EVALUATION OF THE GREAT LAKES FISHERY COMMISSION INTERIM POLICY ON BARRIER PLACEMENT

Final Report submitted to the Great Lakes Fishery Commission

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EXECUTIVE SUMMARY

This final report is the culmination of a three-year project to develop the decision tools needed to implement the Great Lakes Fishery Commission Interim Policy on Barrier Placement, to conduct a pilot project implementing the decision tools and policy on case-study streams, and to assess the policy and the decision tools in light of findings from our pilot implementation. The project involved an extensive field program on nine candidate streams, intensive analyses of existing and newly collected data, and two workshops (planning and closing) with control agents. The project did not differ substantially from the original proposal, but our ideas were refined during the planning workshop held in June 2001.

As a result, the following decision-making tools were developed:

- species-at-risk (formerly VTE) list
- species distribution database
- fish faunal region classification
- rarity, range edge and fragmentation of Great Lakes fishes
- migration and passage knowledge base for Great Lakes stream fishes
- standardized fish sampling protocol
- evaluation of the potential use of historical data, rather than new sampling
- optimatization of sampling effort, required to develop a complete species list for a candidate stream

In addition, two M.S. theses have been successfully defended, and several manuscripts are in preparation. These tools and products were evaluated by the participants of the closing workshop held in July 2003, and were favorably received. It was the consensus of the participants that these tools fulfilled the needs outlined in the interim policy. The participants also provided many constructive comments on our efforts and the interim policy.

This report provides an extensive summary of the results of the development of the decision-making tools.

PROBLEM STATEMENT AND OBJECTIVES:

To (i) develop the decision tools needed to implement the Great Lakes Fishery Commission Interim Policy on Barrier Placement (Figure 1); (ii) to conduct a pilot project implementing the decision tools and policy on six (6) case-study streams in Canada and the United States that are being considered for future barrier construction; and, (iii) to assess the policy and the decision tools in light of findings from our pilot implementation and to suggest modifications to improve their effectiveness for future barrier construction.

RATIONALE AND RELEVANCE TO COMMISSION OBJECTIVES:

The Great Lakes Fishery Commission (GLFC) views barriers that impede the spawning migrations of adult sea lamprey (*Petromyzon marinus*) as a viable and promising alternative to the use of lampricides for the control of the sea lamprey. The GLFC adopted an interim policy for barrier placement in December 1999. The policy recognizes that decisions to construct barriers must consider the possible effects of the barriers on fishes other than sea lampreys, but questions remain regarding the feasibility of its implementation. This proposal addresses this implementation issue and has been prepared at the request of the Research Priorities Working Group of SLIC.

DELIVERABLES:

1. A set of technical, decision tools needed to implement the interim policy, including data and knowledge bases for VTE and nonVTE fishes, identification of fish faunal regions, fish distribution maps, and species lists by watershed (Year 1).

2. A planning workshop with control agents and technical experts identifying the target streams to be used in case (field) studies of the policy, as well as identification of adjacent sample streams within the ecoregion or fish faunal region, and the development of the field survey design (Year 2).
3. Implementation of the decision tools and field sampling design on six (6) case-study streams in Canada and the United States (Year 2 and 3).
4. A closing workshop with control agents and technical experts which assesses the interim policy and deliverables 1 through 3, and which considers modifications of the interim policy and provides a final, proposed protocol for field studies in support of that policy (Year 3).
5. Annual project reports at the end of Years 1 and 2.
6. A final project report at the end of Year 3.
7. A minimum of three (3) graduate theses and corresponding scientific publications (Year 3).
8. A GLFC Technical Report on the status and distribution of VTE fish species in the Great lakes (Year 3)

DELIVERABLES:

Deliverable 1. *A set of technical, decision tools needed to implement the interim policy, including data and knowledge bases for VTE and nonVTE fishes, identification of fish faunal regions, fish distribution maps, and species lists by watershed (Year 1).*

i) Species-At-Risk (formerly VTE) List

A species-at-risk (SAR) list was compiled primarily from web-based listings of species at risk. Species rankings were obtained from federal, state, and provincial agencies as well as the World Conservation Union (IUCN), The Nature Conservancy, and National Heritage Information Centers (NHIC). Sixteen agencies, 9 government and 7 non-government, provided lists and rankings of species. The compiled list is arranged taxonomically, first by orders, then families, and finally genus (see Appendix 1.1 for list). Status rankings from all 16 agencies are given by jurisdiction, using both the traditional ranking system (e.g. Endangered, Threatened, Special Concern) where available, and the NatureServe ranking system (e.g. S1, S2, SX).

Eighty-two species have been identified as being at risk in the Great Lakes basin. Some jurisdictions have assigned a conservation status to species which the American Fisheries Society (AFS) does not recognize, such as *Coregonus bartletti*, the Siskiwit lake cisco, which are listed as *Special Concern* and *S1* in Michigan. Also, several subspecies were listed, such as *Esox masquinongy masquinongy*, the Great Lakes muskellunge. In the case of the Great Lakes muskellunge, which the AFS does not acknowledge as a valid subspecies, rankings were combined under *Esox masquinongy*, the muskellunge. The Siskiwit lake cisco, and likewise the Ives lake cisco (*Coregonus hubbsi*), were kept on the list. However, it is noted on the list that these species are not recognized by the American Fisheries Society.

The species listed by the most agencies (15) is the lake sturgeon *(Acipenser fulvescens)*. In contrast, there are 11 species listed by only one jurisdiction. Ontario has the most listed species at risk (47), based on NatureServe S-rankings. Pennsylvania has the fewest listed species (8), based on the traditional ranking system.

(ii) Species Distribution Database

A fish species distribution database was compiled from 13 agencies and six books on state fishes. Many more distributional records exist but are either difficult to acquire due to proprietary rights, or difficult to use because of inadequate georeferencing. The current distribution database contains 407,913 georeferenced records in a standardized format (species, latitude longitude, watershed, source) (Appendix 1.2). Watersheds (8-digit HUCs (US), tertiary watersheds (Canada)) were assigned to each record using a spatial join between a watershed layer and point layer in ARCView. A map of native species richness by watershed (Appendix 1.3) and a frequency histogram of species richness (Appendix 1.4) indicate that the database provides good coverage for most of the basin except the small watersheds. The paucity of species in these watersheds is the result of lack of distributional records for these watersheds. Additional data acquisition to overcome these shortcomings is ongoing.

(iii) Fish Faunal Region Classification

We proposed that the GLFC consider using fish faunal regions instead of the ecoregions specified in the interim policy because (i) the interim policy intends to protect biodiversity and fish biodiversity is represented better by fish faunal regions than by ecoregions, (ii) ecoregions are based on variables (e.g. climate, landforms, soils, vegetation) thought to influence terrestrial, not aquatic, organisms, and (iii) there is no single ecoregion classification for Canada and United States. The participants of the Planning and Closing workshops agreed with this decision.

Initially, we planned to identify fish faunal regions using spatially-constrained cluster analysis. However, the presence-absence matrix (164 watersheds x 165 native species) currently exceeds the maximum size allowed by the only statistical package (R-package, University of Montreal) that calculates spatially-constrained cluster analysis.

To obtain a fish faunal classification, an unconstrained UPGMA cluster analyses using Jaccard and Ochiai similarity matrices were undertaken based first on the presence-absence matrix measuring 165 species x 5 Great Lakes. The results based on the Jaccard and Ochiai matrices were similar (Appendix 1.5), and it was decided that the fish faunas of each the Great Lakes were distinct enough to warrant a primary subdivision of the fauna into 5 units, each representing a Great Lakes basin. Unconstrained UPGMA cluster analysis using Jaccard and Ochiai similarity matrices were undertaken separately for each Great Lakes basin. The results based on the Jaccard and Ochiai matrices were similar for each basin (Appendix 1.6), and two groups were readily identified with minimal outliers for each basin. Therefore, two fish faunal regions were identified for each Great Lakes basin for a total of 10 fish faunal regions (Appendix 1.7).

iv) Rarity, Range Edge and Fragmentation

The interim policy considers the potential impact of barriers on native fishes that are locally rare or at the edge of their range, or whose range may be fragmented. Local rarity was measured as the proportion of watersheds in each faunal region in which the species was present. A categorization of rarity was proposed (occurrence in <5% of the watersheds within a faunal region - very rare in the faunal region; 5-25% - rare; 26-50% - uncommon; 51-75% - common; >75% - very common), but participants of the second workshop recommended that the raw data be made available, and the users of the data determine what constitutes rarity. Rarity is summarized for each species by faunal region in Appendix 1.8.

For each fish faunal region, each species was coded as either at, or not at, it's range edge for that particular range on longitude. This decision was made with the aid of the distribution database outlined above and the, "*Atlas of North American Freshwater Fishes*". Range edge is summarized for each species by faunal region in Appendix 1.8.

The development of an objective, quantitative measure of fragmentation for each species is a difficult because of the scale of measurement required. As outlined by the interim policy, the occurrence of each species would need to be determined not only for the candidate streams, but also in adjacent streams. In addition, knowledge of the dynamics of adjacent metapopulations would have to be determined for each species to assess the potential impact of proposed barriers. A fragmentation index was developed at the watershed level by measuring the mean distance (and variation) between all pairs of watershed which both contained each species. No clear pattern was discernible in the results, and scale was too coarse to detect possible fragmentation as outlined in the interim policy.

The participants of the second workshop concluded that fragmentation is difficult and costly to measure, existing data are not suitable, and it hard to conceive of a situation where fragmentation would lead to a decline in a species, but the species would not already be identified as a SAR, rare or at it's range edge. Therefore, the fragmentation objective in the draft protocol is difficult to quantify and likely redundant.

v) Migration and Passage Knowledge Base for Great Lakes Stream Fishes

The knowledge base summarizes migration and passage information for Great Lakes fishes and seeks to identify and, in cases where information is lacking, predict species susceptible to low-head barriers, in support of Figures 1 and 2. The conceptual structure and contents of the current knowledge base are summarized in Appendix 1.9. The bulk of the available information has been collected and the data entry audited, but additions are ongoing as new information becomes available. Brief descriptions of the contents are provided below. The database itself is found in the file "dbase.zip".

a) Species List for the Great Lakes Basin. Two species lists are available for Great Lakes fishes: Coon (1999) and Cudmore-Vokey and Crossman (2001). We have created electronic forms of each. There are discrepancies between the two lists regarding whether specific species are present in specific lakes, as well as their status (native or introduced), however we have used the list of Coon (1999). It is more comprehensive than the list of Cudmore-Vokey and Crossman, which is restricted to species found within the lakes proper and not within streams. The list includes 192 species, including Atlantic species in the St. Lawrence portion of the basin and failed introductions from the past. The species list has been used to create an electronic bibliography of Great Lakes fishes (>2200 records) that, at this time, extends back to the 1970's. In addition, we have created a fish passage bibliography (>1000 records) with links to electronic (doc) copies of >400 of the papers referenced in the bibliography.

b) Coarse Habitat Preferences. Species in the Great Lakes species list have been classified as lentic or lotic specialists, or lentic/lotic generalists, using species accounts in Trautman (1981), Scott and Crossman (1973), Forbes and Richardson (1974), Smith (1979), Becker (1983), and Cooper (1983). In addition, proportions of times species have been sampled from lentic vs. lotic habitats were obtained from Forbes and Richardson (1974) and from Mandrak's Canadian Freshwater Fish Distribution Database. Our analyses have indicated that almost all fishes from the Great Lakes species list can be found in lotic habitats. Indeed, most fishes are lentic/lotic generalists and quantitative (proportional) measures are therefore useful to characterize habitat preferences. Quantitative measures from Forbes and Richardson (1974) and Mandrak are moderately correlated ($r = 0.65$, $P < 0.001$, $N = 29$ species) suggesting that measures made from different regions and different times have some predictive value for other regions and times.

c) Migratory Behaviour. Species in the Great Lakes species list have been classified as undertaking migrations between lakes and rivers, within rivers, or as having their migratory behaviour described as uncertain, based on species accounts. Uncertain was considered to be more appropriate than assuming a species was sedentary because few accounts specify unambiguously whether a species is sedentary. Information has been collated from Trautman (1981), Scott and Crossman (1973), Forbes and Richardson (1974), Smith (1979), Becker (1983), and Cooper (1983), as well as publications from the primary literature and government agencies. In addition, mean catch per unit effort (CPUE) for electric weirs and lamprey traps have been calculated using data in the Biological Impacts of Low-head Dams (BILD) historical database.

The migration table contains 1076 records for 178 species. Descriptions of migratory behaviour are typically qualitative and anecdotal. Nevertheless, at least 121 (71%) of the 171 native and introduced species currently inhabiting the Great Lakes basin proper exhibit some form of migration. Seventy-six species (44%) have at least one record of a lake-river migration and 45 of the remaining species have at least one record of migration within a river.

d) Passage at Barriers. Species in the Great Lakes species list have been classified as attempting to pass barriers and as passing successfully. Bunt et al. (1999), O'Connor and Kelso (1999), Porto et al. (1999) and the BILD historical database were used as sources from within the basin and Schwalme et al. (1985), Helfrich et al. (1999) and Wlosinski et al. (2000) as sources from outside of the basin. Analysis of electric weir and trap data from the BILD historical database suggests at least 92 of 171 species can be expected to occur at barriers. Of these, 37 species have been observed to pass at barriers and, for some species, whether they pass successfully differs among study locations. Furthermore, observations of passage by nonsalmonid fishes are often anecdotal and the success at passing barriers is typically very low when measured. Passage studies to date have focused on migratory species and passage has not been investigated for many of the species expected to attempt passage at sea lamprey barriers.

e) Species Impacted at Barriers. A list of species impacted by low-head barriers has been developed using the BILD extensive field survey data. Additional data from literature have also been collected. The list from BILD is based on comparisons of the abundances of a given species above and below real barriers on barrier streams versus abundances above and below hypothetical barriers on reference streams. Of the 81 species sampled in the BILD extensive field survey, 48 species were common enough to calculate measures of impact (Appendix 1.9). Twenty-six species showed signs of their distributions being impacted by low-head barriers; however, only six of 48 were not collected at all (potentially missing) above barriers. The six species were Iowa darter (*Etheostoma exile*), striped shiner (*Luxilus chrysocephalus*), yellow perch (*Perca flavescens*), trout perch (*Percopsis omiscomaycus*), sea lamprey (*Petromyzon marinus*), and northern red belly dace (*Phoxinus eos*). From the literature, an additional 129 assessments were obtained for 69 species. There is a moderate amount of overlap between the

BILD and literature data, with 33 species in common. The literature data are also limited by differences in data collection methods, lack of reference streams, and multiple potential causes of impact, some of which may not be pertinent to sea lamprey barriers, e.g. impoundment of water.

f) Species Using Fishways and Culverts. For fishways, one hundred and fifty four records for 30 species have been obtained from the literature. In addition, we have also acquired records from trap-and-sort fishways operated by Sea Lamprey Control and records from Ontario Ministry of Natural Resources (OMNR). The Sea Lamprey Control data include 55 species. The OMNR data are exclusively for introduced salmonids. For culverts, which present hydraulic challenges similar to those presented by fishways, 65 records have been obtained for 17 species.

g) Jumping Species. The available literature focuses heavily on salmonid fishes. Anecdotal observations of nonsalmonid fishes jumping low-head barriers have been found for central stoneroller (*Campostoma anomalum*) and common carp (*Cyprinus carpio*).

h) Additional Components. There are four additional components which we have considered: timing of migrations by nontarget fishes relative to migrations by sea lamprey, swimming performance measures, external morphological correlates of swimming ability, and life history traits important to local colonization and extinction.

The first two were included in our original proposal but have been given low priority based on what we have learned since then. In the case of the timing of migrations, we have found species accounts too vague regarding timing to be helpful, the BILD historical database does not include adequate data to evaluate timing, and the analysis by Klingler et al. in press suggests the overlap between runs of non-target species and sea lampreys can be high and variable among streams and years. Steve Gephard's presentation at the Fish Passage Workshop (based on experience along the Atlantic Coast) supported a similar conclusion of high overlap. Jerry Weise at Fisheries and Oceans Sault Ste. Marie is analyzing the timing of migration using data collected by his agency. Lastly, there are concerns that the trap data will not adequately reflect the timing and overlap of migration if fishes stage below the barrier for a period before entering traps and fishways.

In the case of swimming performance measures, we have opted to collect available references rather than re-covering well-trodden ground, especially because several contributors at the Fish Passage Workshop raised concerns about the adequacy of swimming performance measures for predicting passage by fishes. Two participants at that workshop (Coutant and Katopodis) have already created databases summarizing measures of swimming performance and we have obtained these data. The two sources include 315 records for 36 Great Lakes species and 36 records (means) for 35 species, respectively.

The last two components, morphological correlates of swimming performance and life history traits important to local colonization and extinction, were not considered in our original proposal. They are being considered by MSc candidate Deb DePasquale (Guelph) in analyses of sensitivity to barriers. We have found that morphological correlates of swimming ability are not useful in predicting whether species are impacted by barriers. A similar analysis is underway using life-history traits as predictors. We do not intend to include these components in the migration and passage database per se, however, predicted sensitivities of species where empirical data are lacking will be added to the knowledge base once the analyses are complete.

We also have extended the development of our database tools beyond what was specified in our original proposal by integrating the species-at-risk list, fish distribution database, fish faunal regions, rarity and range edge data, and fish migration and passage database to develop an easy, flexible prototype tool that would help decision-makers progress through the decision tree for the policy (Figures 1 and 2). The database tool is programmed to first allow users to specify or enter a list of fish species and then obtain summaries of migration and passage information. Four ways of specifying a list of species are provided: (i) selecting a watershed (tertiary in Canada or 8-digit HUC in US) from a map of the basin and obtaining list of species for that watershed, (ii) selecting a stream or river from a list of barrier candidate streams and obtaining a list for the watershed (as above) in which the stream resides, (iii) generating a user-specified list of species based on historical or field survey data for a specific stream or river, or (iv) using the entire list of species for the basin. Once a list is specified, the user can request reports summarizing information about the components of fish passage (a-g above) for each species or reports summarizing information by species for a specified component of passage. Summary reports have been designed to provide additional information regarding the data. For example, clicking on a table title (e.g. migration habits) will, in most cases, provide a screen describing each of the component parts of a table (e.g. descriptions of what is meant by the column headings lake-river, within river, and uncertain). Similarly, clicking on a specific entry in a summary table will provide source details (reference, page, paragraph) regarding where the information was obtained so that users can refer to the original reference, as needed. Additional work is needed before we can make the database available more widely. In particular, we need to add the information on rarity within a faunal region and organize and program the corresponding reports. We also intend to add habitat information that will help control agents complete field surveys by identifying local habitat criteria that can be used in the selection of sample sites for species presumed to be present, but rare, within a given river or stream. Finally, we need to beta-test the programming we have developed to make the database functional. At the closing workshop for the project, it was recommended that we distribute copies to members of the barrier task force and ask them to help test the functionality of the tool.

