E-SRLP	29	6.0	10	4.4	1	1.0	10.3	5.3	6.0	4.6	82.8	3.0	39.6	4.1	6.0	1.3	53.3	4.7	5.86	4.2	60.3	6.6	10.6	1.4	39
475601	HS	CRS	47E-SRLP	29	5.6	13	4.8	1	0.9	13.7	6.0	10.0	6.8	71.8	4.5	77.4	8.1	1.7	0.4	12.7	8.8	6.10	3.3	46.7	8.9	28.0	3.6	51
475602	HS	CRS	47E-SRLP	27	9.3	12	8.7	1	1.7	13.0	10.0	8.0	10.0	75.5	8.3	64.1	6.7	1.0	0.2	22.0	7.9	6.30	2.6	89.9	1.7	57.7	7.4	62
475603	HS	TEST	47E-SRLP	29	5.6	12	4.6	2	1.8	13.7	6.1	11.0	7.5	70.1	4.8	84.4	8.8	5.2	1.2	11.2	9.0	5.81	4.4	58.6	6.9	21.6	2.8	53
475604	HD	TEST	47E-SRLP	27	5.2	8	3.1	1	0.9	10.3	4.6	8.3	5.7	76.1	3.8	81.9	8.6	8.3	1.9	17.2	8.4	5.88	4.1	66.4	5.6	16.2	2.1	45
475701	HD	CRS	47E-SRLP	20	3.8	13	4.9	2	1.8	12.3	5.5	8.0	5.4	57.5	6.7	85.0	8.9	26.4	5.9	6.3	9.5	4.93	7.7	42.8	9.5	57.9	7.4	64
475702	HD	CRS	47E-SRLP	23	4.4	7	2.6	2	1.8	12.5	5.5	7.0	4.8	61.7	6.1	66.7	7.0	10.7	2.4	6.8	9.4	5.86	4.2	57.0	7.2	26.1	3.3	49
475703	HD	WSHD	47E-SRLP	30	5.8	15	5.6	3	2.7	15.3	6.8	10.3	7.0	63.5	5.8	92.4	9.7	18.3	4.1	1.5	10.0	4.65	8.7	51.2	8.1	68.8	8.8	69
475704	HS	WSHD	47E-SRLP	25	4.9	18	7.6	2	1.9	10.7	5.3	8.3	6.0	67.2	5.4	75.5	7.9	1.2	0.3	4.5	9.7	5.55	5.4	64.8	5.9	62.1	7.9	57
475705	HS	WSHD	47E-SRLP	24	4.8	17	7.3	2	1.9	12.0	6.1	9.3	7.0	67.5	5.5	85.9	9.0	2.1	0.5	3.5	9.8	5.71	4.8	56.4	7.3	31.7	4.1	57
475706	HD	WSHD	47E-SRLP	22	4.2	13	4.8	5	4.5	16.0	7.0	12.0	8.2	53.0	7.5	91.5	9.6	17.1	3.8	4.3	9.7	4.80	8.1	47.9	8.7	60.1	7.7	70
475801	HS	CRS	47E-SRLP	23	4.8	14	6.3	1	1.0	13.3	7.0	11.3	8.8	58.0	7.4	63.0	6.6	1.3	0.3	2.7	9.8	5.30	6.3	60.7	6.6	38.7	4.9	58
475802	HS	CRS	47E-SRLP	23	5.9	12	6.5	1	1.2	13.3	8.7	11.0	10.0	58.6	9.3	71.4	7.5	2.1	0.5	2.8	9.8	5.28	6.4	55.4	7.4	51.9	6.6	66
476401	HD	CRS	47F-RLP	20	4.4	13	6.1	3	3.1	14.0	7.8	11.3	9.3	60.7	7.4	71.1	7.4	19.3	4.3	26.9	7.4	4.90	7.8	41.1	9.8	38.0	4.9	67
476402	HS	CRS	47F-RLP	33	7.1	13	6.0	3	3.1	14.0	7.6	9.7	7.7	64.5	6.5	84.5	8.8	26.1	5.8	4.3	9.7	4.54	9.1	52.9	7.9	64.5	8.2	73
476403	HD	CRS	47F-RLP	20	3.8	10	3.7	2	1.8	13.5	5.9	11.5	7.8	46.9	8.4	91.8	9.6	21.1	4.7	7.3	9.4	5.18	6.7	48.1	8.7	71.8	9.2	67
476501	HS	CRS	47F-RLP	29	8.2	10	6.0	2	2.7	12.3	8.9	7.3	7.9	56.0	10.0	42.5	4.4	9.4	2.1	14.0	8.7	5.87	4.2	49.1	8.5	22.2	2.8	62
476502	HS	CRS	47F-RLP	21	4.8	7	3.4	1	1.1	13.0	7.5	5.7	4.8	77.6	4.4	31.8	3.3	25.8	5.8	33.9	6.7	5.47	5.7	39.3	10.0	4.8	0.6	48
476503	HS	CRS	47F-RLP	36	7.2	14	6.0	2	1.9	16.3	8.2	10.7	7.9	48.1	8.7	63.1	6.6	26.0	5.8	2.1	9.9	5.56	5.3	40.5	9.9	25.8	3.3	67
476504	HD	CRS	47F-RLP	37	7.4	16	6.8	3	2.8	16.0	8.0	10.3	7.6	63.7	6.1	87.5	9.2	8.4	1.9	5.6	9.5	5.80	4.4	53.9	7.7	39.4	5.0	64
476505	HS	CRS	47F-RLP	23	4.6	10	4.3	2	1.9	14.0	7.0	7.3	5.4	53.4	7.7	61.8	6.5	16.1	3.6	13.8	8.7	5.20	6.7	52.2	8.0	5.9	0.7	54
476506	HD	TEST	47F-RLP	35	6.7	14	5.3	1	0.9	9.7	4.3	6.0	4.1	78.8	3.4	74.2	7.8	7.0	1.6	23.1	7.8	5.66	5.0	66.1	5.6	9.4	1.2	45
476507	HS	CRS	47F-RLP	24	4.6	11	4.1	0	0.0	11.0	4.8	7.0	4.8	68.3	5.0	52.7	5.5	9.4	2.1	24.8	7.6	5.15	6.9	45.1	9.1	8.0	1.0	46
476601	HD	WSHD	47F-RLP	21	4.7	11	5.3	2	2.1	9.7	5.5	6.3	5.3	78.9	4.1	46.5	4.9	7.1	1.6	51.1	4.9	5.55	5.4	62.2	6.3	22.2	2.8	44
476602	HD	WSHD	47F-RLP	16	3.7	8	3.9	1	1.1	11.3	6.6	8.3	7.2	86.6	2.7	52.9	5.5	3.4	0.8	45.1	5.6	5.63	5.1	57.8	7.0	18.5	2.4	43
476603	HD	WSHD	47F-RLP	21	4.6	12	5.6	1	1.0	8.3	4.6	5.3	4.3	91.6	1.6	30.3	3.2	0.6	0.1	67.8	3.2	5.95	3.9	87.8	2.0	22.8	2.9	31

SITE NUMBER	SH SAMPLE TYPE*	SITE TYPE	ECOREGION	MHTR	MHTR SCORE	MHEPT	MHEPT SCORE	MHSNTR	MHSNSTR SCORE	SHTR	SHTR SCORE	SHEPT	SHEPT SCORE	P3DOM	P3DOM SCORE	PEPT	PEPT SCORE	PSCR	PSCR SCORE	PCHR	PCHR SCORE	BINDX	BINDX SCORE	PDFFG	PDFFG SCORE	PEPHM	PEPHM SCORE	BMIBI
