Quality Assurance Project Plan: Fish Assemblage Assessment of the Lower Des Plaines River

Effective Date: July 1, 2006

Center for Applied Bioassessment & Biocriteria
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Submitted by:

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Exhibit 8
R08-9
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Group A: Project Management Elements

A.3: Distribution List

The Center for Applied Bioassessment and Biocriteria proposes to assess the status and composition of the fish assemblage in the lower Des Plaines River. This will be accomplished by collecting new data from historical and new sites between Lockport and the Kankakee River. The data will eventually be used by Region V, Illinois EPA, Illinois DNR, and others to address multiple issues in the lower Des Plaines including use attainability analyses (UAAs), thermal impacts, and the impacts of multiple chemical and physical stressors. An initial list of interested contacts include:

Illinois EPA, Roy Smogor (Roy.Smogor@epa.state.il.us)
Illinois DNR, Steve Pescitelli (spescitelli@dnrmail.state.il.us)

We will add to the list as new participants are identified. In addition, the U.S. EPA, Region V QA Project Manager, the Center for Applied Bioassessment and Biocriteria Director, the U.S. EPA, Region V Technical Contact, and U.S. EPA, Office of Water, National Biocriteria Program contact (OST-HECD) will also be included in the distribution list as follows:

U.S. EPA, Region V, Project Officer, Lula Spruill (Spruill.Lula@epa.gov)
U.S. EPA, Region V Technical Contact, Ed Hammer (Hammer.Edward@epa.gov)
Center for Applied Bioassessment and Biocriteria, Brian Armitage (barmitage@rrohio.com)

A.4: Project/Task Organization

All phases of the proposed study will be coordinated and conducted by the Center for Applied Bioassessment and Biocriteria (CABB). Chris Yoder will serve as the principal investigator and project coordinator. In this capacity he will provide the primary oversight and management of all aspects of the project, including participating directly in the field sampling and ensuring that all methods and procedures are followed. He will also be directly responsible for maintenance of the QA Project Plan. CABB will assign a qualified crew leader who will be responsible for all data collection activities. Two additional and temporary field personnel will be assigned to assist this person with field work under the direct supervision of the CABB project coordinator. A functional table of organization appears in Figure 1.

Advice and assistance with the design of the proposed study has been sought and will continue to be provided by the applicable state agencies, federal agencies, and nongovernmental organizations. Each agency and organization will benefit from the data and assessment produced by the proposed study. The states will benefit from the development of a large river biological assessment tools, application of a standardized protocol, and the resulting use of the data to calculate biocriteria. Users will benefit from the baseline assessment information and how it relates to the implementation of tiered aquatic life uses (TALUs) and biological criteria for non-wadeable rivers in Illinois and the Midwest in general. The development and evaluation of TALUs is especially important to understanding and resolving issues raised by the Lower Des Plaines use attainability analysis (UAA).

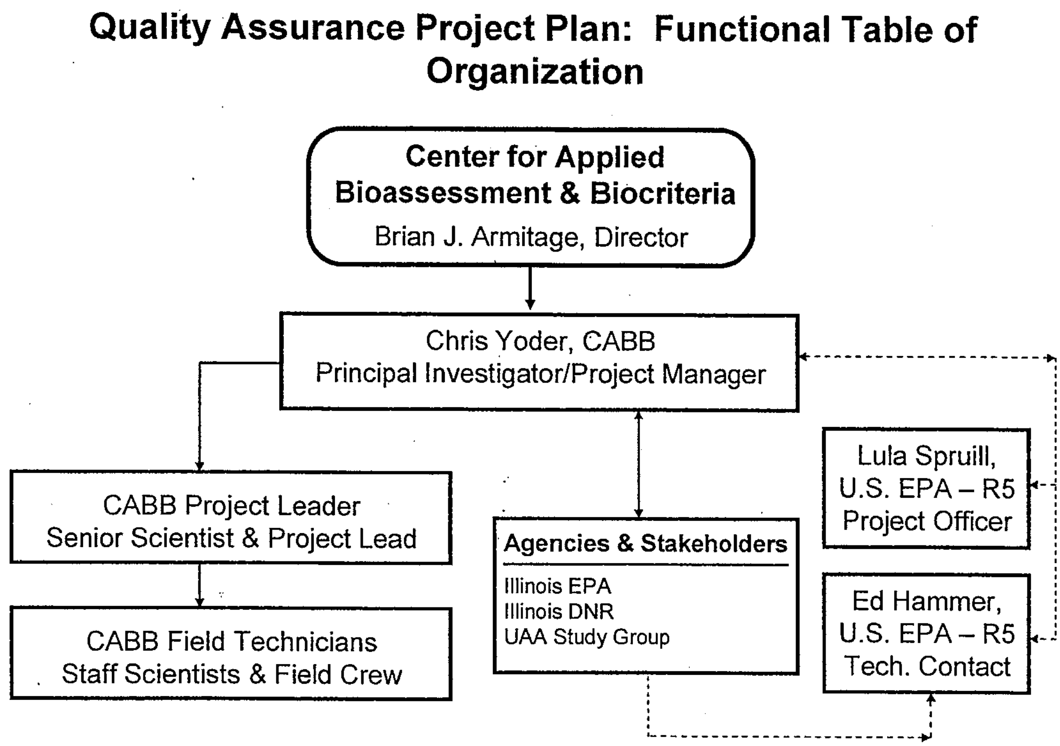

Figure 1. Functional table of organization for project implementation and management.