Deliverable 2. *A planning workshop with control agents and technical experts identifying the target streams to be used in case (field) studies of the policy, as well as identification of adjacent sample streams within the ecoregion or fish faunal region, and the development of the field survey design (Year 2).*

The workshop, **Assessment of the Great Lakes Fishery Commission's Environmental Policy on Barrier Placement,** was held 18-20 June 2001 in Ann Arbor. At the workshop, we (i) summarized our efforts to develop fish faunal regions and compare them with published ecoregions, (ii) summarized our efforts to create a knowledge base regarding the movements of fishes and the impacts of barriers at the fish assemblage and species levels, (iii) received advice on our study design and stream survey methods, and (iv) identified suitable study streams for the project. The workshop provided us with potential new sources of data for our fish distribution database and knowledge base. A list of participants is provided in Appendix 2.

Deliverable 3. *Implementation of the decision tools and field sampling design on six (6) case-study streams in Canada and the United States.*

Plans for our pilot field studies did not changed substantially from our initial proposal. The project team and participants at the Planning Workshop felt it was important to develop a standardized sampling protocol to ensure that whole fish communities in candidate streams were sampled in a similar manner. In addition, the amount of effort required to sample the whole fish community, and subsequent analysis of optimization of sampling effort were also deemed important. To address these objectives, a sampling protocol was drafted (Appendix 3) and applied to nine candidate streams. The candidate streams/rivers sampled were: Big Otter Creek (Lake Erie) and the Boyne River (Lake Huron) for the University of Guelph team; Conneaut Creek, Raccoon Creek (Lake Erie) and Grindstone Creek (Lake Ontario) for the DFO team; and, Harlow (Lake Superior), Sucker (Lake Superior), AuGres (Lake Huron) Little Pigeon (Lake Huron) rivers for Michigan State team.

The following is the concluding section from the graduate thesis of Katherine Smith (the full thesis is provided in Appendix 7). It summarizes the conclusions of her analysis of three key issues related to the challenge of determining the fish species composition in a watershed: 1) the potential utility of historical data, as an alternative to a new field sampling effort; 2) an analysis of sampling effort requirements for a field survey; and, 3) an assessment of the optimal allocation of sampling effort both within and among sample sites (reaches) in the target watershed.

Implementation of the GLFC barrier policy depends on the ability of managers to determine species composition in barrier candidate streams. As budgets are limited for such activities, an understanding of the adequacy of historical data is essential. In addition, estimates *of sampling effort requirements for watershed-level fish community characterization are necessary to determine the feasibility of the barrier policy and to prioritize candidate streams. Increasing the efficiency of fish species inventories will further increase the cost-effectiveness of implementing the barrier policy. Below, I summarize the recommendation and findings from this evaluation of strategies for assessing fish species composition in Great Lakes streams.*

Existing species lists from multiple repeated surveys contained more species than our intensive field survey list, but in general were not as reliable because species composition of the stream may have changed since existing surveys were conducted and errors, due to the goals of existing surveys, are probable. Given our findings from this historical data evaluation, existing survey data should only be used when: (1) lists are no more than 10 to 15 years old, (2) lists are compiled from multiple years of repeated surveys, (3) the watershed was representatively sampled, (4) sampling was conducted in spring and summer, and (5) the number of species on existing lists is comparable to the estimated species richness based on watershed size. It is unlikely that data meeting these criteria are available for most watersheds.

Sampling effort requirements to detect a majority of the estimated species richness of a watershed were relatively small; however, sampling requirements to detect the majority of species were extensive. Sampling an average of 15, 29, 49, and 119 randomly selected reaches of stream, stratified by stream order should on average be sufficient to detect 80, 90, 95, and 100 %, respectively, of species present in Great Lakes watersheds. Because sampling effort requirements will vary by river, to prevent under or over-sampling, field crews should plot species accumulation curves in the field and adjust sampling effort to achieve specific objectives of inventory completeness. Because species of concern found in the region will likely be the rarest and most easily missed species in a survey, these species may be identified from the *regional list and specifically targeted. Based on the difficulty of detecting the last 10 % of species, random sampling to detect 90 % of estimated species richness should be conducted in addition to such targeted sampling.*

Sampling efficiency can be further improved by optimally allocating sampling effort in the watershed. We found that (1) sampling an intermediate number of stream widths at a reach and (2) focusing sampling effort in higher order sections of the watershed can improve rates of species accumulation. Allocating 70 % of sampling effort increases the average number of species detected without increasing the number of headwater species consistently missed. Given our results, field crews should sample reaches of approximately 12 stream widths in length in third order strata and 18 stream widths in first and second order strata. If a reach is particularly diverse or unique, additional sampling may be beneficial. At the watershed level, crews should focus up to 70 % of sampling time to third or higher order strata. Distributing this sampling effort over multiple years is desirable.

Deliverable 4. *A closing workshop with control agents and technical experts which assesses the interim policy and deliverables 1 through 3, and which considers modifications of the interim policy and provides a final, proposed protocol for field studies in support of that policy (Year 3).*

The closing workshop was held 8-9 July, 2003 in Ann Arbor. Prior to the workshop, we ran a sample decision-making exercise on one of the candidate streams. As a result of this exercise, we modified the decision-making framework (Figure 2). The workshop was organized in the same order as our revised decision-making framework. A list of participants is provided in Appendix 4.

At the workshop, we summarized our efforts:

(i) to develop a standardized protocol;

(ii) to evaluate the potential use of historical data, rather than new sampling;

(iii) to analyze our sampling effort based on our field sampling;

(iv) to optimize sampling effort required to develop a complete species list for a candidate stream;

(v) to develop fish faunal regions;

(vi) to determine rarity, range edge and fragmentation by fish faunal region;

(vii) to create a migration and passage knowledge base, regarding the movements of fishes and the impacts of barriers at the fish assemblage and species levels; and,

(viii) to identify species vulnerable to barriers.

The participants of the workshop were asked to comment on every step of the decision-making process. These comments are summarized in Appendix 4 under the following headings: Criteria for Evaluating Historical Data; Concerns Raised about Sampling Protocol; Consensus on Sampling Effort; Faunal Regions, SAR List, Rarity, Fragmentation; Migration and Passage Knowledge Databases; and, General Comments on Interim Policy.

Deliverable 5. *Annual project reports at the end of Years 1 and 2.*

- See Appendix 5.

Deliverable 6. *A final project report at the end of Year 3.*

Deliverable 7. *A minimum of three (3) graduate theses and corresponding scientific publications (Year 3).*

The following theses based on this project have been completed and successfully defended:

Noble, J.J. 2002. Distribution and ecological characteristics of fish species-at-risk in the Great Lakes. Department of Biological Sciences, Youngstown State University. M.S. thesis. 56 pp. + appendices. (Appendix 6).

Smith, K.L. 2003. Strategies for the assessment of fish species composition in Great Lakes streams. Department of Fisheries and Wildlife, Michigan State University. M.S. thesis. 97 pp. (Appendix 7).

A M.Sc. thesis by Deb DePasquale, University of Guelph, is expected to be completed by Spring 2004.

Deliverable 8. *A GLFC Technical Report on the status and distribution of VTE fish species in the Great Lakes (Year 3)*

- See Appendix 8.

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Figure 1. Original schematic of how the decision tools will be used to implement the interim policy in the case studies.

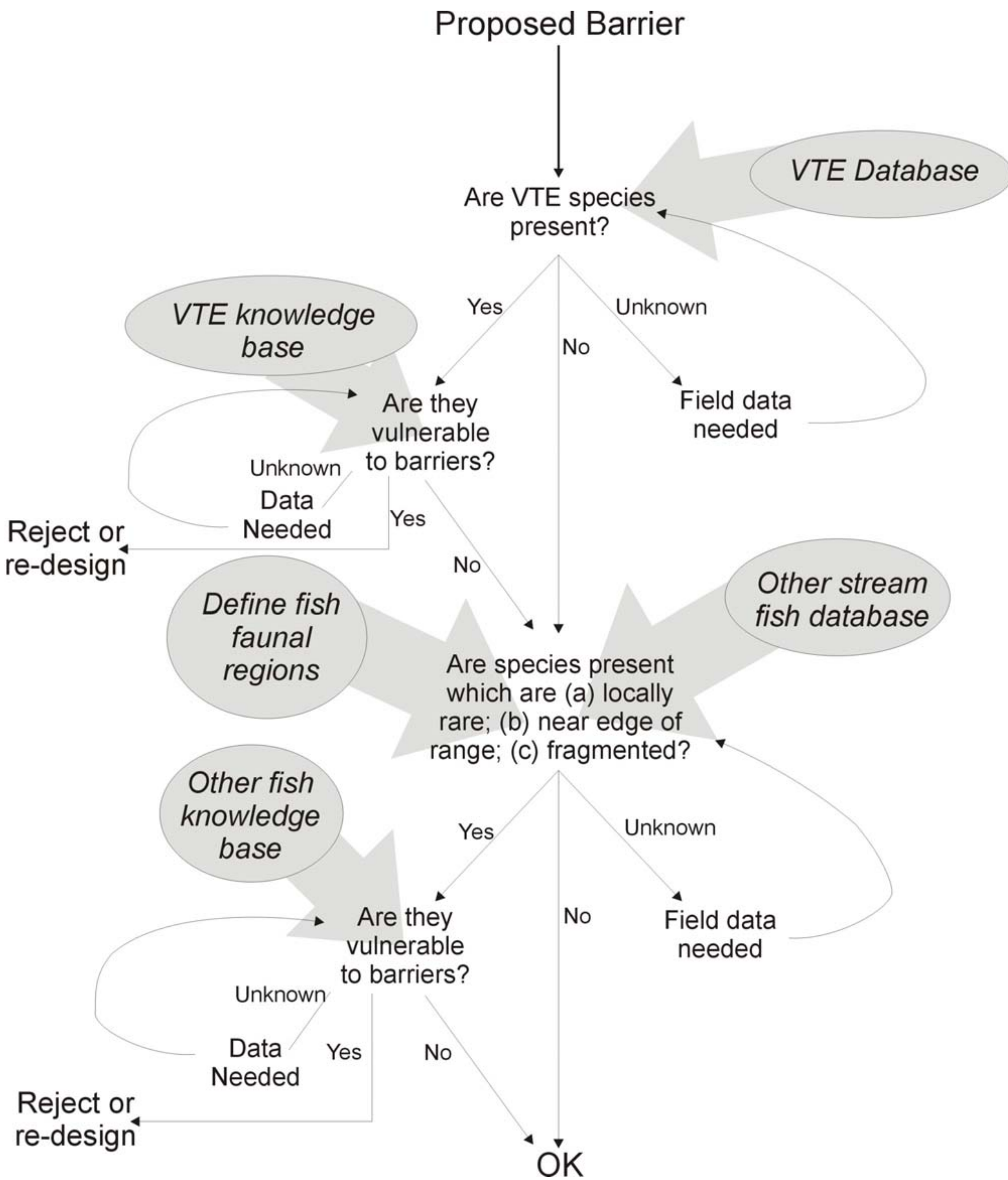
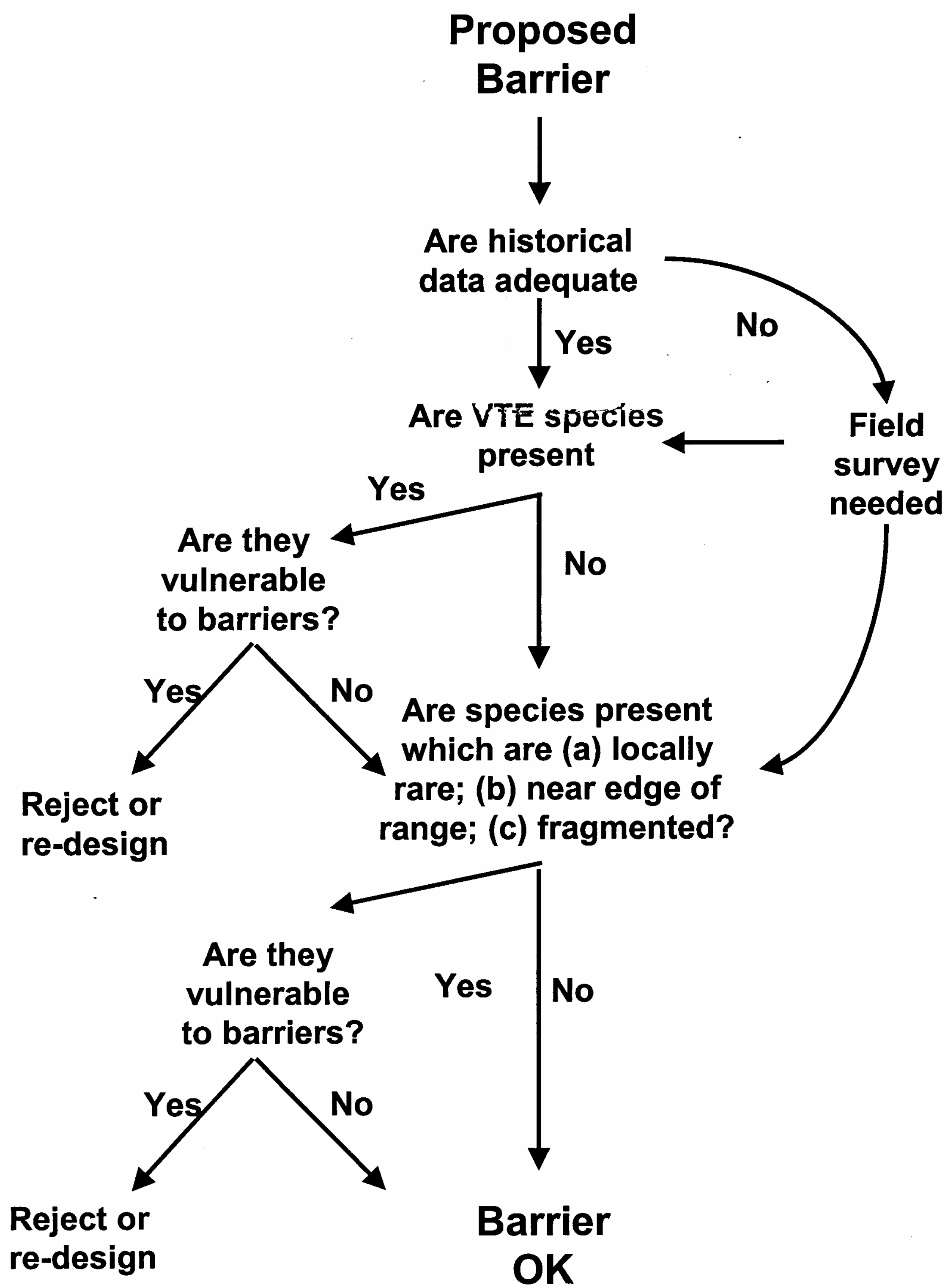


Figure 2. Revised schematic of how the decision tools should be used to implement the interim policy as a result of the case studies.



Appendix 1.1. List of conservation ranks for fish species in the Great Lakes by jurisdiction.

	GCR	IUCN	Canada	US	Illinois	Indiana	Michigan	Minnesota	New York	Ohio	Ontario	Pennsylvania	Wisconsin
Petromyzontidae													
Ichthyomyzon castaneus	G4		SC; N3N4	N4	S3	S4	S4	S?			S?		
Ichthyomyzon fossor	G4		SC; N3	N4	END; S1	S4	S4	SC; S3	S1	END; S2	S3	END; S1	S4
Ichthyomyzon unicuspis	G5		N4	N5	S3	S4	S4		S3	S2	S3	SH	S4
Lampetra appendix	G4		N4	N4	S2	S3	S4	S4	S3	S2S3	S3	S3	S4
Acipenseridae													
Acipenser fulvescens	G3	VUL	NAR; N4	N3	END; S2	END; S1	THR; S2	SC; S3	THR; S1	END; S2S3	S3	END; S1	SC; S3
Polyodontidae													
Polyodon spathula	G4	VUL	EXP; NX	N4	S2S3	S3	EXP; SX	THR; S2	SX	THR; S2	SX	SXSC	THR; S2?
Lepisosteidae													
Lepisosteus oculatus	G5		SC; N2	N5	S2S3	S4	SC; S2S3		S1	END; S1	S2	S1	
Lepisosteus osseus	G5		N4	N5	S3		S4	S?	S3	S?	S4	S2S3	S4
Amiidae													
Amia calva	G5		N4	N5	S3	S4	S4	S?	S4	S?	S4	S2S3	S4
Hiodontidae													
Hiodon tergisus	G5		N4	N5	S2S3	S4	THR; S2	S?	END; S1	S3?	S4	S2?	S4
Anguillidae													
Anguilla rostrata	G5		N5	N5	S2	S4	SE		S5	THR	*S5*	S5	SC; S3
Clupeidae													
Alosa sapidissima	G5										SX		

Dorosoma cepedianum	G5	N5	N5	S5	S4		S?	S3	S?		S4	S4
Cyprinidae												
Campostoma anomalum	G5									S3		
Clinostomus elongatus	G4	SC			END	END; S1S2				S3		SC; S3?
Erimystax x-punctatus	G4	EXP					SC	THR; S1		SX	END; S1	END; S1S2
Exoglossum laurae	G4							S2	THR			
Exoglossum maxillingua	G5									S1S2		
Hybognathus regius	G5									S2		
Luxilus chrysocephalus	G5									S3		END; S1S2
Lythrurus umbratilis	G5							SC; S2			S2	THR; S3
Macrhybopsis storeriana	G5	SC				SC; S2S3		END; SX		S2	S1	SC; SU
Nocomis micropogon	G5			END								
Notropis amblops	G5					EXP						
Notropis anogenus	G3	SC		END		SC; S3	SC	END; S1	EXP	S2		THR; S2S3
Notropis bifrenatus	G5	SC								S2	S1S2	
Notropis dorsalis	G5								THR		S2	
Notropis heterodon	G5			THR				S1	END		S1	
Notropis heterolepis	G5			END					END		SX	
Notropis photogenis	G5	SC				END; S1		S2		S2S3		
Notropis texanus	G5			END		EXP; S1						SC; S3
Opsopoeodus emiliae	G5	SC				END; S1			END	S2		SC; S3?
Phoxinus erythrogaster	G5					END; S1					S2S3	
Catostomidae												
Catostomus catostomus	G5			THR					END		END; S1	
Erimyzon oblongus	G5					END; S1S2						
Erimyzon sucetta	G5	SC						THR; S1	THR	S2	SX	SC; S3?
Ictiobus cyprinellus	G5	SC								S?	SX	

Ictiobus niger	G5		SC			SC; S3	SC			S?		THR; S2?
Lagochila lacera	GX				EXP				EXT			
Minytrema melanops	G5		SC							S2	S2	
Moxostoma carinatum	G4		SC	THR	END	THR; S1		S2?	SI	S2	S3	THR; S2S3
Moxostoma duquesnei	G5		THR					SC; S2		S2		SC; S1
Moxostoma erythrurum	G5									S3		
Moxostoma valenciennesi	G3			END	END			S2	THR	S3		S2S3
Ictaluridae												
Ameiurus melas	G5									S3	S1?	
Noturus insignis	G5		THR							S1		
Noturus miurus	G5		SC			SC; S2S3		S1		S2	S2	
Noturus stigmosus	G3		SC	END		END; S1			END	S1S2	THR; S1	
Esocidae												
Esox americanus vermiculatus	G5									S3		
Esox masquinongy	G5				THR				SI			
Salmonidae												
Coregonus artedi	G5			THR	END	THR; S3			END		SH?	SC; S3
Coregonus clupeaformis	G5								SI		SX	
Coregonus hoyi	G4	VUL						SX				SC; S3?
Coregonus johannae	GX	EXT	EXT		EXP					SX		
Coregonus kiyi	G3	VUL	SC		SC		SC	SX		S3		SC; S3
Coregonus nigripinnis	GXQ	EXT	THR		THR	EXP; SX				SX		
Coregonus reighardi	G1	CRE	THR		THR	EXP		SX		SX		
Coregonus zenithicus	G2	VUL	THR			THR; S2	SC	SX		S2	SX	SC; S3?
Prosopium coulteri	G5											SC; S3?
Prosopium cylindraceum	G5							END; S1				
Salmo salar	G5									SXC		