476604	HD	WSHD	47F-RLP	17	3.3	11	4.3	0	0.0	11.3	5.1	8.3	5.7	70.3	4.7	73.4	7.7	4.6	1.0	19.7	8.1	5.54	5.4	62.9	6.2	9.8	1.3	44
476605	HD	WSHD	47F-RLP	16	3.1	7	2.7	0	0.0	7.0	3.1	5.0	3.4	91.3	1.4	70.3	7.4	1.0	0.2	28.4	7.2	5.92	4.0	64.9	5.9	5.4	0.7	33
476606	HD	WSHD	47F-RLP	20	3.8	11	4.2	0	0.0	8.5	3.8	6.0	4.1	92.5	1.2	57.8	6.1	0.8	0.2	40.2	6.0	5.84	4.3	56.3	7.3	2.1	0.3	34
476607	HD	WSHD	47F-RLP	18	3.7	8	3.5	1	1.0	8.3	4.3	4.3	3.3	86.3	2.4	18.0	1.9	3.1	0.7	54.9	4.6	6.47	2.0	75.0	4.2	4.7	0.6	27
476608	HD	WSHD	47F-RLP	15	3.1	7	3.1	0	0.0	7.7	4.0	4.7	3.5	86.5	2.3	59.4	6.2	0.5	0.1	34.0	6.7	6.40	2.2	51.2	8.1	8.2	1.1	34
476609	HD	WSHD	47F-RLP	20	3.8	3	1.2	0	0.0	7.0	3.2	3.7	2.5	93.1	1.1	10.5	1.1	0.7	0.1	75.4	2.5	5.96	3.9	77.4	3.8	9.5	1.2	20
476610	HD	WSHD	47F-RLP	7	1.3	1	0.4	0	0.0	7.7	3.5	4.3	2.9	90.3	1.5	17.3	1.8	1.8	0.4	66.4	3.4	5.97	3.8	81.3	3.1	17.3	2.2	20
476611	HD	WSHD	47F-RLP	18	3.5	9	3.3	1	0.9	9.7	4.3	7.7	5.2	79.7	3.2	87.9	9.2	0.5	0.1	11.1	9.0	6.18	3.0	75.4	4.1	11.4	1.5	39
476612	HS	CRS	47F-RLP	27	5.2	12	4.4	1	0.9	10.0	4.4	8.3	5.7	73.2	4.3	95.5	10.0	19.3	4.3	3.2	9.8	5.50	5.6	66.4	5.6	31.1	4.0	53
476613	HD	WSHD	47F-RLP							4.7	2.4	0.3	0.3	95.2	0.8	0.7	0.1	2.7	0.6	56.3	4.4	6.57	1.6	76.1	4.0	0.7	0.1	
476701	HS	CRS	47F-RLP	40	7.7	15	6.2	2	1.8	13.3	6.4	8.7	6.1	64.1	5.7	74.5	7.8	5.9	1.3	18.7	8.2	5.13	6.9	69.5	5.1	53.8	6.9	58
476801	HS	CRS	47F-RLP	30	6.4	10	4.5	2	2.0	13.3	7.2	6.7	5.3	71.0	5.2	75.6	7.9	20.0	4.5	1.4	10.0	5.27	6.4	67.9	5.4	6.4	0.8	55
476802	HD	CRS	47F-RLP	27	7.3	11	6.3	1	1.3	12.0	8.3	6.7	6.9	60.8	9.6	75.5	7.9	3.5	0.8	15.1	8.6	5.54	5.4	48.4	8.6	32.0	4.1	63
476803	HS	CRS	47F-RLP	27	7.8	13	8.0	3	4.1	13.0	9.7	9.0	10.0	82.7	4.6	93.3	9.8	2.6	0.6	2.8	9.8	5.26	6.5	47.7	8.7	58.2	7.4	72
476804	HS	CRS	47F-RLP	33	6.3	18	7.3	4	3.6	13.0	6.2	10.0	6.9	72.5	4.4	94.2	9.9	3.5	0.8	2.6	9.8	4.68	8.6	69.6	5.1	68.9	8.8	65
476806	HD	CRS	47F-RLP	26	5.8	12	5.7	2	2.1	10.3	5.8	7.7	6.4	76.5	4.5	68.4	7.2	6.9	1.5	29.3	7.1	5.52	5.5	62.1	6.3	40.3	5.2	53
476807	HD	CRS	47F-RLP	21	4.0	8	3.0	0	0.0	9.3	4.1	7.3	5.0	84.8	2.4	94.1	9.9	65.2	10.0	2.1	9.9	4.84	8.0	65.2	5.8	77.2	9.9	60
476808	HS	CRS	47F-RLP	37	7.1	14	5.2	3	2.7	15.0	6.6	8.7	5.9	63.6	5.8	55.8	5.8	23.8	5.3	10.6	9.0	5.73	4.7	44.0	9.3	28.3	3.6	59
476809	HD	CRS	47F-RLP	34	6.5	13	5.2	1	0.9	10.3	4.8	7.0	4.8	87.8	1.9	88.8	9.3	5.0	1.1	8.9	9.2	5.59	5.2	82.1	3.0	8.1	1.0	44
476810	HD	CRS	47F-RLP	31	9.2	14	8.8	2	2.8	7.3	5.6	5.0	5.7	86.6	3.7	52.1	5.5	11.1	2.5	44.6	5.6	6.10	3.3	78.1	3.6	50.4	6.4	52
476811	HS	CRS	47F-RLP	27	6.2	11	5.4	2	2.2	11.7	6.8	9.3	8.0	71.6	5.6	80.0	8.4	9.3	2.1	18.3	8.3	4.94	7.6	44.4	9.3	49.3	6.3	63
476812	HS	CRS	47F-RLP	39	7.5	18	6.7	5	4.5	12.0	5.3	9.3	6.3	76.0	3.8	96.3	10.0	7.4	1.6	1.0	10.0	4.80	8.2	67.4	5.4	23.0	2.9	60
520401	HS	CRS	52B-PP	24	8.3	9	6.5	4	6.6	11.0	9.9	6.3	8.6	53.0	10.0	66.4	7.0	32.4	7.3	2.0	9.9	4.42	9.6	34.1	10.0	39.5	5.0	82
520402	HS	CRS	52B-PP	25	5.8	11	5.4	3	3.3	12.7	7.4	7.3	6.3	67.2	6.5	79.4	8.3	11.0	2.5	5.7	9.5	4.25	10.0	67.5	5.4	13.3	1.7	60
520403	HS	CRS	52B-PP	25	4.8	9	3.7	6	5.5	13.0	6.2	7.3	5.1	63.2	5.8	58.8	6.2	11.9	2.7	21.8	7.9	4.68	8.6	61.3	6.5	34.2	4.4	56
520501	HS	CRS	52B-PP	28	10.0	8	6.2	3	5.3	15.0	10.0	7.0	10.0	70.9	10.0	79.5	8.3	12.7	2.8	3.1	9.8	3.49	10.0	52.9	7.8	28.8	3.7	78
520502	HS	CRS	52B-PP	24	6.9	10	6.1	1	1.4	13.7	10.0	7.3	8.1	55.7	10.0	69.8	7.3	4.8	1.1	19.1	8.2	4.59	8.9	54.8	7.5	15.2	1.9	65
520503	HS	CRS	52B-PP	24	6.1	9	4.9	3	3.6	15.3	9.9	7.0	6.7	48.5	10.0	39.2	4.1	10.4	2.3	16.0	8.5	4.82	8.1	64.9	5.9	20.9	2.7	61
520504	HS	CRS	52B-PP	30	6.2	14	6.2	5	4.9	13.0	6.8	9.7	7.4	63.5	6.4	91.5	9.6	3.0	0.7	4.8	9.6	5.12	7.0	65.2	5.8	25.8	3.3	62