A.5: Problem Definition and Background

The proposed study will utilize a standardized, pulsed direct current (D.C.) boat electrofishing protocol as a means of assessing the structure, quality, attributes, and health of the fish assemblage. This study will include the mainstem of the lower Des Plaines River between Lockport to downstream from the Kankakee River. This river segment was the subject of a recent use attainability analysis, which included analyses of historical fish assemblage data (Hey and Associates 2003). At issue is the ongoing review of the Illinois EPA designation of the Dresden and Brandon dam pools and segments, parts of which are designated for secondary contact and indigenous aquatic life. In addition, the current Illinois EPA temperature criteria are under review and this project should help to confirm the list of Representative Aquatic Species that is being used in the development of revised criteria.

Methods and procedures for sampling fish assemblages that have proven effective in many areas of the U.S. will be used (Gammon 1973, 1976; Gammon et al. 1981; Hughes and Gammon 1987; Ohio EPA 1989; Lyons et al. 2001; Mebane et al. 2003; Emery et al. 2003). The principal focus of this study is on the fish assemblage and an accompanying qualitative habitat assessment.

Biological Assessment of Non-Wadeable Rivers

The Lower Des Plaines River qualifies as a non-wadeable river in terms of which biological sampling methods are the most appropriate. While there is no single definition of a large, non-wadeable river it generally includes those lotic systems that cannot be *adequately nor consistently* sampled with wadeable sampling protocols. The operational extent of wadeable vs. non-wadeable may also vary between organism groups; for example a river may be wadeable for periphyton or quantitative macroinvertebrate sampling, but not for effective fish sampling. Others have used catchment area definitions; great rivers drain more than 10,000 mi^2 of land area (Simon and Sanders 1999) and large rivers more than 1000 mi^2 (Simon and Lyons 1995; Ohio EPA 1989). What can be agreed upon by most is that the development of biological assessment tools, particularly those focused on assessments of condition and status, has lagged behind the development of wadeable stream methods. Table 1 depicts the range of fish sampling methods and equipment that Ohio EPA uses to sample wadeable and non-wadeable streams and rivers (Table 1).

Biological assessments have been conducted in large, non-wadeable rivers of the U.S. since the late 1940s. Most of the early efforts focused on the more easily measured biota of that time period (i.e., macroinvertebrates, periphyton, plankton), the inclusion of the fish assemblage being a rare and relatively recent addition. Single-gear assessments are even more recent and include the pioneering work by Gammon (1973, 1976, 1980) and Gammon et al. (1981) in Midwestern rivers, principally the Wabash River of Indiana. Other efforts followed and most were associated with studies of thermal effluents in response to Section 316[a] of the Clean Water Act (CWA) in the 1970s and early 1980s. A common frustration with these studies was the lack of a standardized approach to data collection and the absence of a conceptual framework for analyzing the data and producing meaningful and consistent assessments. The development of the IBI type approaches to analyzing and assessing fish and other assemblage data in the early 1980s (Karr 1981; Karr et al. 1986; Fausch et al. 1984) provided the missing conceptual framework. Ohio EPA (1987, 1989) developed fully standardized methods and an IBI for non-wadeable rivers and used it to support the long term assessment of rivers (Yoder et al. 2005). This was followed by the development of new approaches for non-wadeable rivers such as the Ohio River (Simon and Emery 1999; Emery et al. 2003) and for Wisconsin rivers including the Mississippi, Wisconsin, St. Croix, and Chippewa Rivers (Lyons et al. 2001). The Wisconsin study showed the utility of the assessment end product, which is an improved understanding of the ecological consequences of multiple human impacts (point and nonpoint sources, hydromodifications, multiple stressors) in non-wadeable rivers and the

Table 1. Ohio EPA fish assemblage sampling methods for wadeable and non-wadeable sites (after Yoder and Smith 1999).