Salvelinus fontinalis	G5								THR			SC; S1?
Salvelinus namaycush	G5								SI		SH	
Thymallus arcticus	G5					SX	EXP					
Aphredoderidae												
Aphredoderus sayanus	G5						SC		END		SX	SC; S3
Gadidae												
Lota lota	G5								SI		THR; S1S2	
Fundulidae												
Fundulus diaphanus	G5			THR					END			SC; S3?
Fundulus dispar	G4											END; S2
Fundulus notatus	G5		SC							S2		
Cottidae												
Cottus ricei	G5					SC; S3		END; SX	SI			
Myoxocephalus thompsoni	G5		THR					END; SX			SU	
Centrarchidae												
Lepomis gulosus	G5		SC							S1	S1S2	
Lepomis humilis	G5		SC							S3		
Lepomis megalotis	G5							THR; S1		S3	S1	THR; S2
Pomoxis annularis	G5									S3		
Percidae												
Ammocrypta pellucida	G3	VUL	THR		END	THR; S1S2		THR; S1	SI	S2	END; S1	
Etheostoma blennioides	G5		SC									
Etheostoma chlorosomum	G5											END; S1
Etheostoma exile	G5			END				S2	SI		S1	

Etheostoma microperca	G5			SC		SI			SC; S3
Percina copelandi	G4	THR	END; S1S2		S2	THR	S2	THR; S1S2	SC
Percina shumardi	G5		END; S1			THR	S3		
Stizostedion canadense	G5		THR; S1		S1				
Stizostedion vitreum glaucum	GX	EXT	EXP; SX			EXT	SX	SX	