520601	HS	CRS	52B-PP	35	10.0	12	7.5	7	9.9	16.0	10.0	6.0	6.8	53.9	10.0	32.6	3.4	32.4	7.2	14.1	8.7	4.01	10.0	32.4	10.0	3.7	0.5	78
520602	HS	CRS	52B-PP	27	8.9	11	7.6	6	9.4	13.0	10.0	6.7	8.5	67.6	10.0	80.7	8.5	12.4	2.8	4.2	9.7	4.43	9.5	64.1	6.0	58.2	7.4	82
520701	HS	CRS	52B-PP	38	7.3	24	9.9	11	10.0	21.0	10.0	14.0	10.0	48.5	8.3	54.3	5.7	27.6	6.2	22.1	7.9	4.93	7.7	45.2	9.1	32.0	4.1	80

SITE NUMBER	SH SAMPLE TYPE*	SITE TYPE	ECOREGION	MHTR	MHTR SCORE	MHEPT	MHEPT SCORE	MHSNTR	MHSNSTR SCORE	SHTR	SHTR SCORE	SHEPT	SHEPT SCORE	P3DOM	P3DOM SCORE	PEPT	PEPT SCORE	PSCR	PSCR SCORE	PCHR	PCHR SCORE	BINDX	BINDX SCORE	PDFFG	PDFFG SCORE	PEPHM	PEPHM SCORE	BMIBI
520801	HS	CRS	52B-PP	41	10.0	18	10.0	8	10.0	14.0	10.0	8.3	9.0	59.8	10.0	54.4	5.7	1.3	0.3	26.3	7.4	5.26	6.4	61.3	6.4	31.3	4.0	74
520802	HS	CRS	52B-PP	34	6.5	15	5.6	4	3.6	12.7	5.6	10.0	6.8	62.4	6.0	83.6	8.8	30.7	6.9	12.1	8.9	4.29	10.0	51.6	8.1	32.6	4.2	67
720801	HD	CRS	72D-UMRAP	31	9.5	4	2.6	0	0.0	11.0	8.7	2.3	2.8	64.0	10.0	8.8	0.9	0.0	0.0	12.4	8.8	6.97	0.1	70.8	4.9	7.2	0.9	41
720802	HD	CRS	72D-UMRAP	40	9.9	13	6.9	2	2.4	9.0	5.7	5.7	5.3	73.0	5.9	80.2	8.4	2.8	0.6	15.3	8.6	6.11	3.3	55.7	7.4	24.5	3.1	56

* Standard Habitat Sample Type: HD=Hester-Dendy; HS=Hess; M=Missing; SB=Surber.

Appendix 3-3. Metric Values and FIBI Scores from 1994–1998 Sample Sites.

SITE NUMBER	SITE TYPE	COLD WATER	ECOREGION	NTVSP	NTVSP SCORE	SCKRSP	SCKRSP SCORE	SNSTVSP	SNSTVSP SCORE	BINVSP	BINVSP SCORE	P3DOM	P3DOM SCORE	PBINV	PBINV SCORE	POMNV	POMNV SCORE	PTOPC	PTOPC SCORE	PSLTH	PSLTH SCORE	TOLINDX	TOLINDX SCORE	ADJCPUE	ADJCPUE SCORE	PDELT	PDELT SCORE	FIBI
400501	CRS		40A-LFTP	12	4.6	2	3.9	0	0.0	2	2.1	63.9	5.9	1.3	0.3	30.1	6.6	0.5	1.7	0.9	0.5	8.8	1.9	16.9	1.7	2.5	-5	22
400502	CRS		40A-LFTP	19	8.3	4	10.0	0	0.0	7	10.0	52.0	7.5	14.7	3.1	46.4	4.4	2.3	5.7	11.6	4.8	7.8	3.5	81.9	8.2	0.2	0	59
400601	CRS		40A-LFTP	21	6.0	4	5.4	1	0.8	6	5.0	66.6	5.2	13.7	2.5	60.4	2.6	1.3	2.7	12.5	4.5	7.4	4.1	75.1	7.5	0.2	0	42
400602	CRS		40A-LFTP	13	6.1	1	2.8	0	0.0	3	5.4	80.6	3.0	3.7	0.9	26.7	7.0	0.3	0.9	1.5	0.7	8.6	2.2	40.6	4.1	0.3	0	30
400701	CRS		40A-LFTP	16	7.8	2	5.0	0	0.0	6	8.1	69.5	6.4	18.9	6.4	12.6	10.0	0.0	0.0	2.9	2.0	7.3	4.3	31.4	3.1	0.0	0	48
400702	CRS		40A-LFTP	20	5.8	3	4.4	2	1.7	8	6.7	63.2	5.7	19.3	3.9	53.1	3.5	1.8	4.3	12.2	4.9	7.6	3.8	62.6	6.3	0.2	0	46
400703	CRS		40A-LFTP	14	4.0	2	2.7	0	0.0	2	1.7	69.5	4.7	4.0	0.7	52.7	3.6	0.3	0.7	3.8	1.4	8.4	2.6	28.1	2.8	0.5	0	23
400801	TEST		40A-LFTP	24	6.9	4	5.8	1	0.8	6	5.0	77.0	3.6	6.5	1.3	72.5	1.0	1.5	3.6	2.5	1.0	6.9	4.9	34.7	3.5	0.7	0	34
400802	TEST		40A-LFTP	8	6.9	1	4.4	1	2.5	2	4.8	67.9	4.4	28.6	5.0	10.7	5.0	0.0	0.0	0.0	0.0	6.0	5.0	7.5	0.8	7.1	-5	30
400803	TEST		40A-LFTP	9	9.0	0	0.0	0	0.0	0	0.0	79.9	8.6	0.0	0.0	8.1	10.0	0.8	10.0	0.0	0.0	7.8	3.6	18.8	1.9	0.0	0	39
400804	TEST		40A-LFTP	4	5.0	0	0.0	0	0.0	0	0.0	96.9	0.4	0.0	0.0	0.0	5.0	1.5	5.0	0.0	0.0	8.6	2.2	3.6	0.4	1.6	0	16
400805	TEST		40A-LFTP	3	6.0	0	0.0	0	0.0	0	0.0	95.5	0.5	0.0	0.0	0.0	5.0	0.0	0.0	0.0	0.0	9.2	1.2	2.5	0.3	0.0	0	12
400806	TEST		40A-LFTP	16	10.0	1	3.4	1	1.9	5	9.2	64.1	10.0	16.4	7.6	25.6	9.5	0.5	4.6	2.6	2.4	7.3	4.2	53.8	5.4	0.0	0	62
471501	CRS		47A-NWILP	12	6.7	2	6.6	0	0.0	3	6.4	71.3	4.9	4.5	1.2	31.3	6.4	1.1	4.0	0.7	0.4	7.7	3.6	16.0	1.6	0.7	0	38
471502	CRS		47A-NWILP	13	6.1	1	2.8	0	0.0	2	3.6	66.8	5.2	2.3	0.5	15.3	8.5	0.0	0.0	0.0	0.0	6.9	4.9	81.7	8.2	0.1	0	36
471503	CRS		47A-NWILP	15	6.5	3	7.0	0	0.0	3	4.5	44.8	8.6	9.1	1.8	9.8	9.3	1.0	2.4	2.2	0.9	6.5	5.6	87.6	8.8	0.1	0	50
471601	CRS		47A-NWILP	16	7.0	2	4.4	1	3.3	4	5.7	60.2	6.2	7.9	1.5	36.0	5.8	1.4	3.0	2.7	1.0	7.7	3.6	24.0	2.4	0.0	0	40