` - Committee on the Status of Endangered Wildlife in Canada

`` - World Conservation Union

``` - Global Conservation Ranks (as given by The Nature Conservancy)

**Status/Ranking Codes**

END = endangered

EXP = extripated

EXT = extinct

SC = special concern

SI = special interest

THR = threatened

VUL = vulnerable

**Natural Heritage Information Centre Rankings/State Codes**

S1 = extremely rare; 5 or fewer occurrences in province or few remaining individuals

S2 = very rare; usually between 5 and 20 occurrences in province

S3 = rare to uncommon; usually between 20 and 100 occurrences in province
SH = historically present, but no documented occurrences for extended period of time, but still believed to be extant

SX = apparently extripated from province

SXC = naturally extripated but exists in province as cultivated species (C = cultivated or in captivity)

S?/SU = unranked; species thought to be rare but data is insufficient

? = ranking questionable

**Additional IUCN Codes**
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CRE = critically endangered

LR = lower risk; may easily become threatened

Global Conservation Status Ranks

G1 = critically imperiled

G2 = imperiled

G3 = vulnerable

G4 = apparently secure

G5 = secure

GX = presumed extinct

GH = possibly extinct

Q = questionable taxonomy that may reduce conservation priority

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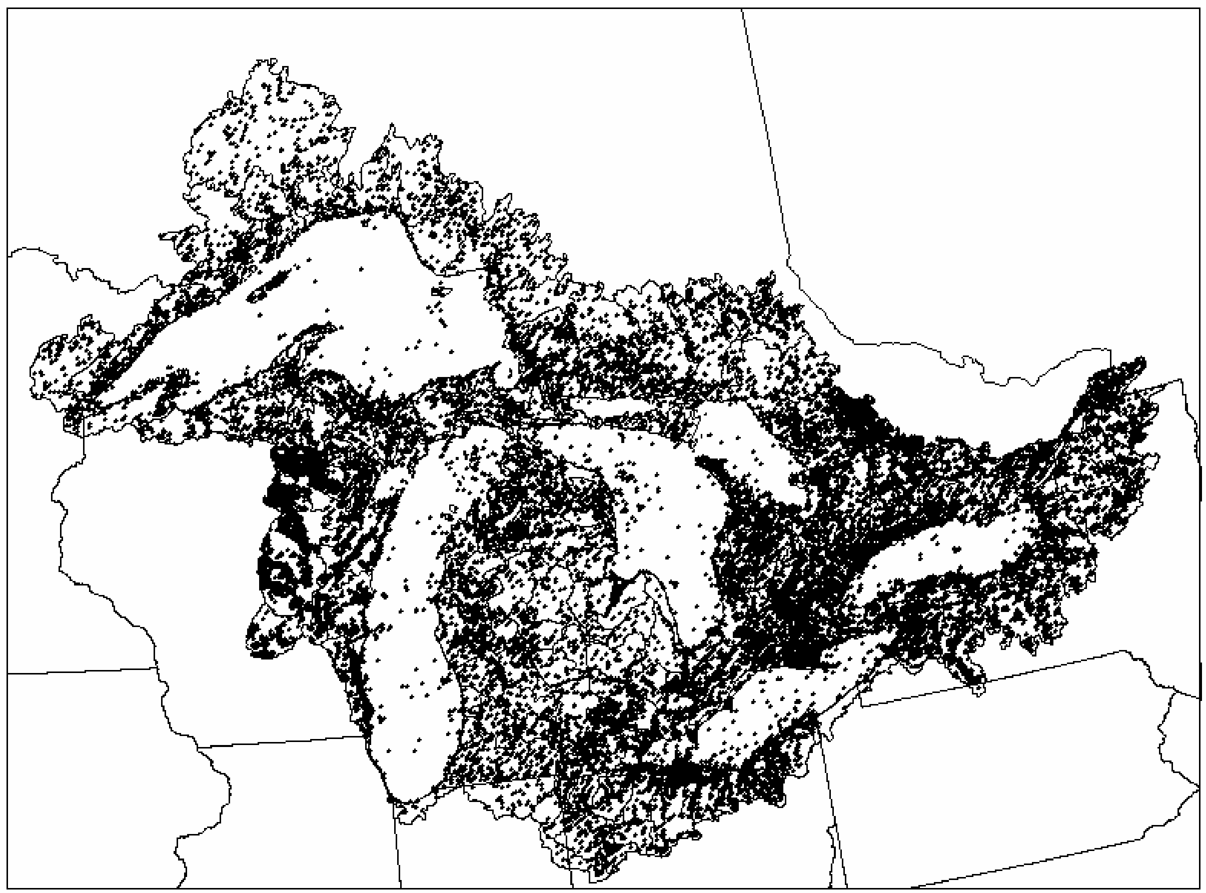
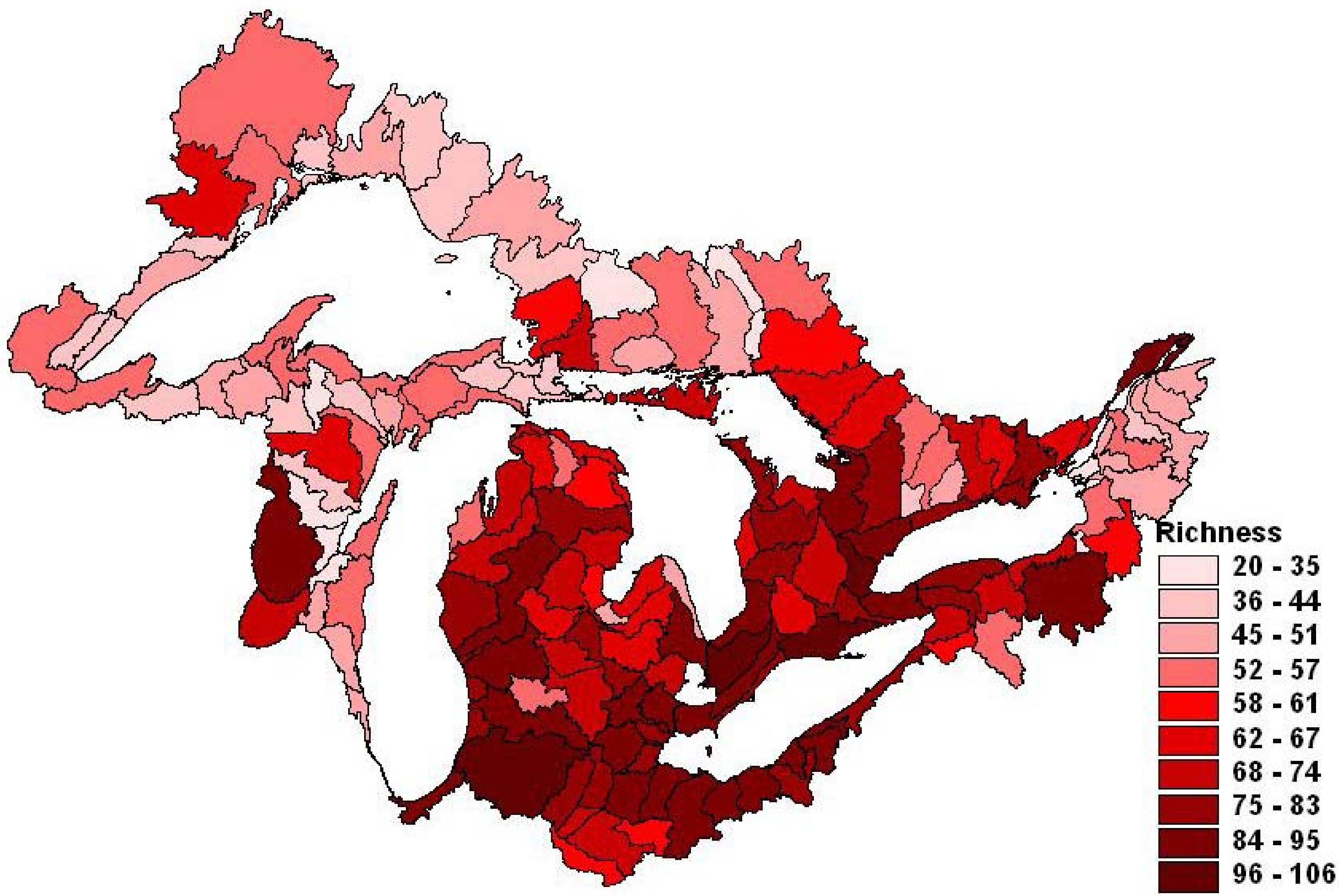
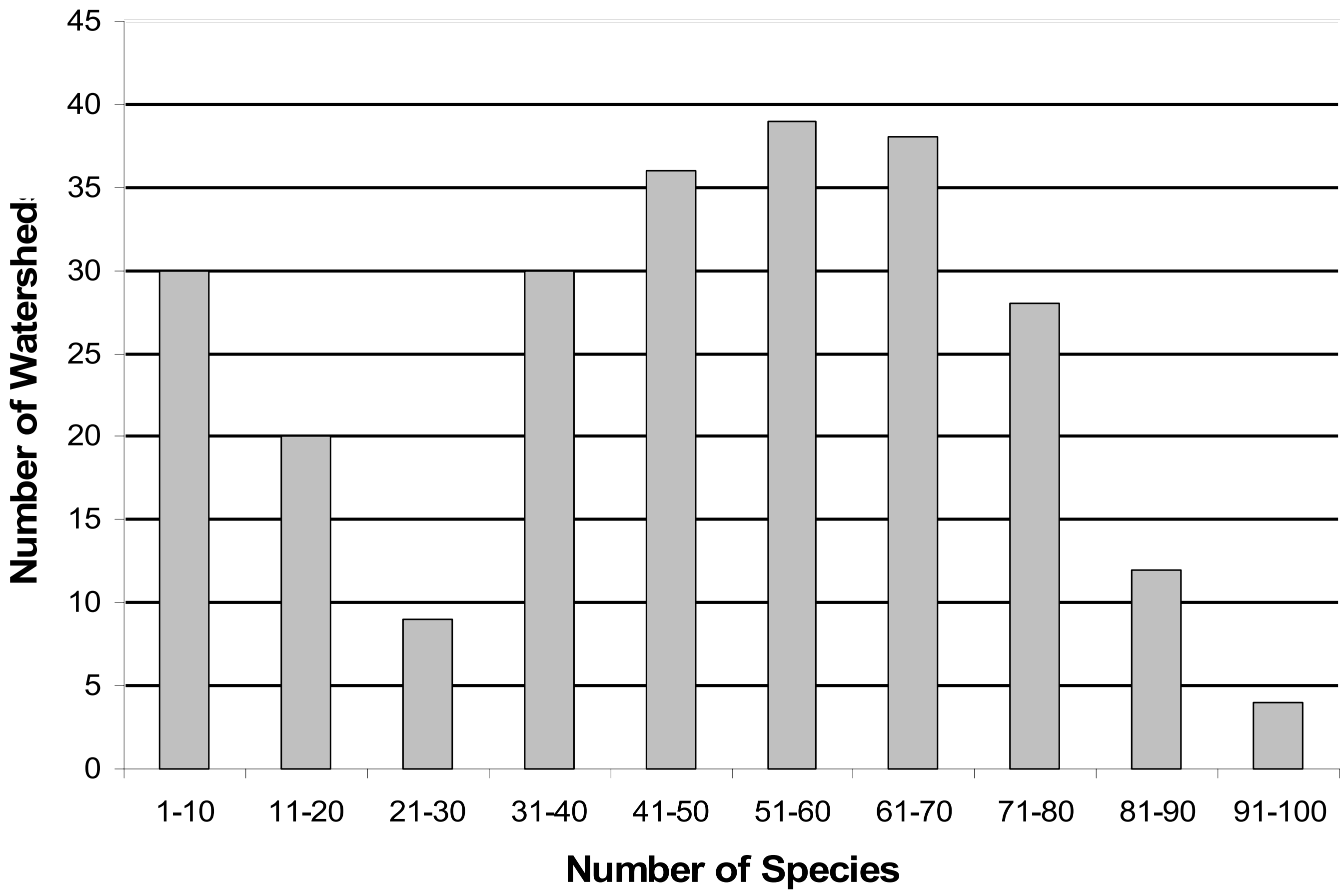
Appendix 1.2. Distribution of locality records in Great Lakes database.



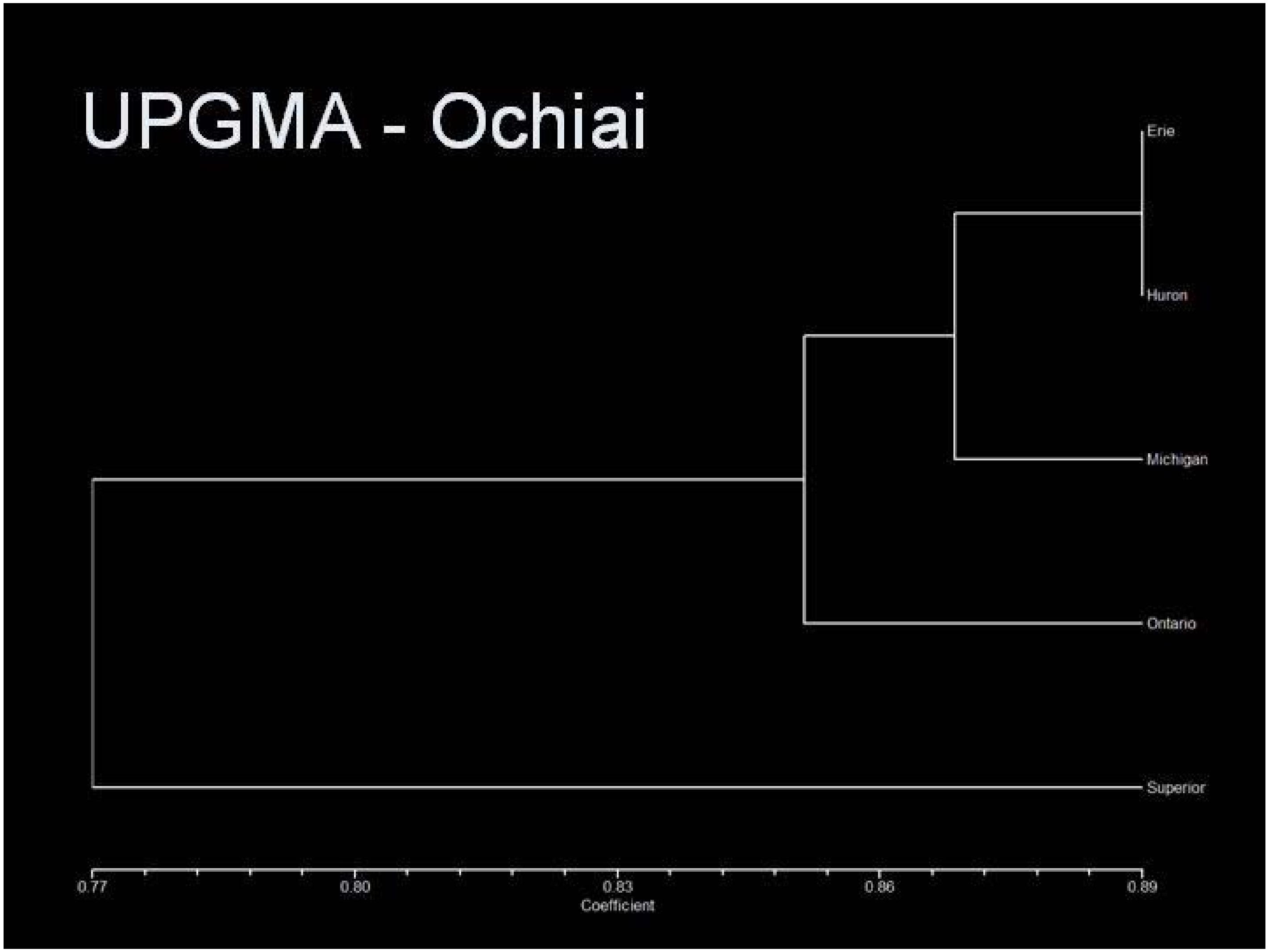
Appendix 1.3. Fish species richness by watershed in the Great Lakes basin.



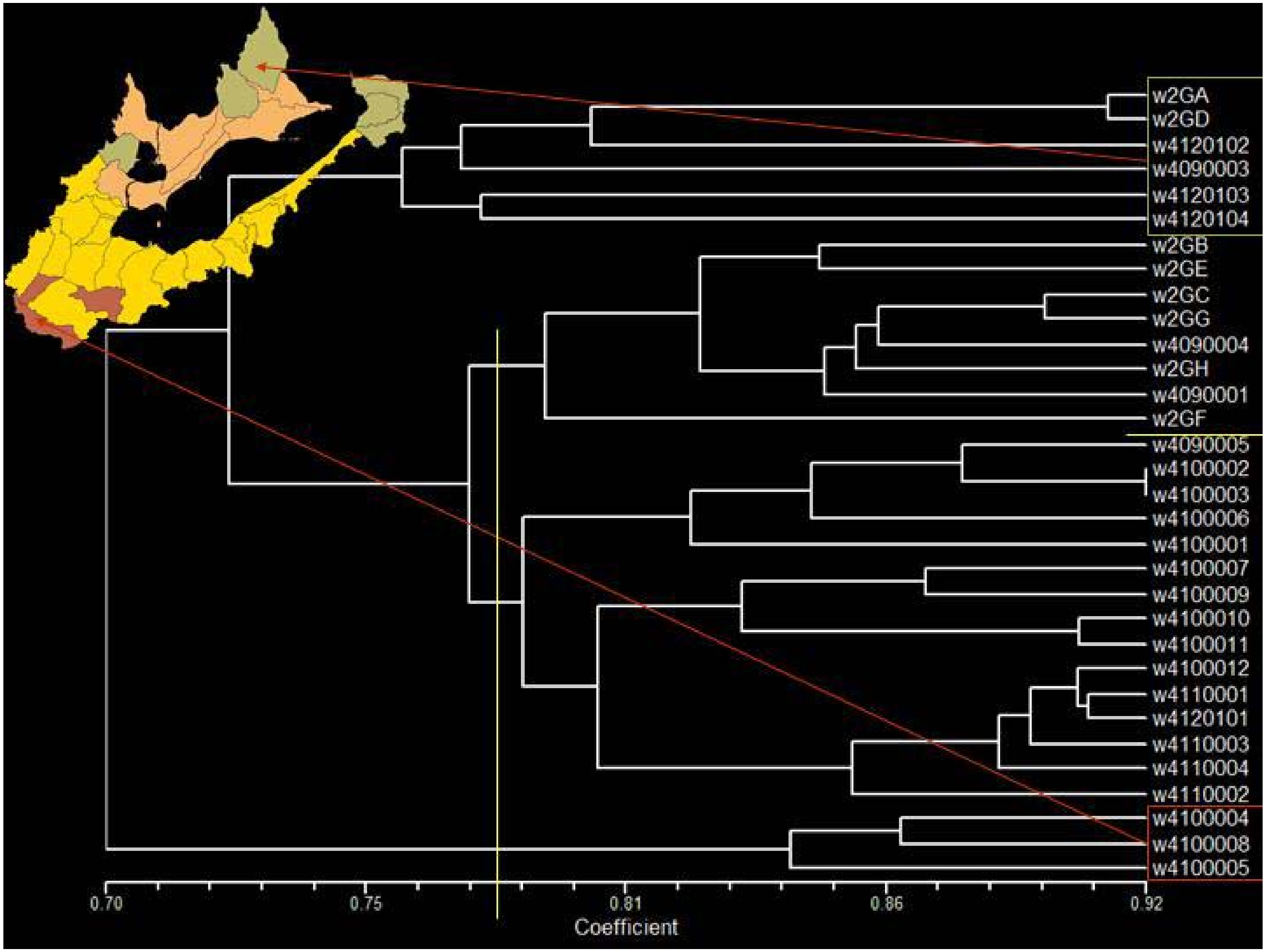
Appendix 1.4. Frequency of occurrence of watersheds by native species richness. Watersheds with less than 20 species are likely underrepresented in the database.

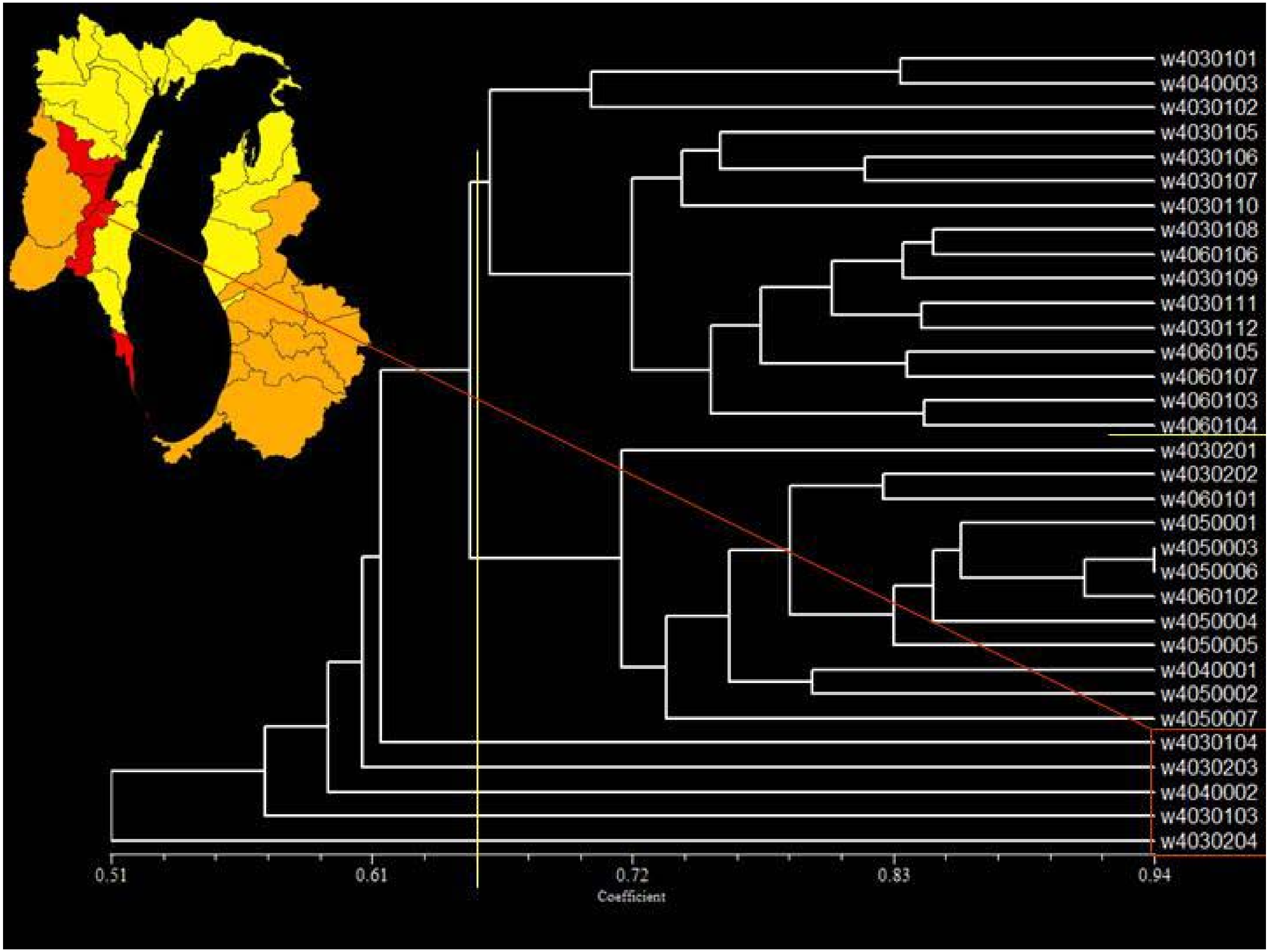


Appendix 1.5. Results of UPGMA cluster analysis of fish species by Great Lakes basin based on the Ochiai similarity coefficient.



Appendix 1.6. Results of UPGMA cluster analysis of fish species by watershed within each of the Great Lakes drainages.

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w4060105
w4060107
w4060103
w4060104
w4030201
w4030202
w4060101
w4050001
w4050003
w4050006
w4060102
w4050004
w4050005
w4040001
w4050002
w4050007
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w4030203
w4040002
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w4030204
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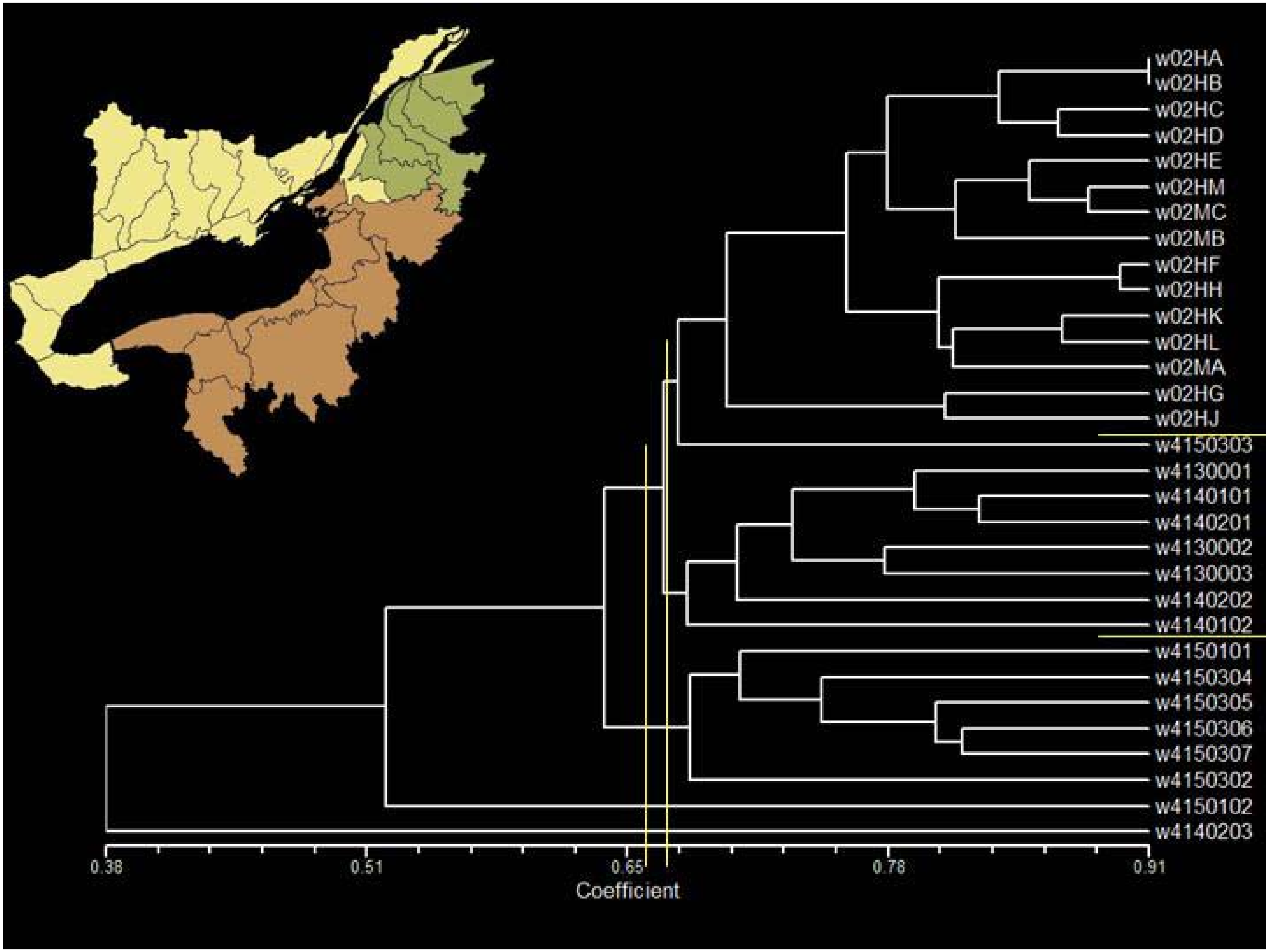
0.61
0.72
0.83
0.94
Coefficient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w02HH
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w02HG
w02HJ
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w4130001
w4140101
w4140201
w4130002
w4130003
w4140202
w4140102
w4150101
w4150304
w4150305
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w4150302
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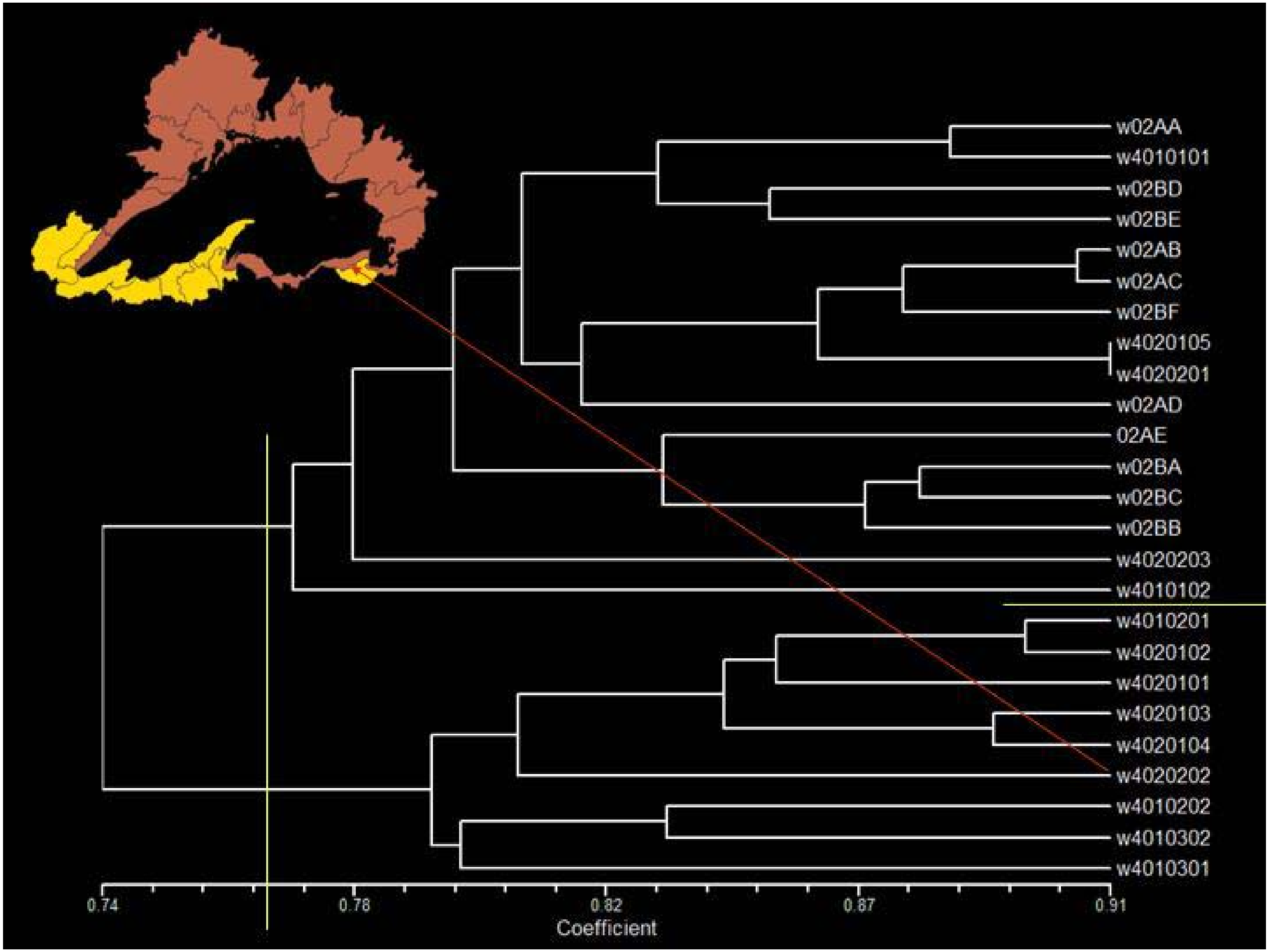
w4140203
0.38
0.51
0.65
0.78
0.91
Coefficient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w4020102
w4020101
w4020103
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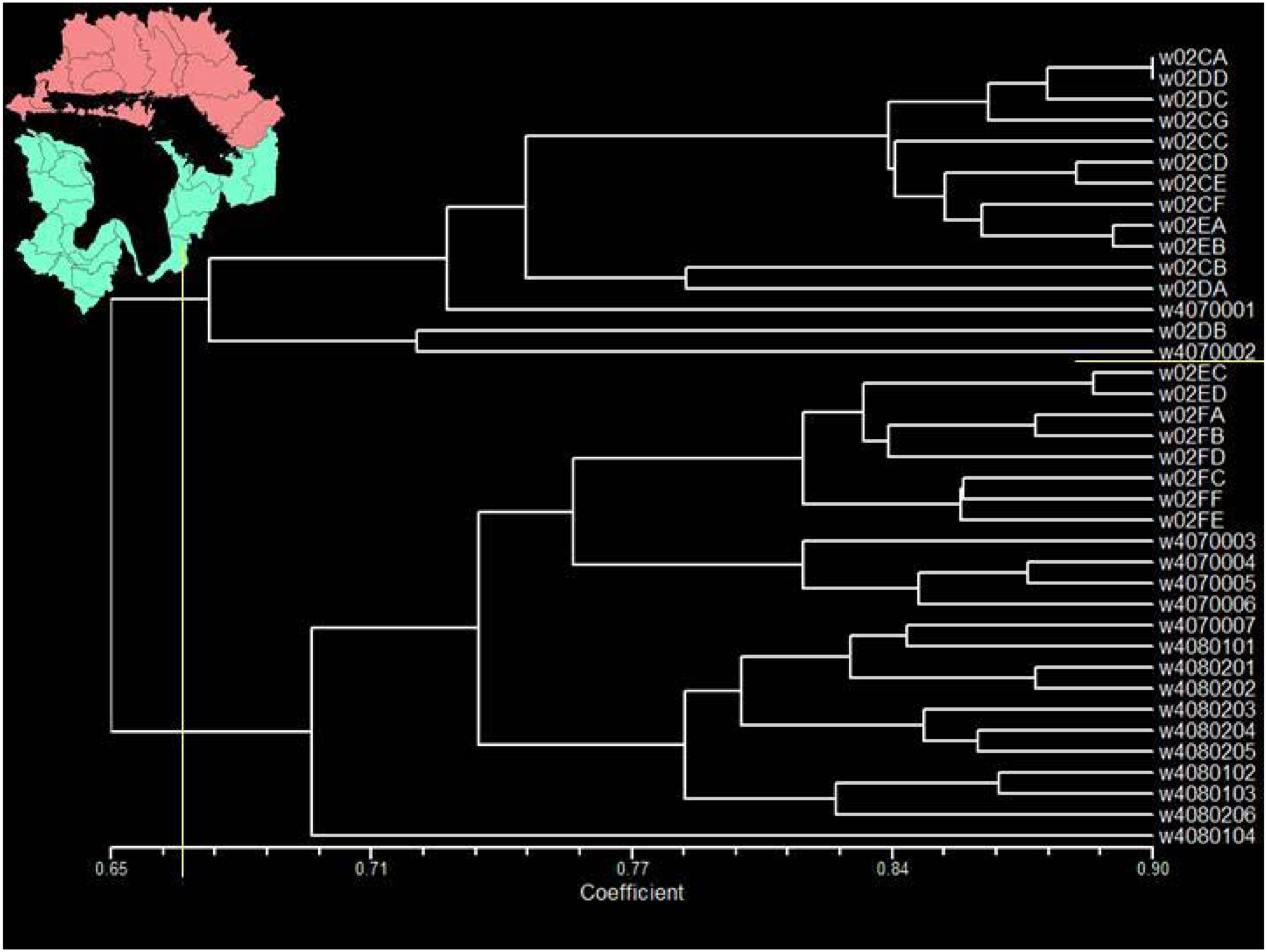
0.87
0.91
Coefficient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w02FE
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w4080102
w4080103
w4080206
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0.77
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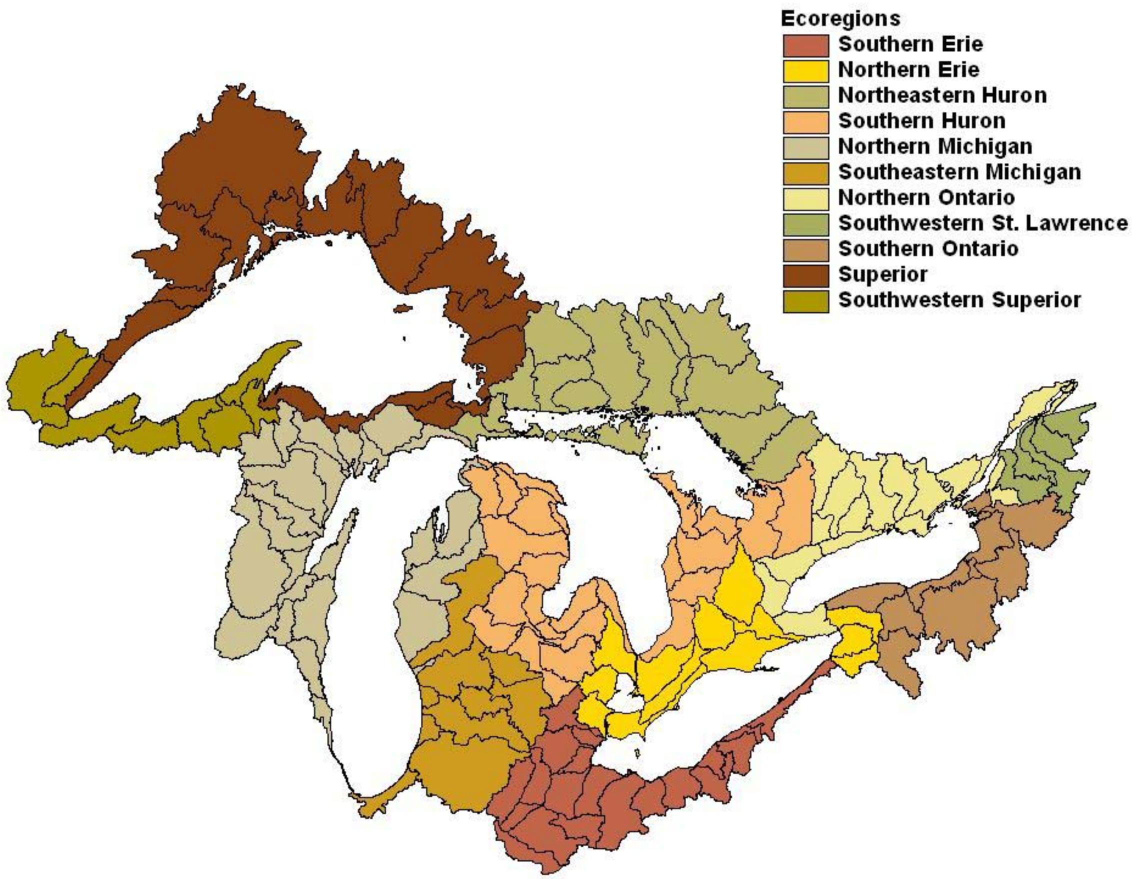
0.90
Coefficient

Appendix 1.7. Fish faunal region classification of the Great Lakes basin based on unconstrained cluster analysis.



Appendix 1.8. Measures of rarity and range edge (0 – no; 1 – yes) by faunal region for each species.

Ecoregion	Northern Erie		Southern Erie		Northeastern Huron		Southern Huron		Southeastern Michigan		Northern Michigan	
Species	Rarity	Range	Rarity	Range	Rarity	Range	Rarity	Range	Rarity	Range	Rarity	Range
Acipenser fulvescens	0.29	0	0.28	0	0.6	0	0.3	0	0.29	0	0.33	0
Alosa pseudoharengus	0.64	0	0.5	0	0.2	0	0.52	0	0.21	0	0.56	0
Ambloplites rupestris	1	0	1	0	1	0	1	0	0.88	0	1	0
Ameiurus catus	0	0	0.11	1	0	0	0	0	0	0	0	0
Ameiurus melas	0.86	0	1	0	0.2	0	0.7	0	0.92	0	0.89	0
Ameiurus natalis	0.93	0	1	0	0.13	0	0.87	0	0.54	0	1	0
Ameiurus nebulosus	1	0	1	0	0.8	0	0.91	0	0.63	0	0.78	0
Amia calva	0.71	0	0.61	0	0.47	0	0.65	0	0.46	0	0.78	0
Ammocrypta clara	0	0	0	0	0	0	0	0	0.13	1	0	0
Ammocrypta pellucida	0.57	0	0.94	0	0	0	0.04	1	0	0	0	0
Anguilla rostrata	0.21	0	0.39	0	0.2	0	0.3	0	0.04	0	0.22	0
Apeltes quadracus	0	0	0	0	0	0	0	0	0	0	0	0
Aphredoderus sayanus	0.07	0	0.06	0	0	0	0.13	1	0.04	1	0.78	1
Aplodinotus grunniens	0.71	0	0.83	0	0.07	0	0.39	0	0.25	0	0.56	0
Campostoma anomalum	0.93	0	1	0	0	0	0.65	1	0.25	1	1	1
Campostoma oligolepis	0	0	0	0	0	0	0	0	0.17	1	0	0
Carassius auratus	0.86	0	0.94	0	0	0	0.22	1	0.04	0	0.44	0
Carpiodes cyprinus	0.86	0	0.89	0	0.13	0	0.52	0	0.08	0	1	0
Carpiodes velifer	0	0	0.06	0	0	0	0	0	0	0	0.11	1
Catostomus catostomus	0.29	0	0	0	0.8	0	0.35	0	0.42	0	0.56	0
Catostomus commersoni	1	0	1	0	1	0	1	0	1	0	1	0
Clinostomus elongatus	0.5	0	0.44	0	0.13	0	0.17	1	0.13	1	0	0
Coregonus artedi	0.36	0	0.17	0	0.87	0	0.7	0	0.5	0	0.89	0
Coregonus clupeaformis	0.36	0	0.17	0	0.8	0	0.26	0	0.13	0	0.33	0
Coregonus nigripinnis	0	0	0	0	0	0	0	0	0	0	0	0
Coregonus zenithicus	0	0	0	0	0	0	0	0	0	0	0	0
Cottus bairdi	0.79	0	0.67	0	0.73	0	0.91	0	0.83	0	1	0
Cottus cognatus	0.5	0	0	0	0.87	0	0.61	0	0.58	0	0.22	0
Cottus ricei	0.14	0	0	0	0.53	0	0.13	0	0.13	0	0	0
Couesius plumbeus	0.07	0	0	0	0.87	0	0.39	0	0.33	0	0.33	0
Ctenopharyngodon idella	0.07	0	0.11	0	0	0	0.04	1	0	0	0.11	1
Culaea inconstans	1	0	0.39	0	1	0	1	0	0.92	0	1	0

Cyprinella analostana	0	0	0	0	0	0	0	0	0	0	0	0
Cyprinella spiloptera	1	0	1	0	0.13	1	0.91	1	0.38	1	0.78	1
Cyprinus carpio	0.93	0	1	0	0.33	0	0.91	0	0.58	0	1	0
Dorosoma cepedianum	0.71	0	1	0	0.2	0	0.83	0	0.17	0	0.67	0
Enneacanthus gloriosus	0	0	0	0	0	0	0	0	0	0	0	0
Erimystax x-punctatus	0.07	0	0	0	0	0	0	0	0	0	0	0
Erimyzon oblongus	0	0	0.39	0	0	0	0	0	0	0	0.22	1
Erimyzon sucetta	0.71	0	0.67	0	0	0	0.26	1	0.08	1	0.78	1
Esox americanus vermiculatus	0	0	0	0	0	0	0	0	0.04	1	1	1
Esox lucius	1	0	0.89	0	1	0	0.96	0	1	0	1	0
Esox masquinongy	0.43	0	0.28	0	0.6	0	0.26	0	0.25	0	0	0
Esox niger	0	0	0	0	0	0	0	0	0	0	0	0
Etheostoma blennioides	0.86	0	1	0	0	0	0.13	1	0	0	0.22	1
Etheostoma caeruleum	0.86	0	0.89	0	0	0	0.91	1	0.13	1	0.89	1
Etheostoma exile	0.93	0	0.56	0	1	0	1	0	0.75	0	0.89	0
Etheostoma flabellare	0.86	0	0.94	0	0.07	0	0.43	0	0.54	1	0.44	1
Etheostoma microperca	0.79	0	0.44	0	0.13	0	0.83	0	0.46	0	0.78	0
Etheostoma nigrum	1	0	1	0	1	0	1	0	1	0	1	0
Etheostoma olmstedi	0	0	0	0	0	0	0	0	0	0	0	0
Etheostoma spectabile	0	0	0.56	0	0	0	0	0	0	0	0.11	1
Etheostoma zonale	0	0	0	0	0	0	0	0	0.21	1	0	0
Exoglossum maxilingua	0	0	0	0	0	0	0	0	0	0	0	0
Fundulus diaphanus	0.64	0	0.44	0	0.47	0	0.78	0	0.58	0	0.67	0
Fundulus dispar	0	0	0	0	0	0	0	0	0	0	0.33	1
Fundulus notatus	0.07	0	0.67	0	0	0	0.04	1	0.13	1	0.56	1
Gambusia affinis	0	0	0.28	1	0	0	0	0	0	0	0	0
Gasterosteus aculeatus	0.29	0	0.06	0	0.07	0	0.22	0	0.13	0	0	0
Gymnocephalus cernuus	0	0	0	0	0	0	0.04	1	0	0	0	0
Hiodon tergisus	0.5	0	0.33	0	0	0	0.04	0	0.04	0	0.11	0
Hybognathus hankinsoni	0.71	0	0	0	0.8	0	0.91	0	0.63	0	0.44	0
Hybognathus regius	0	0	0	0	0	0	0	0	0	0	0	0
Hypentelium nigricans	0.86	0	1	0	0.2	0	0.78	0	0.33	1	0.89	1
Ichthyomyzon castaneus	0	0	0	0	0	0	0	0	0.21	1	0.89	1
Ichthyomyzon fossor	0.5	0	0.22	0	0.13	0	0.61	0	0.33	0	0.67	0
Ichthyomyzon unicuspis	0.57	0	0.5	0	0.33	0	0.57	0	0.21	0	0.33	0
Ictalurus punctatus	0.64	0	1	0	0.4	0	0.61	0	0.17	0	0.89	0
Ictiobus bubalus	0	0	0.72	0	0	0	0	0	0	0	0.11	1

Ictiobus cyprinellus	0.29	0	0.72	0	0	0	0.09	1	0	0	0	0
Ictiobus niger	0.14	0	0.06	0	0	0	0.04	1	0	0	0.44	1
Labidesthes sicculus	0.71	0	1	0	0.13	0	0.3	0	0.17	0	0.89	0
Lampetra appendix	0.57	0	0.44	0	0.13	0	0.57	0	0.5	0	0.78	0
Lepisosteus oculatus	0.36	0	0.17	0	0	0	0	0	0.04	1	0.56	1
Lepisosteus osseus	0.79	0	0.83	0	0.4	0	0.43	0	0.21	0	0.67	0
Lepisosteus platostomus	0	0	0	0	0	0	0	0	0.08	1	0.11	1
Lepomis cyanellus	0.86	0	1	0	0	0	0.7	0	0.75	0	1	0
Lepomis gibbosus	1	0	1	0	0.8	0	0.96	0	0.96	0	1	0
Lepomis gulosus	0.21	0	0.44	0	0	0	0.13	0	0.17	0	0.89	0
Lepomis humilis	0.14	1	0.83	0	0	0	0	0	0	0	0	0
Lepomis macrochirus	1	0	1	0	0.6	0	0.83	0	0.83	0	1	0
Lepomis megalotis	0.86	0	0.94	0	0.07	0	0.74	0	0.25	0	0.89	0
Lepomis microlophus	0	0	0.5	0	0	0	0	0	0	0	0.67	1
Lota lota	0.21	0	0.17	0	0.8	0	0.48	0	0.54	0	0.78	0
Lythrurus umbratilis	0.86	0	0.83	0	0	0	0.52	1	0.17	1	0.44	1
Macrhybopsis storeriana	0.36	1	0.17	0	0	0	0	0	0	0	0	0
Margariscus margarita	0.5	0	0	0	1	0	0.7	0	0.83	0	0.22	0
Micropterus dolomieu	1	0	1	0	0.87	0	1	0	0.92	0	1	0
Micropterus salmoides	1	0	1	0	0.6	0	0.96	0	0.83	0	1	0
Minytrema melanops	0.36	0	0.94	0	0	0	0.04	1	0.04	1	0.67	1
Misgurnus anguillicaudatus	0	0	0	0	0	0	0.04	1	0	0	0	0
Morone americana	0.5	0	0.67	0	0	0	0.26	0	0	0	0	0
Morone chrysops	0.71	0	0.61	0	0.27	0	0.43	0	0.25	0	0.44	0
Morone mississippiensis	0	0	0	0	0	0	0	0	0.08	1	0	0
Morone saxatilis	0	0	0	0	0	0	0	0	0	0	0.11	0
Moxostoma anisurum	1	0	0.83	0	0.4	0	0.61	0	0.42	0	0.89	0
Moxostoma carinatum	0.07	0	0.22	0	0	0	0.04	1	0	0	0.44	1
Moxostoma duquesnei	0.57	0	0.78	0	0	0	0.3	1	0	0	0.67	1
Moxostoma erythrurum	0.86	0	0.94	0	0	0	0.52	1	0.38	0	1	0
Moxostoma macrolepidotum	1	0	0.89	0	0.6	0	0.7	0	0.5	0	1	0
Moxostoma valenciennesi	0.64	0	0.44	0	0.07	0	0.61	0	0.42	0	0.78	0
Myoxocephalus thompsoni	0	0	0	0	0.13	0	0.13	0	0	0	0.11	0
Neogobius melanostomus	0.43	0	0.39	0	0	0	0.09	1	0	0	0	0
Nocomis biguttatus	1	0	0.5	0	0.2	0	0.96	0	0.67	0	1	0
Nocomis micropogon	0.93	0	0.61	0	0.13	0	0.7	0	0	0	0.89	0
Notemigonus crysoleucas	1	0	1	0	0.93	0	0.96	0	0.88	0	1	0

Notropis amblops	0	0	0.61	1	0	0	0	0	0	0	0.22	1
Notropis anogenus	0.5	0	0.22	0	0	0	0.35	0	0.17	1	0.56	1
Notropis atherinoides	0.93	0	0.94	0	0.73	0	0.91	0	0.71	0	0.78	0
Notropis bifrenatus	0	0	0	0	0	0	0	0	0	0	0	0
Notropis blennius	0	0	0	0	0	0	0	0	0.08	1	0	0
Notropis buccatus	0	0	1	1	0	0	0	0	0	0	0.22	1
Notropis buchanani	0.36	0	0.56	0	0	0	0.09	1	0	0	0	0
Notropis chalybaeus	0	0	0	0	0	0	0	0	0	0	0.22	1
Notropis dorsalis	0.21	0	0.06	0	0	0	0	0	0.21	1	0.56	1
Notropis heterodon	0.64	0	0.28	0	0.6	0	0.87	0	0.63	0	0.89	0
Notropis heterolepis	0.93	0	0.61	0	1	0	1	0	0.79	0	0.89	0
Notropis hudsonius	0.86	0	0.72	0	0.87	0	0.83	0	0.75	0	0.78	0
Notropis photogenis	0.29	0	0.61	0	0	0	0.04	1	0	0	0.11	0
Notropis procne	0	0	0	0	0	0	0	0	0	0	0	0
Notropis rubellus	0.86	0	0.72	0	0.33	0	0.91	0	0.58	0	0.89	0
Notropis stramineus	0.86	0	1	0	0.27	0	0.91	0	0.75	0	1	0
Notropis texanus	0	0	0	0	0	0	0.04	1	0.08	1	0.22	1
Notropis volucellus	1	0	0.78	0	0.93	0	0.91	0	0.63	0	0.89	0
Noturus flavus	0.93	0	0.94	0	0	0	0.7	1	0.08	1	0.67	1
Noturus gyrinus	0.71	0	0.72	0	0	0	0.74	1	0.5	0	1	0
Noturus insignis	0	0	0	0	0.07	1	0	0	0	0	0	0
Noturus miurus	0.43	0	0.56	0	0	0	0	0	0	0	0.11	1
Noturus stigmosus	0.29	1	0.06	0	0	0	0	0	0	0	0	0
Oncorhynchus gorbuscha	0.07	0	0	0	0.2	0	0.09	0	0	0	0	0
Oncorhynchus kisutch	0.43	0	0.28	0	0.27	0	0.35	0	0.42	0	0.67	0
Oncorhynchus mykiss	0.79	0	0.5	0	0.87	0	0.78	0	0.71	0	0.78	0
Oncorhynchus nerka	0.07	0	0	0	0.07	0	0.09	0	0	0	0.11	0
Oncorhynchus tshawytscha	0.14	0	0.28	0	0.67	0	0.57	0	0.33	0	0.56	0
Opsopoeodus emiliae	0.29	0	0.67	0	0	0	0	0	0.08	1	0.11	1
Osmerus mordax	0.5	0	0.33	0	0.6	0	0.52	0	0.25	0	0.33	0
Perca flavescens	0.93	0	1	0	1	0	1	0	0.96	0	0.89	0
Percina caprodes	0.93	0	1	0	0.93	0	0.91	0	0.83	0	1	0
Percina copelandi	0.5	0	0.28	0	0	0	0.26	0	0	0	0	0
Percina evides	0	0	0.11	1	0	0	0	0	0	0	0	0
Percina maculata	1	0	1	0	0.07	0	0.96	0	0.75	0	1	0
Percina phoxocephala	0	0	0	0	0	0	0	0	0.08	1	0	0
Percina shumardi	0.14	0	0.17	0	0	0	0.09	0	0.13	1	0	0

Percopsis omiscomaycus	0.79	0	0.56	0	0.93	0	0.52	0	0.46	0	0.33	0
Petromyzon marinus	0.43	0	0.33	0	0.47	0	0.48	0	0.46	0	0.22	0
Phenacobius mirabilis	0	0	0.61	0	0	0	0	0	0	0	0	0
Phoxinus eos	0.71	0	0.06	0	1	0	1	0	0.83	0	0.56	0
Phoxinus erythrogaster	0	0	0.61	1	0	0	0	0	0.25	1	0.11	1
Phoxinus neogaeus	0.29	0	0.06	0	0.93	0	0.65	0	0.58	0	0.22	0
Pimephales notatus	1	0	1	0	0.93	0	1	0	1	0	1	0
Pimephales promelas	1	0	1	0	0.93	0	1	0	0.92	0	1	0
Pimephales vigilax	0	0	0.06	0	0	0	0	0	0.04	1	0	0
Pomoxis annularis	0.64	0	1	0	0.07	0	0.3	0	0.29	0	0.67	0
Pomoxis nigromaculatus	1	0	1	0	0.47	0	0.7	0	0.71	0	1	0
Prosopium cylindraceum	0	0	0	0	0.67	0	0.26	0	0.13	0	0.33	0
Proterorhinus marmoratus	0.29	1	0.17	0	0	0	0	0	0	0	0	0
Pungitius pungitius	0.21	0	0	0	0.73	0	0.43	0	0.25	0	0.56	0
Pylodictis olivaris	0.07	1	0.28	0	0	0	0.04	1	0.17	1	0.56	1
Rhinichthys atratulus	0.71	0	0.78	0	0.67	0	1	0	0.92	0	1	0
Rhinichthys cataractae	0.71	0	0.22	0	0.93	0	0.78	0	0.83	0	0.67	0
Salmo salar	0	0	0	0	0.07	0	0.04	0	0	0	0	0
Salmo trutta	0.79	0	0.33	0	0.53	0	0.74	0	0.71	0	1	0
Salvelinus fontinalis	0.71	0	0.22	0	1	0	0.83	0	0.71	0	0.89	0
Salvelinus namaycush	0.14	0	0	0	0.87	0	0.26	0	0.21	0	0.44	0
Scardinius erythrophthalmus	0	0	0	0	0	0	0	0	0	0	0	0
Semotilus atromaculatus	1	0	1	0	1	0	1	0	0.96	0	1	0
Semotilus corporalis	0	0	0	0	0	0	0	0	0	0	0	0
Stizostedion canadense	0.43	0	0.56	0	0.33	0	0.09	0	0.17	0	0.11	0
Stizostedion vitreum	1	0	0.83	0	0.8	0	0.87	0	0.54	0	0.89	0
Thymallus arcticus	0	0	0	0	0	0	0.09	1	0	0	0	0
Umbra limi	1	0	0.83	0	0.87	0	1	0	0.92	0	1	0
Ecoregion	Northern Ontario		Southern Ontario		Southwestern St. Lawrence		Southwestern Superior		Superior			
Species	Rarity	Range	Rarity	Range	Rarity	Range	Rarity	Range	Rarity	Range		
Acipenser fulvescens	0.5	0	0.2	0	0	0	0.47	1	0.38	0		
Alosa pseudoharengus	0.56	0	0.6	0	0.4	0	0.53	1	0	0		
Ambloplites rupestris	1	0	0.8	0	1	0	0.76	1	1	0		
Ameiurus catus	0	0	0	0	0	0	0	0	0	0		
Ameiurus melas	0.25	0	0.8	0	0.2	0	0.29	1	0.88	0		
Ameiurus natalis	0.81	0	0	0	0	0	0	0	0	0		

Ameiurus nebulosus	1	0	0.7	0	1	0	0.35	1	0.5	0		
Amia calva	0.63	0	0.1	0	0.4	0	0	0	0	0		
Ammocrypta clara	0	0	0	0	0	0	0	0	0	0		
Ammocrypta pellucida	0.06	1	0.4	0	0.2	0	0	0	0	0		
Anguilla rostrata	0.81	0	0.6	0	0.6	0	0.18	1	0.13	0		
Apeltes quadracus	0	0	0	0	0	0	0.06	1	0	0		
Aphredoderus sayanus	0	0	0.3	1	0	0	0	0	0	0		
Aplodinotus grunniens	0.44	0	0.1	0	0.2	0	0	0	0.13	1		
Campostoma anomalum	0.13	0	0.3	0	0.2	0	0	0	0	0		
Campostoma oligolepis	0	0	0	0	0	0	0	0	0	0		
Carassius auratus	0.25	0	0.9	0	0	0	0	0	0	0		
Carpiodes cyprinus	0.31	0	0.6	0	0	0	0.06	1	0	0		
Carpiodes velifer	0	0	0	0	0	0	0	0	0	0		
Catostomus catostomus	0.69	0	0.6	0	0.8	0	1	1	0.88	0		
Catostomus commersoni	1	0	0.3	0	1	0	1	1	1	0		
Clinostomus elongatus	0.31	0	0.4	0	0	0	0	0	0.13	1		
Coregonus artedi	0.81	0	0.4	0	0.4	0	0.94	1	0.63	0		
Coregonus clupeaformis	0.75	0	0	0	0.4	0	0.88	1	0.13	0		
Coregonus nigripinnis	0	0	0	0	0	0	0.06	1	0	0		
Coregonus zenithicus	0	0	0	0	0	0	0.06	1	0	0		
Cottus bairdi	0.94	0	0.6	0	0.2	0	1	1	1	0		
Cottus cognatus	0.75	0	0.1	0	1	0	0.94	1	0.75	0		
Cottus ricei	0.13	0	0.8	0	0	0	0.29	1	0	0		
Couesius plumbeus	0.69	0	0.2	0	0.8	0	0.88	1	0.5	0		
Ctenopharyngodon idella	0.06	0	0.6	0	0	0	0	0	0	0		
Culaea inconstans	1	0	0.7	0	0.6	0	1	1	1	0		
Cyprinella analostana	0	0	0.6	1	0	0	0	0	0	0		
Cyprinella spiloptera	0.69	0	0.1	0	0.6	0	0	0	0	0		
Cyprinus carpio	0.88	0	0.7	0	0.6	0	0.41	1	0.13	0		
Dorosoma cepedianum	0.5	0	0.2	0	0	0	0.18	1	0	0		
Enneacanthus gloriosus	0	0	0.4	1	0	0	0	0	0	0		
Erimystax x-punctatus	0	0	0	0	0	0	0	0	0	0		
Erimyzon oblongus	0	0	0.8	1	0	0	0	0	0	0		
Erimyzon sucetta	0.06	1	0.1	0	0	0	0	0	0	0		
Esox americanus vermiculatus	0	0	0	0	0	0	0	0	0	0		
Esox lucius	0.88	0	0.4	0	0.6	0	1	1	1	0		
Esox masquinongy	0.94	0	0.3	0	0.6	0	0.29	1	0.5	0		

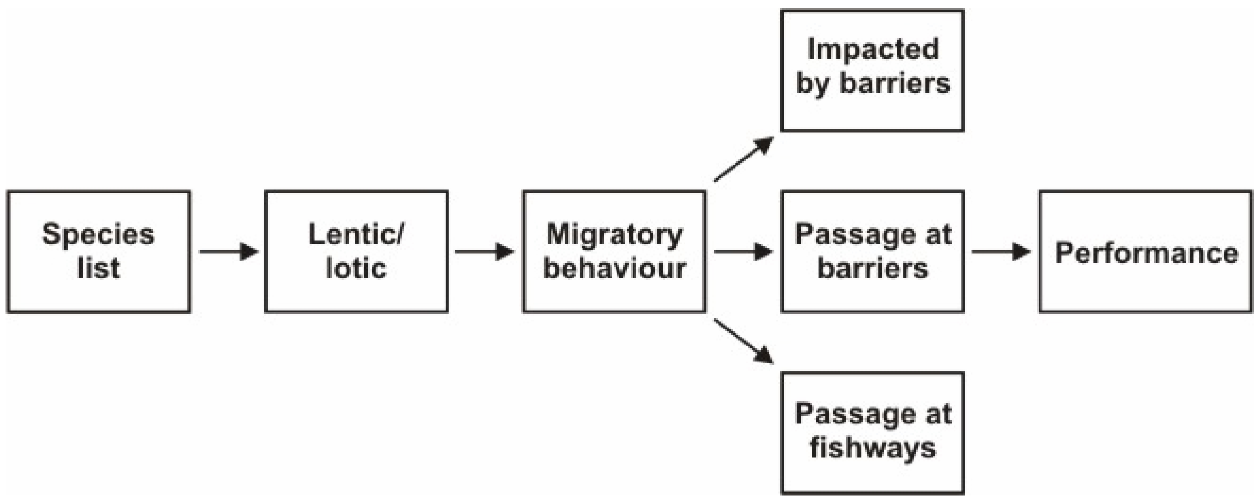
Esox niger	0.06	1	0.7	0	0.2	0	0	0	0	0		
Etheostoma blennioides	0	0	0.8	0	0	0	0	0	0	0		
Etheostoma caeruleum	0.31	1	0	0	0	0	0	0	0	0		
Etheostoma exile	1	0	0.4	0	0	0	0.94	1	1	0		
Etheostoma flabellare	0.75	0	0.9	0	0.8	0	0	0	0	0		
Etheostoma microperca	0.25	0	0.8	0	0	0	0.18	1	0.13	0		
Etheostoma nigrum	0.88	0	0.7	0	0.8	0	0.88	1	1	0		
Etheostoma olmstedi	0.69	1	0	0	0.6	0	0	0	0	0		
Etheostoma spectabile	0	0	0	0	0	0	0	0	0	0		
Etheostoma zonale	0	0	0	0	0	0	0	0	0	0		
Exoglossum maxilingua	0.13	1	0.4	0	1	0	0	0	0	0		
Fundulus diaphanus	1	0	0	0	0.4	0	0.06	1	0	0		
Fundulus dispar	0	0	0	0	0	0	0	0	0	0		
Fundulus notatus	0.06	1	0.3	0	0	0	0	0	0	0		
Gambusia affinis	0	0	0	0	0	0	0	0	0	0		
Gasterosteus aculeatus	0.44	0	0.5	0	0.2	0	0.18	1	0.13	0		
Gymnocephalus cernuus	0	0	0	0	0	0	0.12	1	0.38	0		
Hiodon tergisus	0.38	0	0.7	0	0.2	0	0	0	0	0		
Hybognathus hankinsoni	0.94	0	0	0	1	0	0.47	1	0.88	0		
Hybognathus regius	0.31	0	0.1	0	0.2	0	0	0	0	0		
Hypentelium nigricans	0.56	0	0.2	0	0	0	0	0	0	0		
Ichthyomyzon castaneus	0	0	0	0	0	0	0	0	0	0		
Ichthyomyzon fossor	0.19	0	0	0	0	0	0.47	1	0.38	0		
Ichthyomyzon unicuspis	0.25	0	0	0	0	0	0.41	1	0.5	0		
Ictalurus punctatus	0.63	0	0.5	0	0	0	0	0	0.25	1		
Ictiobus bubalus	0	0	0	0	0	0	0	0	0	0		
Ictiobus cyprinellus	0.13	1	0.2	0	0	0	0	0	0	0		
Ictiobus niger	0.06	1	0	0	0	0	0	0	0	0		
Labidesthes sicculus	0.63	0	0.5	0	0	0	0.12	1	0	0		
Lampetra appendix	0.31	0	0	0	0	0	0.47	1	0.13	0		
Lepisosteus oculatus	0.06	1	0	0	0	0	0	0	0	0		
Lepisosteus osseus	0.56	0	0.6	0	0.4	0	0.06	1	0	0		
Lepisosteus platostomus	0	0	0	0	0	0	0	0	0	0		
Lepomis cyanellus	0.31	0	0.1	0	0	0	0.06	1	0.25	0		
Lepomis gibbosus	1	0	0.3	0	1	0	0.47	1	1	0		
Lepomis gulosus	0	0	0	0	0	0	0	0	0	0		
Lepomis humilis	0	0	0	0	0	0	0	0	0	0		

Lepomis macrochirus	1	0	0.3	0	0.2	0	0.29	1	0.63	0		
Lepomis megalotis	0.19	0	0.8	0	0	0	0	0	0	0		
Lepomis microlophus	0	0	0	0	0	0	0	0	0	0		
Lota lota	0.81	0	0.1	0	0.2	0	1	1	1	0		
Lythrurus umbratilis	0.13	0	0.9	0	0	0	0	0	0	0		
Macrhybopsis storeriana	0	0	0	0	0	0	0	0	0	0		
Margariscus margarita	0.94	0	0.3	0	1	0	1	1	0.88	0		
Micropterus dolomieu	1	0	0.6	0	1	0	0.82	1	0.75	0		
Micropterus salmoides	1	0	0	0	0.8	0	0.29	1	1	0		
Ecoregion	Northern Ontario		Southern Ontario		Southwestern St. Lawrence		Southwestern Superior		Superior			
Species	Rarity	Range	Rarity	Range	Rarity	Range	Rarity	Range	Rarity	Range		
Minytrema melanops	0	0	0	0	0	0	0	0	0	0		
Misgurnus anguillicaudatus	0	0	0	0	0	0	0	0	0	0		
Morone americana	0.63	0	0.2	0	0	0	0.06	1	0.13	0		
Morone chrysops	0.5	0	0	0	0	0	0	0	0	0		
Morone mississippiensis	0	0	0	0	0	0	0	0	0	0		
Morone saxatilis	0	0	0	0	0	0	0	0	0	0		
Moxostoma anisurum	0.63	0	0.4	0	0.6	0	0.29	1	0.38	0		
Moxostoma carinatum	0.19	1	0.5	0	0	0	0	0	0	0		
Moxostoma duquesnei	0.06	0	0.4	0	0	0	0	0	0	0		
Moxostoma erythrurum	0.13	0	0.1	0	0	0	0	0	0	0		
Moxostoma macrolepidotum	0.56	0	0	0	0.8	0	0.41	1	1	0		
Moxostoma valenciennesi	0.56	0	0.5	0	0.4	0	0	0	0	0		
Myoxocephalus thompsoni	0.25	0	0.3	0	0	0	0.35	1	0	0		
Neogobius melanostomus	0.06	0	0.9	0	0	0	0	0	0	0		
Nocomis biguttatus	0.44	0	0.1	0	0	0	0.12	1	0.88	0		
Nocomis micropogon	0.31	0	0.1	0	0	0	0	0	0	0		
Notemigonus crysoleucas	1	0	0.7	0	1	0	0.71	1	1	0		
Notropis amblops	0	0	0.8	1	0	0	0	0	0	0		
Notropis anogenus	0.06	1	0.2	0	0	0	0	0	0.13	1		
Notropis atherinoides	0.75	0	0.4	0	0.2	0	0.88	1	0.63	0		
Notropis bifrenatus	0.38	1	0.8	0	0.8	0	0	0	0	0		
Notropis blennius	0	0	0	0	0	0	0	0	0	0		
Notropis buccatus	0	0	0	0	0	0	0	0	0	0		
Notropis buchanani	0	0	0	0	0	0	0	0	0	0		
Notropis chalybaeus	0	0	0	0	0	0	0	0	0	0		

Notropis dorsalis	0	0	0.4	1	0	0	0	0	0.25	1		
Notropis heterodon	0.88	0	0	0	0	0	0.35	1	0.13	0		
Notropis heterolepis	0.94	0	0.1	0	0.6	0	1	1	1	0		
Notropis hudsonius	1	0	0.5	0	0.2	0	0.88	1	0.75	0		
Notropis photogenis	0.06	0	0.7	0	0	0	0	0	0	0		
Notropis procne	0	0	0.6	1	0	0	0	0	0	0		
Notropis rubellus	0.5	0	0.8	0	0.8	0	0.06	1	0	0		
Notropis stramineus	0.56	0	0.7	0	0.2	0	0.24	1	0.63	0		
Notropis texanus	0	0	0	0	0	0	0	0	0	0		
Notropis volucellus	0.69	0	0.2	0	0.8	0	0.59	1	0.75	0		
Noturus flavus	0.56	0	0.4	0	0.6	0	0	0	0.13	1		
Noturus gyrinus	0.56	0	0	0	0.2	0	0.06	1	0.38	0		
Noturus insignis	0.06	1	0.3	0	0.2	0	0	0	0	0		
Noturus miurus	0	0	0.8	0	0	0	0	0	0	0		
Noturus stigmosus	0	0	0	0	0	0	0	0	0	0		
Oncorhynchus gorbuscha	0.13	0	0.4	0	0	0	0.59	1	0.25	0		
Oncorhynchus kisutch	0.38	0	0.1	0	0	0	0.65	1	0.38	0		
Oncorhynchus mykiss	0.88	0	0.4	0	1	0	1	1	0.88	0		
Oncorhynchus nerka	0	0	0	0	0	0	0	0	0	0		
Oncorhynchus tshawytscha	0.38	0	1	0	0	0	0.53	1	0.38	0		
Ecoregion	Northern Ontario		Southern Ontario		Southwestern St. Lawrence		Southwestern Superior		Superior			
Species	Rarity	Range	Rarity	Range	Rarity	Range	Rarity	Range	Rarity	Range		
Opsopoeodus emiliae	0	0	0	0	0	0	0	0	0	0		
Osmerus mordax	0.69	0	0	0	0.8	0	0.76	1	0.13	0		
Perca flavescens	1	0	0.6	0	1	0	1	1	1	0		
Percina caprodes	1	0	0.6	0	0.6	0	0.82	1	0.88	0		
Percina copelandi	0.13	0	0.7	0	0.6	0	0	0	0	0		
Percina evides	0	0	0	0	0	0	0	0	0	0		
Percina maculata	0.19	0	0.3	0	0	0	0.18	1	0	0		
Percina phoxocephala	0	0	0	0	0	0	0	0	0.13	1		
Percina shumardi	0	0	0	0	0	0	0	0	0	0		
Percopsis omiscomaycus	0.81	0	0.2	0	0.2	0	1	1	0.88	0		
Petromyzon marinus	0.56	0	0.9	0	0	0	0.82	1	0.63	0		
Phenacobius mirabilis	0	0	0	0	0	0	0	0	0	0		
Phoxinus eos	0.94	0	0.6	0	1	0	0.94	1	1	0		
Phoxinus erythrogaster	0	0	0	0	0	0	0	0	0	0		

Phoxinus neogaeus	0.81	0	0.1	0	1	0	0.94	1	1	0		
Pimephales notatus	1	0	0.6	0	1	0	0.76	1	0.88	0		
Pimephales promelas	0.94	0	0.1	0	1	0	1	1	0.88	0		
Pimephales vigilax	0	0	0	0	0	0	0	0	0	0		
Pomoxis annularis	0.31	0	0.2	0	0	0	0	0	0.13	1		
Pomoxis nigromaculatus	0.81	0	0.1	0	0.2	0	0.18	1	0.88	0		
Prosopium cylindraceum	0.44	0	0.9	0	0.8	0	0.71	1	0.13	0		
Proterorhinus marmoratus	0	0	0	0	0	0	0	0	0	0		
Pungitius pungitius	0.38	0	0.9	0	0	0	0.94	1	0.25	0		
Pylodictis olivaris	0	0	0	0	0	0	0	0	0	0		
Rhinichthys atratulus	0.88	0	0.9	0	0.2	0	0.94	1	1	0		
Rhinichthys cataractae	0.81	0	0.7	0	0.8	0	1	1	1	0		
Salmo salar	0.31	0	0.5	0	0.4	0	0	0	0	0		
Salmo trutta	0.81	0	0	0	0.8	0	0.71	1	1	0		
Salvelinus fontinalis	0.94	0	0.8	0	1	0	1	1	1	0		
Salvelinus namaycush	0.81	0	0.5	0	1	0	0.88	1	0	0		
Scardinius erythrophthalmus	0.06	1	0	0	0	0	0	0	0	0		