471602	CRS		47A-NWILP	14	9.9	2	8.3	1	5.8	3	8.0	65.8	7.3	2.7	1.0	10.9	10.0	0.0	0.0	0.5	0.3	6.8	5.1	55.2	5.5	0.2	0	56
471701	WSHD		47A-NWILP	8	4.9	1	3.6	0	0.0	1	2.3	85.9	2.6	2.9	0.9	15.2	9.0	0.8	3.4	0.0	0.0	7.1	4.6	37.1	3.7	0.6	0	32
471702	WSHD		47A-NWILP																									
471703	WSHD		47A-NWILP	10	6.1	1	3.6	1	5.1	1	2.3	79.6	3.8	8.3	2.5	10.5	9.6	0.6	2.4	0.0	0.0	7.8	3.6	22.2	2.2	0.3	0	38
471704	WSHD		47A-NWILP	11	6.6	1	3.5	0	0.0	2	4.6	73.8	4.8	6.9	2.1	6.0	10.0	1.3	5.7	0.0	0.0	6.8	5.1	32.4	3.2	0.3	0	41
471705	WSHD		47A-NWILP	14	6.1	4	9.9	0	0.0	3	4.8	63.5	5.7	4.2	0.9	17.5	8.2	1.3	3.2	1.1	0.5	6.8	5.0	45.1	4.5	0.5	0	44
471706	WSHD		47A-NWILP	14	6.1	3	6.4	0	0.0	3	4.3	79.6	3.2	4.6	0.8	7.9	9.5	1.4	2.8	0.2	0.1	7.8	3.5	16.4	1.6	0.4	0	35
471707	WSHD		47A-NWILP	8	4.4	1	3.3	0	0.0	2	4.2	75.6	4.1	9.6	2.6	20.3	7.9	0.0	0.0	0.0	0.0	8.5	2.3	14.8	1.5	0.0	0	28
471708	WSHD		47A-NWILP	10	5.4	2	6.4	0	0.0	2	4.1	73.9	4.3	7.2	1.9	6.8	9.7	0.6	2.3	0.0	0.0	7.2	4.4	24.7	2.5	0.0	0	37
471709	WSHD		47A-NWILP	12	6.4	3	9.4	0	0.0	2	4.0	82.8	2.8	3.0	0.8	27.8	6.9	1.0	3.5	0.0	0.0	8.6	2.2	9.1	0.9	0.0	0	33
471710	WSHD		47A-NWILP	9	5.0	1	3.3	0	0.0	2	4.2	76.2	4.0	6.5	1.8	3.7	10.0	0.0	0.0	0.0	0.0	7.0	4.8	64.3	6.4	0.1	0	36
471711	WSHD		47A-NWILP																									

SITE NUMBER	SITE TYPE	COLD WATER	ECOREGION	NTVSP	NTVSP SCORE	SCKRSP	SCKRSP SCORE	SNSTVSP	SNSTVSP SCORE	BINVSP	BINVSP SCORE	P3DOM	P3DOM SCORE	PBINV	PBINV SCORE	POMNV	POMNV SCORE	PTOPC	PTOPC SCORE	PSLTH	PSLTH SCORE	TOLINDX	TOLINDX SCORE	ADJCPUE	ADJCPUE SCORE	PDELT	PDELT SCORE	FIBI
471712	WSHD		47A-NWILP																									
471801	CRS		47A-NWILP	14	6.1	3	6.2	0	0.0	3	4.3	64.8	5.5	12.9	2.2	27.8	6.9	1.5	3.0	7.5	2.6	7.2	4.5	59.4	5.9	0.2	0	43
472401	CRS		47B-DML	14	5.5	1	2.0	3	3.4	5	5.4	63.3	6.1	8.2	2.2	13.3	8.8	0.8	2.9	4.0	2.2	8.2	2.9	17.2	1.7	1.2	0	39
472402	TEST		47B-DML	17	6.5	3	5.8	1	1.1	5	5.3	76.0	3.9	10.3	2.7	4.2	10.0	0.4	1.2	2.6	1.4	8.1	3.0	37.1	3.7	0.0	0	41
472403	CRS		47B-DML	23	7.3	4	6.5	7	6.5	9	7.9	45.5	8.5	20.7	4.6	20.1	7.9	0.5	1.5	5.3	2.3	6.2	6.0	56.9	5.7	0.0	0	59
472501	CRS		47B-DML	14	6.1	1	2.2	4	5.1	2	2.4	64.6	6.6	18.3	5.6	19.5	8.4	0.0	0.0	0.0	0.0	5.3	7.4	147.2	10.0	0.1	0	49
472502	CRS		47B-DML	16	6.2	4	7.9	4	4.5	7	7.5	64.7	5.8	18.6	5.0	7.8	9.5	0.5	1.8	2.3	1.2	5.0	7.9	85.9	8.6	0.2	0	60
472503	CRS		47B-DML	13	6.2	2	5.6	0	0.0	3	5.4	60.2	6.2	10.0	2.4	25.3	7.2	0.0	0.0	1.7	0.8	7.7	3.6	15.9	1.6	0.0	0	36
472504	CRS		47B-DML	28	8.3	6	9.1	5	4.3	11	9.2	52.3	7.4	15.8	3.3	20.7	7.8	1.4	3.6	5.9	2.4	6.7	5.2	99.0	9.9	0.4	0	64
472505	CRS		47B-DML	35	10.0	7	10.0	9	7.6	12	10.0	45.2	8.5	27.5	5.5	16.6	8.4	1.9	4.5	22.0	8.8	5.5	7.2	47.3	4.7	0.4	0	78
472506	CRS		47B-DML	16	4.6	3	4.4	3	2.5	6	5.0	65.9	5.3	19.0	3.8	42.0	5.0	2.6	6.2	0.3	0.1	7.9	3.4	9.0	0.9	0.0	0	37
472507	CRS		47B-DML	24	6.9	5	6.7	4	3.3	9	7.5	65.5	5.4	5.1	0.9	28.5	6.8	0.8	1.7	2.7	1.0	7.0	4.7	72.9	7.3	0.1	0	47
472508	CRS		47B-DML	22	6.3	6	7.6	3	2.5	7	5.8	40.5	9.2	20.1	3.5	34.4	6.0	3.4	6.9	12.2	4.2	5.8	6.7	81.6	8.2	0.3	0	61
472601	CRS		47B-DML	12	3.8	1	1.6	0	0.0	5	4.5	62.7	5.8	5.7	1.3	16.0	8.4	0.0	0.0	0.7	0.3	8.1	3.1	14.2	1.4	0.0	0	28
472602	CRS		47B-DML	20	8.7	3	7.5	3	10.0	5	8.0	78.8	3.3	1.2	0.3	23.4	7.5	1.0	2.4	0.0	0.0	6.6	5.5	178.2	10.0	0.1	0	57
472603	CRS		47B-DML	18	7.8	5	10.0	1	3.3	4	5.7	70.9	4.5	9.6	1.6	16.7	8.4	3.2	6.4	4.9	1.6	5.8	6.7	69.5	6.9	0.2	0	57
472604	CRS		47B-DML	21	6.0	6	7.7	4	3.3	9	7.5	36.5	9.9	46.4	8.2	15.2	8.6	1.9	3.7	28.7	10.0	4.5	8.8	15.3	1.5	0.0	0	68
472605	CRS		47B-DML	21	8.5	3	6.2	6	7.1	8	9.0	43.5	9.8	21.0	6.0	16.8	8.4	2.9	10.0	3.6	2.0	5.4	7.3	23.3	2.3	1.4	0	70
472701	CRS		47B-DML	14	4.9	3	5.4	2	2.1	4	3.9	66.1	5.3	4.1	1.0	66.7	1.8	0.0	0.0	1.2	0.6	8.0	3.1	58.1	5.8	0.0	0	31
472702	CRS		47B-DML	17	5.5	4	6.6	5	4.7	6	5.4	60.1	6.2	19.8	4.5	38.1	5.5	1.4	4.0	8.3	3.7	6.1	6.1	38.2	3.8	0.2	0	51
472703	WSHD		47B-DML	13	6.0	1	2.4	1	1.3	3	3.8	70.4	5.8	4.3	1.4	16.7	9.1	0.3	1.6	0.1	0.1	8.4	2.5	46.2	4.6	0.0	0	35
472704	WSHD		47B-DML																									
472705	WSHD		47B-DML	11	5.1	1	2.4	0	0.0	2	2.6	76.0	4.7	6.9	2.2	32.8	6.8	0.0	0.0	0.0	0.0	9.0	1.6	16.8	1.7	0.0	0	25
472706	WSHD		47B-DML	25	7.1	6	7.5	3	2.5	7	5.8	50.4	7.7	19.7	3.3	31.5	6.4	2.4	4.8	16.6	5.5	6.7	5.2	54.2	5.4	0.1	0	56
472707	WSHD		47B-DML	14	5.2	2	3.8	1	1.1	5	5.1	53.1	7.4	16.8	4.3	17.6	8.2	0.0	0.0	6.3	3.2	7.6	3.8	23.2	2.3	0.0	0	40
472708	WSHD		47B-DML	18	5.1	4	5.0	2	1.7	4	3.3	51.5	7.5	19.5	3.2	22.2	7.6	1.6	3.2	14.0	4.7	6.1	6.2	87.1	8.7	0.0	0	51
472709	WSHD		47B-DML	16	6.4	2	4.1	1	1.2	4	4.4	65.9	5.8	8.7	2.4	39.0	5.4	0.0	0.0	2.8	1.5	8.2	2.9	62.2	6.2	0.0	0	37
472710	WSHD		47B-DML	9	3.6	0	0.0	0	0.0	1	1.1	79.4	3.5	7.3	2.0	18.7	8.1	0.0	0.0	0.0	0.0	9.0	1.6	13.0	1.3	0.0	0	19
472711	WSHD		47B-DML	13	5.6	3	6.6	2	2.5	5	6.0	74.0	4.8	12.6	3.8	25.3	7.5	0.0	0.0	0.4	0.2	7.6	3.9	20.0	2.0	0.0	0	39
472712	WSHD		47B-DML	17	4.9	6	7.5	3	2.5	5	4.2	59.9	6.2	30.6	5.1	18.5	8.1	1.9	3.8	10.1	3.4	6.2	6.0	27.7	2.8	0.0	0	50
472714	WSHD		47B-DML	12	3.4	2	2.8	2	1.7	3	2.5	60.8	6.1	13.0	2.5	11.1	9.1	0.4	1.0	3.8	1.5	7.8	3.6	37.2	3.7	0.2	0	34
472715	WSHD		47B-DML	9	3.1	1	1.8	0	0.0	2	1.9	80.3	3.1	5.3	1.3	37.6	5.6	0.0	0.0	0.0	0.0	8.9	1.7	18.9	1.9	0.2	0	18

SITE NUMBER	SITE TYPE	COLD WATER	ECOREGION	NTVSP	NTVSP SCORE	SCKRSP	SCKRSP SCORE	SNSTVSP	SNSTVSP SCORE	BINVSP	BINVSP SCORE	P3DOM	P3DOM SCORE	PBINV	PBINV SCORE	POMNV	POMNV SCORE	PTOPC	PTOPC SCORE	PSLTH	PSLTH SCORE	TOLINDX	TOLINDX SCORE	ADJCPUE	ADJCPUE SCORE	PDELT	PDELT SCORE	FIBI
472716	WSHD		47B-DML	11	3.5	1	1.6	0	0.0	1	0.9	68.2	4.9	6.4	1.4	42.9	4.9	0.0	0.0	0.0	0.0	8.5	2.4	23.5	2.4	0.0	0	20
472717	WSHD		47B-DML	19	5.4	5	6.8	3	2.5	6	5.0	50.2	7.7	33.1	6.1	31.7	6.4	2.5	5.4	29.9	10.0	4.8	8.3	29.3	2.9	0.0	0	61
472718	WSHD		47B-DML																									
472719	WSHD		47B-DML	21	6.0	5	6.8	3	2.5	7	5.8	64.5	5.5	13.9	2.6	33.5	6.1	1.9	4.1	9.0	3.3	6.4	5.7	63.9	6.4	5.5	-10	40
472720	WSHD		47B-DML	18	5.1	3	4.1	2	1.7	5	4.2	61.6	6.0	19.9	3.7	24.6	7.3	0.9	1.8	15.2	5.6	5.9	6.6	55.9	5.6	0.5	0	47
472721	CRS		47B-DML	12	3.4	4	5.0	0	0.0	3	2.5	74.3	4.0	3.9	0.6	48.6	4.1	2.1	4.1	3.5	1.2	7.1	4.5	22.6	2.3	1.4	0	29
472722	WSHD		47B-DML																									
472801	TEST		47B-DML	22	6.9	4	6.4	1	0.9	5	4.4	65.5	5.4	7.0	1.5	8.7	9.4	5.2	10.0	5.1	2.2	7.2	4.5	15.6	1.6	0.9	0	48
472802	CRS		47B-DML	25	7.1	6	7.5	4	3.3	8	6.7	54.7	7.0	14.8	2.5	22.9	7.5	2.2	4.4	11.4	3.8	5.6	7.0	41.7	4.2	0.4	0	56
472803	CRS		47B-DML	31	8.9	6	7.5	8	6.7	11	9.2	58.5	6.4	14.1	2.3	6.1	9.8	2.3	4.7	8.7	2.9	4.8	8.3	128.6	10.0	0.6	0	70
472804	TEST		47B-DML	7	3.6	0	0.0	1	1.5	1	1.4	95.7	0.9	0.6	0.2	0.0	10.0	0.0	0.0	0.0	0.0	7.0	4.8	21.1	2.1	1.2	0	22
472805	TEST		47B-DML	14	7.1	2	5.2	2	3.0	4	5.7	70.0	6.5	6.1	2.2	8.3	10.0	0.0	0.0	0.2	0.2	5.7	6.9	128.5	10.0	0.0	0	52
473401	CRS		47C-IS	25	10.0	4	8.3	11	10.0	10	10.0	44.1	9.7	19.0	5.4	18.7	8.2	1.2	4.7	6.4	3.6	5.5	7.1	65.5	6.6	0.8	0	76
473402	CRS		47C-IS	26	8.4	4	6.6	6	5.7	9	8.1	46.8	8.3	34.7	7.9	11.4	9.1	0.0	0.0	15.3	6.9	5.1	7.7	75.9	7.6	0.1	0	69
473403	TEST		47C-IS	26	8.0	4	6.3	8	7.2	9	7.7	46.5	8.3	21.6	4.6	28.3	6.8	1.0	2.7	2.6	1.1	6.8	5.1	48.6	4.9	0.1	0	57
473404	CRS		47C-IS	18	5.1	2	2.8	5	4.2	7	5.8	63.3	5.7	17.5	3.4	8.3	7.5	0.9	2.1	1.7	0.6	7.6	3.8	3.7	0.4	1.7	0	38