Semotilus atromaculatus	1	0	0.8	0	1	0	0.88	1	1	0		
Semotilus corporalis	0.88	1	1	0	1	0	0.12	1	0	0		
Stizostedion canadense	0.44	0	0	0	0	0	0.24	1	0.25	0		
Stizostedion vitreum	0.88	0	0	0	0.2	0	1	1	1	0		
Thymallus arcticus	0	0	0	0	0	0	0.12	1	0.13	0		
Umbra limi	1	0	0	0	1	0	0.65	1	1	0		

Appendix 1.9. Components of the migration and passage knowledge base for Great Lakes stream fishes.



Appendix 1.9. Identification of species sensitive to low-head barriers based on three measures of sensitivity. Lower and upper 95% confidence limits are provided in brackets for each measure. A value of 1 indicates the distribution of a species above and below real barriers on barrier streams is the same as the distribution of that species above and below hypothetical barrier locations on reference streams. Values appearing in bold differ significantly from 1.

Common Name	Scientific Name	CPUE Ratio	Odds Ratio	Common Odds Ratio	Occurrence	
					stream pairs	both streams of pair
Striped shiner	*Luxilus chrysocephalus*	0 (0 - >999)	0 (0 - 6.65)	-	2	0
Northern redbelly dace	*Phoxinus eos*	0 (0 - >999)	**0** (0 - 0.11)	**0** (0 - 0.46)	10	2
Iowa darter	*Etheostoma exile*	0 (0 - >999)	0 (0 - 4.99)	-	3	0
Sea lamprey	*Petromyzon marinus*	0 (0 - >999)	**0** (0 - 0.48)	**0** (0 - 0.69)	11	3
Yellow perch	*Perca flavescens*	0 (0 - >999)	**0** (0 - 0.68)	**0** (0 - 0.52)	9	2
Trout-perch	*Percopsis omiscomaycus*	0 (0 - >999)	0 (0 - 8.06)	0 (0 - 29.0)	4	1
Fathead minnow	*Pimephales promelas*	**0.02** (0.00 - 0.15)	**0.02** (0 - 0.16)	**0.07** (0 - 0.79)	9	2
Northern pike	*Esox lucius*	**0.05** (0.01 - 0.35)	**0.05** (0.01 - 0.41)	0 (0 - 4.99)	9	1
Logperch	*Percina caprodes*	**0.09** (0.03 - 0.25)	**0.09** (0.03 - 0.26)	**0.05** (0 - 0.23)	17	7
Pearl dace	*Margariscus margarita*	0.14 (0.01 - 1.42)	0.14 (0.01 - 1.31)	-	6	0
Fallfish	*Semotilus corporalis*	0.17 (0.01 - 2.82)	0.17 (0.01 - 3.17)	0.17 (0.01 - 3.17)	1	1
Northern hog sucker	*Hypentelium nigricans*	0.19 (0.02 - 2.21)	0.19 (0.01 - 2.60)	0.67 (0.01 - 11.6)	3	2
Largemouth bass	*Micropterus salmoides*	0.19 (0.02 - 2.25)	0.19 (0.01 - 2.28)	0.11 (0.00 - 3.19)	4	1
Cutlips minnow	*Exoglossum maxilingua*	**0.24** (0.08 - 0.77)	**0.24** (0.07 - 0.82)	**0.24** (0.07 - 0.82)	1	1
Central mudminnow	*Umbra limi*	**0.27** (0.17 - 0.43)	**0.26** (0.17 - 0.42)	1.45 (0.76 - 3.20)	19	12
Common carp	*Cyprinus carpio*	0.39 (0.09 - 1.68)	0.31 (0.07 - 1.47)	1.80 (0.15 - 94.19)	5	2
Longnose dace	*Rhinichthys cataractae*	**0.44** (0.37 - 0.52)	**0.44** (0.37 - 0.52)	**0.82** (0.63 - 0.97)	23	16
Brook stickleback	*Culaea inconstans*	0.47 (0.21 - 1.02)	0.47 (0.21 - 1.02)	**0.28** (0.07 - 0.92)	17	4
Rosyface shiner	*Notropis rubellus*	0.58 (0.21 - 1.59)	0.58 (0.21 - 1.63)	-	4	0
American brook lamprey	*Lampetra appendix*	0.69 (0.23 - 2.09)	0.69 (0.23 - 2.13)	**10.5** (1.09 - 254)	6	1
Rock bass	*Ambloplites rupestris*	0.70 (0.45 - 1.09)	0.72 (0.46 - 1.15)	**0.36** (0.16 - 0.59)	22	10

Coho salmon	*Oncorhynchus kisutch*	0.73 (0.17 - 3.14)	0.73 (0.16 - 3.61)	-	4	0
Mottled sculpin	*Cottus bairdi*	**0.80** (0.67 - 0.96)	**0.80** (0.67 - 0.96)	**0.80** (0.60 - 0.94)	21	17
White sucker	*Catostomus commersoni*	0.83 (0.57 - 1.21)	0.84 (0.56 - 1.24)	**0.60** (0.35 - 0.99)	22	16
Common shiner	*Notropis cornutus*	0.87 (0.62 - 1.23)	0.87 (0.62 - 1.24)	**0.45** (0.24 - 0.72)	16	10
Smallmouth bass	*Micropterus dolomieui*	0.89 (0.15 - 5.27)	0.89 (0.15 - 7.19)	>999 (0.14 - >999)	8	1
Blacknose dace	*Rhinichthys atratulus*	0.98 (0.83 - 1.16)	1.00 (0.84 - 1.18)	**1.35** (1.16 - 1.73)	22	15
Rainbow darter	*Etheostoma caeruleum*	1.00 (0.55 - 1.82)	1.00 (0.53 - 1.83)	1.02 (0.55 - 1.91)	2	2
Stonecat	*Noturus flavus*	1.10 (0.13 - 9.32)	1.10 (0.10 - 11.9)	-	4	0
Creek chub	*Semotilus atromaculatus*	1.13 (0.89 - 1.42)	1.16 (0.91 - 1.47)	**1.5** (1.22 - 2.25)	23	17
Johnny darter	*Etheostoma nigrum*	1.22 (0.92 - 1.61)	1.29 (0.96 - 1.72)	**1.91** (1.45 - 3.30)	22	15
Pumpkinseed	*Lepomis gibbosus*	1.23 (0.38 - 3.97)	1.21 (0.36 - 4.00)	0.02 (0.00 - 1.33)	15	3
Blackside darter	*Percina maculata*	1.23 (0.33 - 4.52)	1.23 (0.32 - 4.83)	2.18 (0.43 - 24.2)	9	2
Rainbow trout	*Oncorhynchus mykiss*	**1.27** (1.02 - 1.57)	**1.27** (1.02 - 1.58)	**1.38** (1.02 - 2.05)	21	16
Bluntnose minnow	*Pimephales notatus*	1.39 (0.46 - 4.19)	1.39 (0.46 - 4.34)	>999 (0.75 - >999)	12	1
Brown trout	*Salmo trutta*	1.70 (0.67 - 4.30)	1.70 (0.66 - 4.38)	1.80 (0.29 - 15.3)	13	2
Fantail darter	*Etheostoma flabellare*	**1.85** (1.20 - 2.86)	**1.85** (1.18 - 2.88)	**2.49** (1.56 - 4.07)	4	3
Hornyhead chub	*Nocomis biguttatus*	**2.45** (1.49 - 4.05)	**2.45** (1.48 - 4.07)	**4.07** (1.94 - 7.85)	9	2
Spotfin shiner	*Cyprinella spilopterus*	3.07 (0.27 - 35.3)	3.07 (0.10 - 33.3)	7 (0.15 - 276)	3	1
Brassy minnow	*Hybognathus hankinsoni*	3.49 (0.72 - 17.1)	**7.00** (1.12 - 43.6)	-	10	0
Brook trout	*Salvelinus fontinalis*	**3.70** (1.45 - 9.48)	**3.70** (1.40 - 9.50)	0 (0 - 57)	12	1
Blacknose shiner	*Notropis heterolepis*	**5.24** (1.07 - 25.6)	5.25 (0.91 - 27.9)	1.7 (0.25 - 23.9)	7	3
Bluegill	*Lepomis macrochirus*	6.00 (0.94 - 38.5)	6.00 (0.81 - 40.4)	-	5	0
Black bullhead	*Ameiurus melas*	**188** (26.5 - >999)	**189** (24.8 - >999)	-	-	0
Black crappie	*Pomoxis nigromaculatus*	667 (0 - >999)	>999 (0.03 - >999)	-	-	0
Brown bullhead	*Ameiurus nebulosus*	>999 (0 - >999)	>999 (0.20 - >999)	-	4	0
Blackchin shiner	*Notropis heterodon*	>999 (0 - >999)	**>999** (10.5 - >999)	-	4	0
Greater redhorse	*Moxostoma valenciennesi*	>999 (0 - >999)	>999 (0.5 - >999)	-	2	0

Appendix 2. List of participants at Planning Workshop held in Ann Arbor, 18-20 June, 2001.

Jones, Mike, MSU
Mandrak, Nick, Youngstown State University
McLaughlin, Rob , Guelph
Carl, Leon, OMNR
Christie, Gavin , GLFC
DeKerckhove, Derrick , Guelph
Eshenroder, Randy, GLFC
Fago, Don, WDNR
Goddard, Chris, GLFC
Hallett, Andrew, DFO
Hayes, Dan, MSU
Jackson, Don, Toronto
Krueger, Chuck, GLFC
Lavis, Denis, USFWS
Newman, Kurt
Noble, Josh, Youngstown State University
O'Connor, Lisa, DFO
Stanfield, Les, OMNR
Weise, Jerry, SLCC

Appendix 3. Sampling Protocol

STANDARDIZED FIELD SAMPLING PROTOCOL

I. Stream and Site Delineation

Delineate the target watershed using 1:50,000 scale topographical maps and assign orders to all streams using the Strahler Method. Categorize streams by order as follows: Group I includes first order streams; Group II includes second order streams; Group III includes third order streams; and Group IV includes fourth and higher order streams. A "stretch" of stream refers to a continuous length of channel of the same order.

After assigning order and group type to all stretches of the stream, randomly select nine stretches of stream from each group. Partition long stretches so that they are not underrepresented in the random selection process. Within each of these selected nine stretches, determine all apparent access points on the map and randomly select one access point at which to conduct sampling. If the access point is unusable, sample at the nearest access point on the same stretch or if there are no other access points on that stretch, the nearest stretch of the same order. Plan to conduct sampling at the first six access points selected and sample at the remaining three if further sampling is needed to detect all species.

A reach refers to the section of stream to be sampled at an access point. Aim to sample at least 6 reaches per Group. Each reach should be a minimum of 30 stream widths in length. Subdivide Group I and II reaches in to 20 sample units of 3 streams widths each in length and subdivide Group III and IV reaches in to 20 sample units of 1.5 stream widths in length. If two consecutive sample units yield no new species, skip the third sample unit and resume sampling on the fourth and fifth sample unit. Repeat this process throughout the sample unit whenever no new species are discovered in two consecutive sample units.

In spring sampling, randomly select 50% of the reaches from each group to be marked for return sampling. These reaches will be sampled three times in total; once in spring, summer, and fall sampling. The remaining 50% will only be sampled once in spring and new sites will be selected in the following seasons. In spring and fall sampling, randomly select 50% of the reaches in each group to sample for a length of only 15 stream widths. Sample the remaining reaches and all summer reaches for the full 30 stream widths. Within each group, sample at least one randomly selected reach for a length of approximately 90 stream widths during summer sampling only.

II. Sampling Objectives

Aim to sample a minimum of six reaches from each group for a total of up to 24 reaches per river. After sampling all reaches, plot a species accumulation curve (SAC), sampling effort vs. cumulative species richness, to ensure that sampling effort was sufficient to reach an asymptote in a SAC. If more samples are needed, determine how best to allocate further samples between stream order groups by plotting a SAC for each stream group. Ensure sufficient sampling has been completed before beginning to sample the second stream.

III. Standard Sampling Protocol

A. Site Delineation

At each reach, randomly decide to begin sampling upstream or down stream of the access point and begin to sample approximately five stream widths above or 10 stream widths below the access point. Measure the stream width at a point of average width at the beginning of each sample unit and visually estimate the end point of the sample unit. After sampling the unit, measure the exact length of the unit by chaining down the middle of the stream with a tape measure. Do not cut off bends in the sample unit while measuring length. At the beginning, middle, and end of each sample unit in a location of average depth, record the depth of the stream measuring along the deepest point of the channel. Face the thin edge of the meter stick upstream toward the flow and read depth from the downstream side. Record all UTMs in decimal degrees from the middle of the stream at the beginning and end of each reach. Flag all reaches selected for return sampling.

B. Backpack Electrofishing Protocol

At each reach, enter the water 5-10 meters downstream of the start point and adjust the shocker settings to ensure it is effectively turning fish. Adjust electrofishing settings as necessary at each reach based on stream size, visual cues of fish behaviour, and frequency of the beeper. After adjusting the electrofishing unit, move to the start of the first sample unit, ensure the counter is set to zero, record the start time, and begin shocking. At the end of a sample unit, record the sampling end time, remove fish for processing, and move on to the next sample unit.

Only conduct electrofishing during suitable flow and weather conditions. For example, do not sample if glare, turbidity, or rain significantly limit visibility. A three person field crew will conduct sampling in a upstream direction, moving back and forth across the river while moving the anode in a continuous *m* pattern (Figure 1) with effort made to sample the entire unit. Focus effort on areas where fish are likely to be found (ex. around large woody debris) and move quickly through unproductive areas (ex. sandy open areas). In pools or other deep areas, experiment with different techniques using the anode to draw fish towards the netters. In large or deep reaches, the electrofisher should stand slightly in front of and to the side facing the far bank of the netters while moving the anode in a downstream motion towards the netters.

C. Crew Size
In calm or narrow reaches, one person will operate the electrofisher and hold the fish collection bucket, while another nets fish, and the third records data and processes fish. In faster or wider reaches or if the crew leader determines that fish are being missed, two netters will assist the electrofisher.

D. Second Pass
If some areas in a sample unit cannot be adequately sampled with a backpack electrofisher due to depth or other hazard, conduct sampling as completely as possible with a backpack electrofisher. Conduct a second pass covering all un-sampled areas with a more suitable gear such as a seine, barge, or boat shocker. Use a separate data sheets for each gear type and draw a map indicating the areas where the gear could be used. The seine map should include an outline of the subunits, landmarks, direction of seining and number of hauls. If the reach appears difficult to sample with a backpack unit, write in the Notes field of the data sheet if a barge or boat could be used to sample the area.

E. Seine protocol

Some areas of rivers too deep to electrofish by backpack (e.g. deep pools, deep runs), may be suitable for sampling by seining. Such areas should be relatively free of snags (e.g. woody debris, cobble, stones, boulders, rebar, concrete, scrap metal, bicycles, shopping carts, appliances, cars) and less than 2 meters deep (i.e. less than depth of seine net). Seining should be done within the sampling units outlined above using a 25' long by 6' high seine (3/8" ace mesh) with a 6'h x 6'w x 6'deep bag (5/16" ace mesh).

Backpack electrofishing should first be completed where possible in the sampling unit. The portion of the sampling unit that could not be sampled by electrofishing but less than 2m deep, should be divided into areas of homogeneous habitat (i.e. pool or run) with dimensions less than the length of the seine. These areas are termed subunits (Figure 2).

Each subunit should be seined at least three times using a depletion method (i.e. samples should be retained until the sampling of the subunit is completed). If a new species is collected during the third haul, three more seine hauls should be completed. This process should be repeated until no new species are found during the third haul.

Subunits should be sampled in a downstream to upstream order (in larger rivers, it is acceptable to sample all subunits on one bank in this order, and then switch to the other bank. (N.B. river should always be crossed downstream of subunits) (Figure 2). This minimizes the disturbance of downstream subunits. Each subunit should be sampled from the upstream side of the subunit to the downstream side. This facilitates easier hauling with the current and takes advantage of the tendency of startled fishes to swim against the current. Netters should move as quickly as safety permits. The use of a third person to position the bag and to undo snags is advantageous.

F. Boat shocking technique

Some areas of streams too deep to effectively sample using backpack electrofishing or seining (e.g. river mouths), may be sampled using an electrofishing boat. Boat electrofishing is an effective sampling method in depths of 0-3m in most streams, except those with extremely low (e.g. on igneous bedrock) and extremely high conductivity (e.g. saline). The following protocol is suitable for most boat electrofishing units currently on the market (e.g. Smith-Root 5.0 GPP). The boat may be any length but smaller (<16'), flat-bottomed boats will allow sampling in shallower water.

Reaches to be sampled using a boat electrofisher should be divided into 15 sample units measuring one stream width each. For efficiency, the sample units may be delineated using buoys placed in the middle of the channel at intervals of one stream width. Sampling should be depth stratified, using either point or transect sampling methods (see Appendix for comparison of point and transect sampling). For each sample unit, the following depths will be sampled for 10 seconds: 0m, 1m and 2m off of both banks. Points at the 0m contour should be fished by "nosing" the anode into shore. Fishes collected at each point, or along each transect, should be kept in separate containers or in a partitioned live well and processed on a regular basis.

Sampling upstream to downstream is preferred, but downstream to upstream sampling is acceptable when the current is strong enough to make maneuvering the boat difficult. A single depth contour along one bank should be sampled, then a single depth contour along the opposite bank should be sampled. This procedure should be repeated until all depth contours are sampled. To maximize the independence between sample points, depth contours should be sampled in the following order (alternating between banks): 2m, 0m, 1m. Depths should be measured using a depth finder, and a GPS should be used to record the geographic coordinates of each point sampled.

III. FISH PROCESSING

During processing, hold all captured fishes in stream using flow through containers or in large buckets in the shade. Sort, count, and identify to species all fishes collected within a sample unit. Preserve one representative of each species found at a reach and all unknown species for verification and reference. After one representative of a species has been preserved in a watershed, a digital photo displaying identifying characteristics may substitute for additional voucher specimens at each reach. ONLY photograph key features of any endangered species for positive identification. Do not take any endangered or threatened species. Preserve fishes in 10% formalin with the reach, sample unit, date, collector's name, and species name (if known) recorded in pencil or non-degradable ink on waterproof paper inside the jar. Be sure to keep fish from each sample unit separated in individual bags of jars. Do not preserve fishes from multiple sample units in the same jar. Release fishes at least 25 m below the sample unit.

IV. SITE DOCUMENTATION

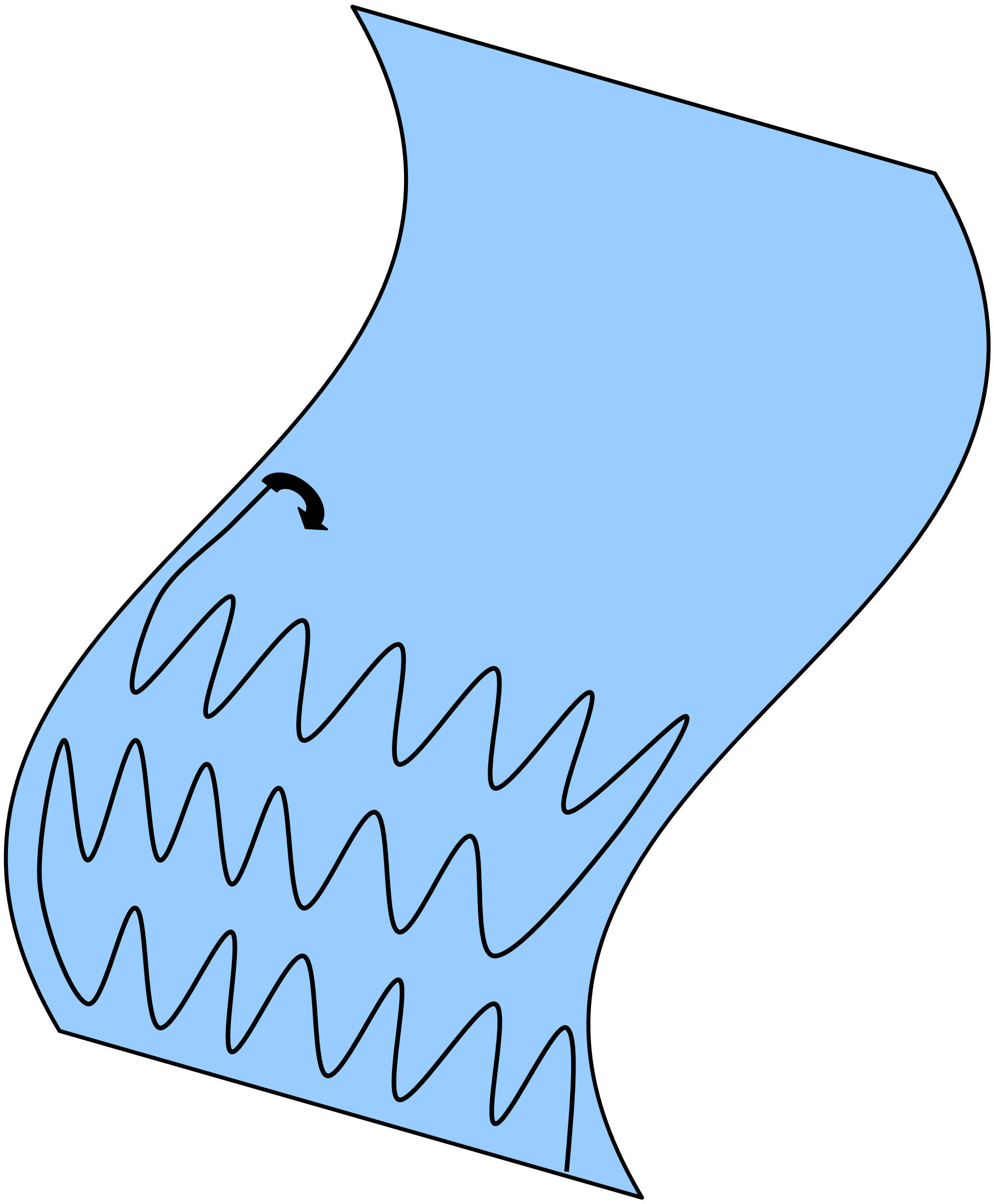
A. General

Take a photograph of the beginning of each reach. Include in the photograph a person holding up a white board that indicated the river name, date, location, and reach number for reference (Table 1). Photograph the beginning of each sample unit and take additional pictures of interesting specimens or site features. At the end of each reach, take an image of the final data sheet. Refer to the attached datasheet explanation form for details on each field and measurement. Write in the notes field in the Datasheet the sample unit which contains the overpass or road crossing associated with the access point. Proof and initial all datasheets before leaving the reach. If a measurement cannot be taken, note the reason and place an X in the cell.

Table 1: White Board Photograph

DATE: RIVER NAME: REACH No.: GPS :

Figure 1: Sampling Procedure



Appendix

Comparison of Point and Transect Sampling Methods for Boat Electrofishing

Sampling fishes using boat electrofishing can be undertaken using a variety of methods. These methods may include targeting specific species or habitats, or more systematic sampling targeting the whole fish community based on points or transects. Point sampling involves sampling specific points for a specific length of shocking time. Transect sampling involves sampling along a predetermined transect for a specific length of actual or shocking time. A comparison of point and transect methods was undertaken at two sites on the AuGres River, MI on August 6 and 7, 2002 (see Table 1 for details).

When the sampling crew arrived at a selected site, a mean stream width was determined using a handheld GPS unit. Sampling upstream or downstream of an access point was randomly determined at the access point with a coin toss. Sampling began either five meters upstream or ten meters downstream from the selected access point. The length of the site was equal to 15 stream widths. Site length was delineated using a Lowrance X-15ci GPS/Sonar Unit. The boat crew then traveled to the beginning of the site to commence sampling. If the crew sampled upstream of the access point, they began five meters upstream from the access point. If the crew sampled downstream from the access point, sampling commenced an equivalent length of 15 stream widths downstream from the 10-meter access point boundary. Boat electrofishing sites were first sampled with the depth-stratified point sampling method. Transect sampling began upon the completion of the point sampling. Both point and transect sampling exercises were completed within the same day.

Table 1. Sample site parameters.

Site*	Date	Duration	Air Temp	Water Temp	***Conductivity***
1	08/06/03	1402h-1742h	25.5C	25.3C	1016uS
2	08/07/03	0957h-1432h	22.3C	23.3C	1073uS

* 1. Augres River Mouth; u/s and d/s of boat municipal boat ramp; Arenac County, MI.

2. Augres River; d/s of bridge (approx. 250m) within the Town of Augres; Arenac County, Michigan

Point Sampling

The site was divided into 15 sampling units. The length of each sampling unit was equivalent to one stream width. Systematic sampling was performed along a diagonal line extending from one end of a sampling unit to the other end (Figure 1). Points were sampled for 10 seconds each at the following depths off of both shores: 0 meter (0m), 1 meter (1m) and 2 meters (2m) (Figure 1). Sampling depth and UTM location of each sampling point was determined using a Lowrance X-15ci GPS/Sonar Unit. Zero meter points were defined as the closest the boat could travel safely against the riverbank. Sampling began with the sampling the nearest 0m sampling point. The sampling crew then moved diagonally to the 1m depth contour sample point (Figure 1). When the bow of the boat reach the 1m contour, the electrofishing unit was engaged and the point was sampled for 10 seconds. This sampling pattern was repeated until all six points within the unit were sampled (Figure 1). Fishes were sorted by point, identified and processed upon completion of each sampling unit. One specimen of each species was kept from the site for later verification. Number of fish captured by species and point UTM coordinates were recorded for each point. The entire site was comprised of 6 points in each of 15 sampling units for a total of 90 points. Data recorded for the entire site included: air temperature; water temperature; conductivity; boat power settings; travel time; and, start and stop times.