473501	CRS		47C-IS	15	8.7	1	2.9	3	5.1	3	4.8	68.4	7.8	4.0	1.6	23.2	9.2	0.0	0.0	0.0	0.0	8.0	3.2	44.5	4.5	0.1	0	43
473502	CRS	X	47C-IS	19	8.6	3	7.0	6	8.0	6	7.6	52.3	9.3	39.6	10.0	16.9	9.0	1.1	5.0	1.4	0.9	5.4	7.3	94.2	9.4	0.0	0	75
473503	CRS		47C-IS	25	8.8	5	9.0	10	10.0	9	8.8	47.6	8.1	22.4	5.5	4.3	10.0	2.9	9.2	5.5	2.7	2.5	10.0	123.9	10.0	0.0	0	84
473504	CRS		47C-IS	22	7.7	3	5.4	5	5.1	8	7.8	40.4	9.3	25.6	6.2	19.0	8.1	1.5	4.8	19.4	9.4	5.9	6.5	57.7	5.8	0.4	0	69
473505	CRS		47C-IS	26	8.1	4	6.4	10	9.1	8	6.9	67.9	5.0	46.2	10.0	5.3	9.9	1.2	3.2	1.4	0.6	3.8	9.8	167.9	10.0	0.1	0	72
473506	CRS		47C-IS	30	8.6	7	8.8	10	8.3	12	10.0	35.6	10.0	58.8	10.0	11.5	9.0	2.3	4.7	23.4	8.0	4.0	9.5	65.7	6.6	0.1	0	85
473601	CRS		47C-IS	20	5.7	6	7.5	4	3.3	7	5.8	61.3	6.0	14.9	2.5	15.9	8.5	1.4	2.8	12.1	4.1	5.8	6.7	30.9	3.1	0.6	0	51
473602	CRS		47C-IS	28	10.0	4	7.4	11	10.0	10	10.0	55.5	6.9	30.3	7.7	6.3	9.7	1.3	4.3	5.7	2.8	5.0	8.0	89.4	8.9	0.1	0	78
473603	CRS		47C-IS	11	3.7	3	5.1	1	1.0	4	3.7	67.2	5.1	6.6	1.5	9.9	9.3	0.0	0.0	0.9	0.4	7.2	4.4	28.1	2.8	0.5	0	34
473604	CRS		47C-IS	19	6.1	6	9.8	3	2.8	7	6.2	37.9	9.6	30.7	6.8	17.9	8.2	0.0	0.0	9.4	4.2	5.9	6.5	25.7	2.6	1.0	0	57
473605	CRS		47C-IS	16	4.7	6	8.9	2	1.7	5	4.2	54.1	7.1	28.4	5.8	19.7	8.0	0.7	1.8	26.8	10.0	6.6	5.4	10.7	1.1	0.5	0	53
473606	CRS		47C-IS	29	8.3	8	10.0	8	6.7	10	8.3	36.7	9.8	37.6	6.9	16.2	8.4	2.1	4.5	30.0	10.0	5.1	7.8	72.2	7.2	0.1	0	80
473607	CRS	X	47C-IS	15	6.1	1	2.1	5	5.9	3	3.4	53.6	8.0	8.6	2.4	32.8	6.3	0.0	0.0	0.0	0.0	7.5	4.0	70.4	7.0	0.0	0	41
473608	CRS		47C-IS	16	5.8	1	1.8	7	7.4	6	6.0	55.9	6.9	32.3	8.2	11.0	9.1	0.5	1.7	0.0	0.0	4.8	8.3	39.7	4.0	0.5	0	54
473701	CRS		47C-IS	15	4.3	2	2.8	6	5.0	5	4.2	49.8	7.8	15.2	3.0	23.9	7.4	1.9	4.3	0.4	0.2	5.6	6.9	18.6	1.9	0.0	0	43
473702	CRS		47C-IS	24	9.7	6	10.0	6	7.1	10	10.0	58.3	7.2	21.0	6.0	26.7	7.1	1.5	5.8	7.1	4.0	5.1	7.8	121.4	10.0	0.0	0	77

SITE NUMBER	SITE TYPE	COLD WATER	ECOREGION	NTVSP	NTVSP SCORE	SCKRSP	SCKRSP SCORE	SNSTVSP	SNSTVSP SCORE	BINVSP	BINVSP SCORE	P3DOM	P3DOM SCORE	PBINV	PBINV SCORE	POMNV	POMNV SCORE	PTOPC	PTOPC SCORE	PSLTH	PSLTH SCORE	TOLINDX	TOLINDX SCORE	ADJCPUE	ADJCPUE SCORE	PDELT	PDELT SCORE	FIBI
473703	CRS		47C-IS	23	7.2	4	6.4	6	5.5	9	7.9	52.3	7.4	26.3	5.8	25.7	7.2	1.0	2.7	7.4	3.2	6.3	5.9	43.0	4.3	0.0	0	58
473704	CRS		47C-IS	27	7.7	5	6.3	12	10.0	9	7.5	43.1	8.8	44.6	7.5	10.6	9.2	3.6	7.3	27.7	9.2	2.6	10.0	67.2	6.7	0.0	0	82
475401	CRS		47E-SRLP	10	5.7	0	0.0	0	0.0	2	4.3	76.8	5.5	16.1	4.5	7.1	7.5	0.9	3.7	15.2	7.5	6.0	6.3	20.4	2.0	0.0	0	43
475402	CRS		47E-SRLP	10	4.4	2	5.2	0	0.0	1	1.7	82.4	2.7	2.9	0.6	5.9	7.5	1.4	3.7	2.9	1.3	7.4	4.1	6.1	0.6	1.0	0	29
475403	TEST		47E-SRLP	8	3.5	1	2.3	0	0.0	1	1.5	72.8	4.2	7.6	1.5	16.3	5.0	2.3	5.0	7.6	2.9	7.8	3.5	5.6	0.6	0.0	0	27
475404	CRS		47E-SRLP	10	4.3	1	2.2	0	0.0	2	2.9	64.6	5.5	4.5	0.8	12.1	9.0	5.0	10.0	2.4	0.9	6.4	5.7	15.1	1.5	0.8	0	39
475501	CRS		47E-SRLP	8	4.0	0	0.0	0	0.0	2	3.8	94.7	0.8	1.4	0.3	16.5	8.4	1.1	3.5	0.9	0.4	6.3	5.8	64.0	6.4	0.2	0	30
475601	CRS		47E-SRLP	9	3.9	1	2.2	0	0.0	1	1.4	68.5	4.9	10.1	1.9	59.1	2.8	0.0	0.0	10.5	3.9	8.4	2.5	3.4	0.3	0.0	0	22
475602	CRS		47E-SRLP	8	8.7	0	0.0	0	0.0	1	4.1	61.6	10.0	4.6	2.4	25.3	10.0	0.0	0.0	5.6	5.9	7.7	3.7	35.1	3.5	0.0	0	44
475603	TEST		47E-SRLP	7	3.0	0	0.0	0	0.0	2	3.2	91.1	1.4	6.2	1.3	51.0	3.8	0.0	0.0	5.8	2.4	7.6	3.8	67.1	6.7	0.0	0	23
475604	TEST		47E-SRLP	7	3.0	0	0.0	0	0.0	1	1.6	92.9	1.1	4.4	0.9	38.6	5.5	0.0	0.0	4.4	1.8	7.0	4.7	37.0	3.7	0.3	0	20
475701	CRS		47E-SRLP	6	2.6	0	0.0	0	0.0	0	0.0	70.0	2.5	0.0	0.0	70.0	1.3	2.4	2.5	0.0	0.0	8.3	2.5	1.7	0.2	0.0	0	11
475702	CRS		47E-SRLP	5	2.2	0	0.0	0	0.0	0	0.0	62.5	2.5	0.0	0.0	12.5	2.5	0.0	0.0	0.0	0.0	8.1	2.5	1.2	0.1	6.3	-5	4
475703	WSHD		47E-SRLP	14	6.1	4	8.0	0	0.0	4	5.7	61.5	6.0	4.4	0.7	25.2	7.2	1.9	3.8	0.7	0.2	7.6	3.9	5.4	0.5	0.0	0	38
475704	WSHD		47E-SRLP	12	5.7	1	2.8	0	0.0	2	3.6	63.2	5.7	1.5	0.4	3.0	10.0	2.0	5.9	0.0	0.0	6.7	5.2	34.0	3.4	0.0	0	39
475705	WSHD		47E-SRLP	9	4.4	1	2.9	0	0.0	1	1.9	60.1	6.2	6.7	1.6	6.2	9.7	2.2	6.8	0.0	0.0	7.7	3.6	9.7	1.0	0.0	0	35
475706	WSHD		47E-SRLP	12	5.2	3	6.0	0	0.0	3	4.3	63.0	5.7	4.3	0.7	13.0	8.8	2.2	4.4	2.0	0.7	6.4	5.8	13.5	1.3	0.4	0	39
475801	CRS		47E-SRLP	14	7.2	4	12.2	0	0.0	3	5.9	57.9	7.5	10.3	2.6	18.7	7.5	2.0	6.6	8.7	4.4	6.5	5.5	13.1	1.3	0.0	0	55
475802	CRS		47E-SRLP	10	6.8	1	4.0	0	0.0	3	7.7	75.1	5.1	11.2	3.7	27.4	7.7	0.0	0.0	7.2	4.8	7.3	4.2	16.0	1.6	1.4	0	41
476401	CRS		47F-RLP	12	4.7	1	2.0	0	0.0	2	2.2	85.0	2.5	10.0	2.7	8.5	9.4	0.0	0.0	9.8	5.4	9.0	1.6	15.0	1.5	0.0	0	29
476402	CRS		47F-RLP	17	6.4	2	3.9	2	2.2	4	4.2	51.5	7.8	14.7	3.9	32.9	6.2	0.8	2.7	9.6	5.0	7.9	3.4	39.4	3.9	1.1	0	45
476403	CRS		47F-RLP	9	2.6	1	1.4	0	0.0	1	0.8	68.6	2.5	27.5	5.0	17.6	5.0	2.5	5.0	29.2	5.0	7.7	3.6	3.3	0.3	0.0	0	28
476501	CRS		47F-RLP	14	7.8	2	5.7	0	0.0	3	4.6	67.4	7.7	13.3	5.2	31.7	7.7	0.0	0.0	13.1	10.0	7.9	3.3	38.8	3.9	0.1	0	51
476502	CRS		47F-RLP	20	8.2	4	8.4	1	1.2	6	6.8	56.0	7.7	23.6	6.8	48.3	4.3	0.0	0.0	10.0	5.7	7.9	3.4	49.9	5.0	0.0	0	52
476503	CRS		47F-RLP	23	7.9	5	8.8	5	5.0	10	9.6	61.2	6.0	35.3	8.5	40.9	5.2	2.6	8.1	29.8	10.0	6.4	5.8	29.0	2.9	1.1	0	71
476504	CRS		47F-RLP	17	5.8	1	1.8	2	2.0	3	2.9	65.8	5.3	4.9	1.2	14.4	8.7	1.0	3.1	0.4	0.2	6.6	5.4	163.1	10.0	0.0	0	42
476505	CRS		47F-RLP	16	5.5	1	1.7	4	4.0	5	4.7	72.0	4.3	60.8	10.0	26.1	7.1	0.7	2.1	2.5	1.2	5.0	7.9	37.2	3.7	0.5	0	48
476506	TEST		47F-RLP	11	4.8	1	2.4	0	0.0	3	4.6	91.4	1.3	0.8	0.2	53.1	3.5	2.1	5.0	0.2	0.1	7.7	3.7	45.7	4.6	0.0	0	27
476507	CRS		47F-RLP	30	8.6	7	10.0	2	1.7	9	7.5	66.5	5.2	26.7	5.3	45.5	4.5	0.9	2.2	22.5	8.8	8.0	3.2	39.7	4.0	0.2	0	56
476601	WSHD		47F-RLP	12	4.8	1	2.1	0	0.0	2	2.2	66.4	5.8	5.4	1.5	49.8	4.0	0.0	0.0	3.1	1.7	8.3	2.7	98.8	9.9	2.7	-5	27
476602	WSHD		47F-RLP	17	7.0	2	4.2	0	0.0	4	4.6	63.0	6.5	4.1	1.2	42.7	5.0	0.3	1.4	2.4	1.4	8.2	2.9	68.6	6.9	1.1	0	37
476603	WSHD		47F-RLP	14	5.4	2	3.9	1	1.1	3	3.2	77.4	3.7	4.0	1.1	30.2	6.6	0.0	0.0	2.1	1.1	8.9	1.8	71.3	7.1	0.0	0	32

SITE NUMBER	SITE TYPE	COLD WATER	ECOREGION	NTVSP	NTVSP SCORE	SCKRSP	SCKRSP SCORE	SNSTVSP	SNSTVSP SCORE	BINVSP	BINVSP SCORE	P3DOM	P3DOM SCORE	PBINV	PBINV SCORE	POMNV	POMNV SCORE	PTOPC	PTOPC SCORE	PSLTH	PSLTH SCORE	TOLINDX	TOLINDX SCORE	ADJCPUE	ADJCPUE SCORE	PDELT	PDELT SCORE	FIBI
476604	WSHD		47F-RLP	21	6.3	6	9.2	4	3.5	7	5.9	65.8	5.3	55.8	10.0	22.5	7.6	3.8	9.7	52.8	10.0	4.7	8.4	130.8	10.0	0.1	0	78
476605	WSHD		47F-RLP	22	6.6	4	6.1	3	2.6	7	5.8	75.5	3.8	7.2	1.5	60.9	2.5	1.5	3.8	3.0	1.2	6.1	6.1	72.9	7.3	0.4	0	43
476606	WSHD		47F-RLP	21	6.3	3	4.6	2	1.7	4	3.3	78.6	3.3	8.6	1.8	33.2	6.2	1.0	2.5	2.8	1.1	6.1	6.2	48.5	4.8	0.2	0	38
476607	WSHD		47F-RLP	17	6.0	1	1.8	1	1.0	4	3.9	72.9	4.2	3.0	0.7	65.6	1.9	0.0	0.0	1.2	0.6	8.6	2.1	56.1	5.6	11.8	-10	15
476608	WSHD		47F-RLP	14	5.0	1	1.8	0	0.0	2	2.0	69.3	4.8	2.0	0.5	60.4	2.6	0.0	0.0	0.5	0.3	8.8	1.9	59.4	5.9	5.3	-10	12
476609	WSHD		47F-RLP	14	4.2	2	3.1	0	0.0	1	0.8	66.0	5.3	1.5	0.3	58.6	2.8	0.7	1.8	0.0	0.0	9.2	1.3	5.7	0.6	0.5	0	18
476610	WSHD		47F-RLP	14	4.2	2	3.1	0	0.0	2	1.7	75.0	3.9	3.9	0.8	56.9	3.0	0.5	1.4	0.0	0.0	9.4	1.0	6.8	0.7	0.0	0	18
476611	WSHD		47F-RLP	27	7.7	7	9.2	5	4.2	6	5.0	50.8	7.6	11.4	2.1	36.6	5.7	2.6	5.3	9.9	3.5	6.5	5.5	41.5	4.1	0.9	0	55
476612	CRS		47F-RLP	21	6.0	7	8.8	0	0.0	4	3.3	68.0	5.0	3.6	0.6	68.7	1.5	3.5	7.0	3.5	1.2	8.0	3.2	26.1	2.6	0.6	0	36