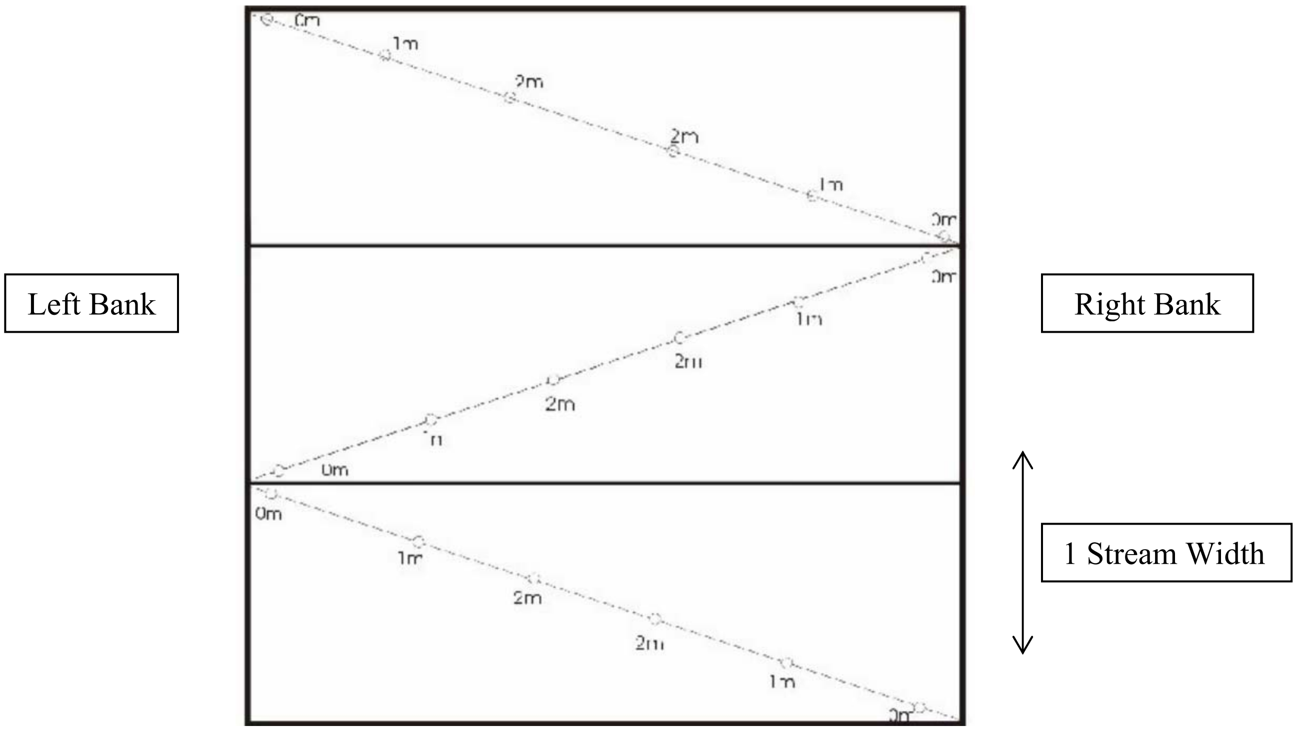


Figure 1. Site schematic diagram for depth-stratified point sampling of the Augres River, Michigan.

<u>Transect Sampling</u>

Upon completion of the depth-stratified point sampling, the boat crew began transect sampling of along the shoreline. Each sampling unit was sampled by navigating the boat in a continuous path along the shoreline. The boat was navigated as close to the shoreline as possible, typically sampling in depths of less than 1 meter. Upon completion of shocking of each sampling unit, fishes were processed, and number of fish captured by species and point UTM coordinates recorded. All fishes were identified at the site and one specimen of each species was kept for verification. While the distance shocked was the same for each sampling unit, shocking time varied between sampling units. Data recorded for the entire site included: air temperature; water temperature; conductivity; boat power settings; travel time; and, start and stop times.

Table 1. Species captured using depth-stratified point sampling and transect sampling with boat electrofishing unit in the Augres River, Michigan (bold denotes species only captured at depths >1m).

Species	**Transect**	**Point**	*Point*		
			0m	**1m**	**2m**
(41) Longnose Gar	■	■	■		
(51) Bowfin	■				
(63) Gizzard Shad	■	■	■	■	■
(131) Northern Pike	■	■	■	■	
(161) Quillback		■			■
(169) Black Redhorse		■	■	■	■
(170) Golden Redhorse	■	■	■	■	■
(172) Greater Redhorse	■				
(186) Common Carp	■	■	■	■	■
(194) Golden Shiner	■	■	■	■	
(198) Common Shiner	■	■	■	■	
(201) Spottail Shiner	■	■	■	■	
(200) Blacknose Shiner	■				
(203) Spotfin Shiner	■				
(208) Bluntnose Minnow	■	■	■		
(209) Fathead Minnow		■	■		
(232) Yellow Bullhead	■				
(233) Brown Bullhead	■				
(311) Rock Bass	■	■	■		
(312) Green Sunfish	■	■	■		
(313) Pumkinseed	■	■	■		
(314) Bluegill	■	■	■		
(316) Smallmouth Bass	■				
(317) Largemouth Bass	■	■	■	■	
(319) Black Crappie		■			■
(331) Yellow Perch	■	■	■		
(334) Walleye		■		■	
(361) Banded Killifish	■	■	■		
(366) Round Goby	■	■	■		
(371) Freshwater Drum		■			■
(601) Goldfish X Common Carp Hybrid					■
Species Richness	**25**	**24**	**19**	**10**	**8**

RESULTS

Species Richness

Species richness (SR) values varied between both sites. Total sampling (point and transect) combined, yielded 31 species from both sites. Point and transect sampling yielded a total of 24 species and 25 species, respectively (Table 1). Although many species caught were common to both methods, some differed. Seven species not detected by point sampling were found in the transect sampling (Table 1). Conversely, six species not detected by transect sampling which were found in the point sampling (Table 1). Two of these species (freshwater drum and quillback) were only detected when sampling depths were greater than 1 metre (Table 1).

Sampling Efficiency

Sampling efficiency was quantified using two units of measurement. Catch per Unit Effort (CUE) was described as the number of fish captured per electrofishing minute (fish/emin) and richness efficiency (RE) was described as the number of species captured per electrofishing minute (spp/emin). Sampling efficiency was similar between point sampling and transect sampling (Table 2). Point sampling at Site 1 demonstrated a slightly higher CUE (3.20 fish/emin) than transect sampling (3.06 fish/emin) (Table 2). Point sampling at Site 2 demonstrated a slightly lower CUE (2.53 fish/emin) than transect sampling (2.76 fish/emin) (Table 2). Combined sampling results from both sites indicated that transect sampling yielded a slightly greater CUE (2.933 fish/emin) than point sampling (2.87 fish/emin) (Table 2).

Table 2. **Sampling effort and results for point and transect sampling at two sites on the Augres River, Michigan.**

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	Site 1		Site 2		Combined	
	Point	Shoreline	Point	Shoreline	Point	Shoreline
Elapsed Sampling Time (min)	135	83	121	50	256	133
Sampling Effort (min)	15	52.7	15	35.93	30	88.63
Total Fish Captured	48	161	38	99	86	260
Species Richness	17	21	14	21	24	25
Catch Per Unit Effort (fish/min)	3.20	3.06	2.53	2.76	2.87	2.93
Abundance Efficiency (spp/min)	1.13	0.40	0.93	0.58	0.80	0.28

Richness efficiency at Site 1 was greater using the point sampling (1.13 spp/emin) than transect sampling (0.40 spp/emin) (Table 2). RE at Site 2 was only slightly great using point sampling (0.933 spp./emin) than transect sampling (0.584 spp./emin)(Table 2). Combined richness efficiency was greatest using point sampling (0.80 spp./min) compared to transect sampling (0.28 spp/min)(Table 2). Considerable differences in total elapsed time were observed between the two methods. Total elapsed time for point sampling for Site 1 and Site 2 was 256 minutes combined to 133 minutes combined for transect sampling (Table 2). Conversely, sampling effort (shocking time in minutes) was much lower for point sampling (30 minutes total) than for transect sampling (88.5 minutes).

Conclusions

The objective of sampling in the Barrier Placement Protocol is to identify the composition of the whole fish community in an efficient manner. The results of this modest method comparison indicate that the different methods tested collected many of the same species, but some different ones as well. Three of the six species collected only by point sampling were collected only in depths greater than 1m, depths that were not sampled by the transect sampling. When standardized by shocking time, point sampling caught a greater abundance and richness of species. Although point sampling required substantially less actual shocking time (total of 30 minutes compared to 88.6 min in the transect sampling), the total time spent sampling was almost double (256 min compared to 133 min). However, transect sampling was only conduct along two transects at a depth of 0m. If it was to be also conducted along two transects at depths of 1m and 2m Total four additional transects), then the total sampling time would be tripled, and exceed the total point sampling time. Based on this limited analysis, point sampling is more efficient method that can be more easily conducted in a standardized format; therefore, it is recommended that point sampling be used in the Barrier Placement Protocol, but that additional data be collected to redo this analysis using a larger data set.

Appendix 4.1. List of participants at Closing Workshop held in Ann Arbor, 8-9 July 2003.

Jones, Mike, MSU
Mandrak, Nick, DFO
McLaughlin, Rob, Guelph
DePasquale, Deb, Guelph
Smith, Katherine, MSU
Burkett, Dale, GLFC
Christie, Gavin, GLFC
Galloway, Jim, USACE
Gaston, Dave, USACE
Hallett, Andrew, DFO
Hanshu, Sharon, MDNR
Hartford, Bill, Guelph
Hayes, Dan, MSU
Heinrich, John, USFWS
Jones, Mike, MSU
Lavis, Dennis, USFWS
Macdonald, Gord, Guelph
Mandrak, Nick, DFO
McLaughlin, Rob, Guelph
Mullett, Kasia, USFWS
O'Connor, Lisa, DFO
Weise, Jerry, SLCC
Westman, Wayne, SLCC

Appendix 4.2. Summary of comments by, and discussions with, participants at Closing Workshop.

Criteria for Evaluating Historical Data

Historical data would be deemed an acceptable alternative to new sampling if the historical data fulfilled the following criteria:

1. Age of data < 10 years old.
2. Complete coverage for the entire watershed. (There were differing opinions among participants whether or not data were required for the whole watershed or only for the area likely to be impacted by the proposed barrier).
3. More than one year of data.
4. Spring and summer data.
5. Observed richness was similar to expected richness based on watershed size.

Concerns Raised About Sampling Protocol

- What about estimates of abundance/production (required to plan fish passage capacity)?
- Whole watershed versus only below barriers
    - Uncertainty about "non-migratory" species movement needs.
    - Is it possible to use data from upstream habitats to prescribe mitigation benefits (i.e. net gain)?
    - Depends on assumption about vulnerability of species above barriers.

Consensus on Sampling Effort

- Allocate most of effort to systematic survey to capture 90% of species present.
- Allocate remaining effort to targeted sampling to detect species of concern (based on historical, watershed and faunal region lists).

- Need to distribute sampling among seasons (spring-summer) and, when possible, over more than 1 year.
- Use general results to plan Year 1 survey; then use Year 1 results to refine Year 2 survey.

Faunal Regions, SAR list, Rarity, Fragmentation

- Fish faunal regions more appropriate than ecoregions. Proposed fish faunal region classification seemed appropriate. Peer review of methods and conclusions important.
- Both SAR (jurisdiction and NGO) should be used, but should recognize that official federal, provincial and state SAR lists represent legal lists.
- Are fish faunal regions adequate for defining local rarity? Rarity should be given as proportion, not category.
- Fragmentation is difficult to measure, existing data are not suitable, and it hard to conceive of a situation where fragmentation would lead to a decline in a species, but the species would not already be identified as a SAR, rare or at it's range edge. Therefore, the fragmentation clause in the draft protocol is difficult to quantify and likely redundant.
- Data are not available to apply concept and would be costly to collect.

Migration and Passage Knowledge Databases

- Distribute database as prototype to agents to test on candidate streams.
- Seek partnership funding for internet-based application.
- Include home range of species, spatial patterns of distribution in watersheds, and differentiate vulnerability to seasonal versus fixed barriers.

Comments on Interim Policy

- Policy doesn't explicitly address issues of species reintroduction.

- Guideline #6 could be modified slightly to emphasize role of partnerships/agency management plans.

Appendix 5. Annual project reports, Years 1 and 2.

Annual Project Report, Year 1 – See file “AnnRpt01.pdf”

Annual Project Report, Year 2 – See file “AnnRpt02.pdf”

Appendix 6. M.S. Thesis of Josh Noble.

See file “Noble2002.pdf”

Appendix 7. M.S. Thesis of Katherine Smith.

See file “Smith2003.pdf”

Appendix 8. Draft GLFC Technical Report on the status and distribution of VTE fish species in the Great Lakes.

See file “GLFCTechRpt_Draft.pdf”