476613	WSHD		47F-RLP																									
476701	CRS		47F-RLP	19	6.2	5	8.3	2	1.9	7	6.3	49.0	7.9	15.4	3.5	17.7	8.2	0.6	1.8	13.6	6.1	6.8	5.1	48.2	4.8	0.0	0	55
476801	CRS		47F-RLP	23	8.6	3	5.7	2	2.2	7	7.2	48.6	8.2	16.7	4.4	49.4	4.0	1.3	4.3	0.8	0.4	6.5	5.6	20.6	2.1	4.7	-10	38
476802	CRS		47F-RLP	19	9.9	1	2.7	4	6.1	5	7.3	54.3	10.0	20.8	7.6	12.5	10.0	2.1	10.0	0.0	0.0	7.6	3.8	17.8	1.8	0.3	0	63
476803	CRS		47F-RLP	19	10.0	2	5.9	1	1.7	6	9.6	57.7	10.0	9.4	3.8	26.7	8.6	0.3	2.2	4.6	3.7	7.1	4.6	84.4	8.4	0.3	0	62
476804	CRS		47F-RLP	9	4.0	1	2.7	0	0.0	2	3.4	83.0	2.6	5.3	1.2	66.4	1.8	0.0	0.0	3.9	1.7	8.8	1.9	12.9	1.3	0.7	0	19
476806	CRS		47F-RLP	22	8.7	2	4.0	3	3.5	5	5.5	56.7	7.3	3.5	1.0	22.5	7.6	1.2	4.6	0.8	0.5	7.2	4.4	32.0	3.2	0.0	0	46
476807	CRS		47F-RLP	14	4.0	2	2.5	0	0.0	2	1.7	93.0	1.1	0.6	0.1	93.4	0.0	1.1	2.1	0.7	0.2	5.7	6.8	35.6	3.6	0.5	0	20
476808	CRS		47F-RLP	18	7.8	3	6.1	0	0.0	4	5.7	88.6	1.8	3.2	0.5	79.1	0.1	3.5	6.9	2.9	1.0	8.8	1.9	10.8	1.1	0.0	0	30
476809	CRS		47F-RLP	10	4.4	1	2.6	0	0.0	2	3.4	84.6	2.4	1.0	0.2	57.1	3.0	0.0	0.0	0.7	0.3	8.3	2.8	14.3	1.4	0.0	0	19
476810	CRS		47F-RLP	9	5.4	0	0.0	0	0.0	2	3.3	68.4	8.1	11.9	5.0	21.2	9.7	0.0	0.0	0.0	0.0	8.7	2.0	31.2	3.1	0.4	0	33
476811	CRS		47F-RLP	13	7.5	2	6.8	0	0.0	3	6.6	61.1	6.8	9.2	2.6	38.9	5.5	1.1	4.5	7.4	4.2	8.1	3.0	29.9	3.0	0.3	0	46
476812	CRS		47F-RLP	22	6.3	3	3.9	1	0.8	8	6.7	70.6	4.6	8.3	1.5	69.4	1.4	4.2	8.5	5.0	1.8	6.8	5.1	100.7	10.0	0.0	0	46
520401	CRS	X	52B-PP	7	5.4	1	3.9	3	6.7	1	2.1	84.1	2.3	52.2	7.5	5.1	7.5	3.2	7.5	0.0	0.0	4.9	7.5	29.1	2.9	0.0	0	49
520402	CRS	X	52B-PP	7	2.9	1	2.1	4	4.8	4	4.6	78.2	3.9	76.9	10.0	9.7	9.5	0.8	3.3	0.0	0.0	1.5	10.0	87.5	8.8	0.0	0	54
520403	CRS		52B-PP	17	5.5	2	3.3	4	3.7	6	5.3	75.5	3.8	47.2	10.0	36.3	5.8	1.1	3.2	0.2	0.1	3.8	9.9	59.9	6.0	0.0	0	51
520501	CRS	X	52B-PP	8	6.9	1	4.4	4	10.0	4	9.5	87.5	4.6	82.7	10.0	3.0	10.0	0.5	10.0	0.0	0.0	1.8	10.0	95.2	9.5	0.0	0	77
520502	CRS	X	52B-PP	16	9.2	2	5.9	7	10.0	4	6.4	62.2	9.3	54.5	10.0	10.0	10.0	0.9	6.5	0.1	0.1	3.8	9.9	270.4	10.0	0.0	0	79
520503	CRS	X	52B-PP	11	5.2	1	2.4	4	5.6	3	4.0	64.2	7.3	49.9	10.0	25.7	7.9	0.9	4.8	0.0	0.0	3.5	10.0	516.7	10.0	0.0	0	61
520504	CRS		52B-PP	16	5.7	2	3.7	4	4.2	6	6.0	55.2	7.0	24.5	6.2	20.4	7.9	2.0	6.4	7.4	3.7	4.8	8.3	208.0	10.0	0.1	0	63
520601	CRS	X	52B-PP	4	2.4	0	0.0	4	7.0	2	3.3	95.7	1.1	74.0	10.0	3.3	10.0	4.7	10.0	0.0	0.0	0.3	10.0	97.5	9.8	0.0	0	58
520602	CRS	X	52B-PP	5	3.5	1	3.6	6	10.0	3	5.9	97.4	0.8	96.0	10.0	0.9	10.0	1.7	10.0	0.0	0.0	0.0	10.0	98.3	9.8	0.0	0	67

SITE NUMBER	SITE TYPE	COLD WATER	ECOREGION	NTVSP	NTVSP SCORE	SCKRSP	SCKRSP SCORE	SNSTVSP	SNSTVSP SCORE	BINVSP	BINVSP SCORE	P3DOM	P3DOM SCORE	PBINV	PBINV SCORE	POMNV	POMNV SCORE	PTOPC	PTOPC SCORE	PSLTH	PSLTH SCORE	TOLINDX	TOLINDX SCORE	ADJCPUE	ADJCPUE SCORE	PDELT	PDELT SCORE	FIBI
520701	CRS		52B-PP	27	8.9	5	8.4	11	10.0	12	10.0	52.7	7.4	53.7	10.0	13.9	8.7	1.0	3.0	5.7	2.6	3.6	10.0	125.1	10.0	0.0	0	81
520801	CRS		52B-PP	13	7.2	2	5.7	4	6.5	3	4.6	69.2	7.3	20.3	7.9	14.2	10.0	0.0	0.0	0.2	0.1	5.6	7.0	80.4	8.0	0.0	0	59
520802	CRS		52B-PP	23	6.6	3	3.9	9	7.5	9	7.5	66.7	5.2	55.6	9.9	11.4	9.1	1.2	2.5	1.2	0.4	3.6	10.0	63.1	6.3	0.2	0	63
720801	CRS		72D-UMRAP	16	10.0	1	3.2	2	3.7	3	5.2	62.4	10.0	6.1	2.7	60.2	3.3	1.6	10.0	0.0	0.0	7.4	4.1	43.5	4.4	0.5	0	51
720802	CRS		72D-UMRAP	22	10.0	1	2.4	0	0.0	5	6.4	45.8	10.0	14.5	4.7	24.7	7.9	0.6	2.7	0.8	0.5	7.0	4.7	48.7	4.9	0.0	0	49

Iowa Department of Natural Resources
Environmental Services Division
Wallace Building
502 East 9th Street
Des Moines, Iowa 50319-0034
(515) 281-5918