	Wading Methods		Boat Methods		
Category	Small Streams	Other Streams	Small Rivers	Large Rivers	Great Rivers[1] Lake Erie[2]
Waterbody Size Dimensions:[3]	<1.0-10 mi^2 <0.3-0.5m depth 1-2m width	10-500 mi^2 0.5-1.0m depth 2-20m width	150-1000 mi^2 >1.0m depth 10-100m width	1000-6000mi^2 >1.0m depth >50m width	>6000 mi2 >1.0 m depth (Ohio River)
Platform:	Backpack; Bank set	Tow boat; Bank set	12-14' boat	14'-16' boat	18' boat 21' boat
Unit:	Battery/ Generator	Generator	Generator	Generator	Generator
Power Source:	12v battery/ 300-1750W alt.	1750-2500W alternator	2500-3500W alternator	3500-5000W alternator	5000/7500W alternator
Amperage Output:	1.5-2A; 2-12A	2-12A	4-15A	15-20A	15-20A
Volts D.C. Output:	100-200; 150-300	150-300; 300-1000	500-1000	500-1000	500-1000
Anode Location:	Net ring	Net ring	Boom (Droppers)	Boom (Droppers)	Boom; Spheres[4]
Sampling Direction:	Upstream	Upstream	Downstream	Downstream	Downstream; Downcurrent
Distance Sampled:	0.15-0.20km	0.15-0.20km	0.5km	0.5km	0.5-1.0km
CPUE[5] Basis:	per 0.3km	per 0.3km	per 1.0km	per 1.0km	per 1.0km
Time Sampled (Typical):[6]	1800-3600 sec	1800-3600 sec	1600-3500 sec	1600-4500 sec	2000-3500
Time of Sampling:	Daylight	Daylight	Daylight	Daylight	Twilight/ Night

1 Great Rivers generally exceed 6000 square miles drainage area at the sampling site.
2 Lake Erie methods similar to great river methods (see Thoma 1999).
3 Maximum pool depth in small streams; sampling depth along shoreline in larger rivers.
4 Droppers are used in inland rivers and the Ohio R.; electrosphere design is used on Lake Erie only.
5 CPUE: catch per unit of effort.
6 Normal range - sampling time may vary upwards due to factors such as cover and instream obstructions.

sequence in which they occur. Ohio is the only state in Region V that has developed and applied TALUs to non-wadeable rivers (Table 2).

Biological Criteria Development
An important objective of this project is to contribute data to the development and use of biological criteria in Illinois and on a regional basis, specifically for non-wadeable rivers. Biological criteria are numeric values or narrative expressions that describe the biological condition of an aquatic assemblage inhabiting the waters of a given designated use (U.S. EPA 1990). Benchmarks for TALUs are developed with respect to reference condition (least impacted), which is derived from assemblage data at least impacted reference sites and/or by an expert derivation process. While the restoration of most U.S. waters to a pristine state is not presently feasible, it is reasonable to base contemporary restoration goals on regional reference conditions that describe the best attainable biological condition and performance (Davis and Simon 1995). Principles for the successful development of numeric biological criteria include developing a reference condition, a regional framework, a characterization of the aquatic assemblage, and a habitat evaluation for specifically defined aquatic ecotypes (e.g., large rivers, wadeable streams, headwater streams, wetlands, lakes, etc.). Hey and Associates (2003) tested the possible application of TALUs in the

Table 2. Example of TALUs for non-wadeable rivers; numeric biological criteria for the Index of Biotic Integrity (IBI) that are applicable to boat electrofishing sites in Ohio (Ohio Administrative Code Chapter 3745-1).

Ecoregion	Modified Warmwater Habitat (MWH)[1]	Warmwater Habitat (WWH)	Exceptional Warmwater Habitat (EWH)
HELP - Huron/Erie Lake Plain	20/22	34	48
EOLP - Erie/Ontario Lake Plain	24/30	40	48
IP - Interior Plateau	24/30	38	48
ECBP - E. Corn Belt Plains	24/30	42	48
WAP - W. Allegheny Plateau	24/30	40	48

[1] MWH biocriteria for channelized/impounded sites.

Lower Des Plaines River using the Ohio EPA system of designated aquatic life uses (Table 2). Ohio EPA has been a national leader in the development and use of biological criteria and other Region V states are in the process of developing similar approaches.

A U.S. EPA working group established in 1999 developed a concept termed the Biological Condition Gradient, which is intended to foster the consistent development of biological assessment frameworks and biological criteria development across the U.S. This concept is also intended to enhance communication, understanding, and visualization of biological condition relative to the absolute gradient of possible biological quality from pristine to extremely degraded (Figure 2). A challenge for developing biological criteria for non-wadeable rivers is the apparent lack of reference analogs, at least compared to that which is more commonly available for wadeable streams. As an alternative, using direct sampling data combined with historical knowledge and reconstruction of historical assemblages by expert analysis may be used as a partial substitute for directly measured reference condition (Emery et al. 2003). The proposed study will contribute to this process on both a national and regional basis.

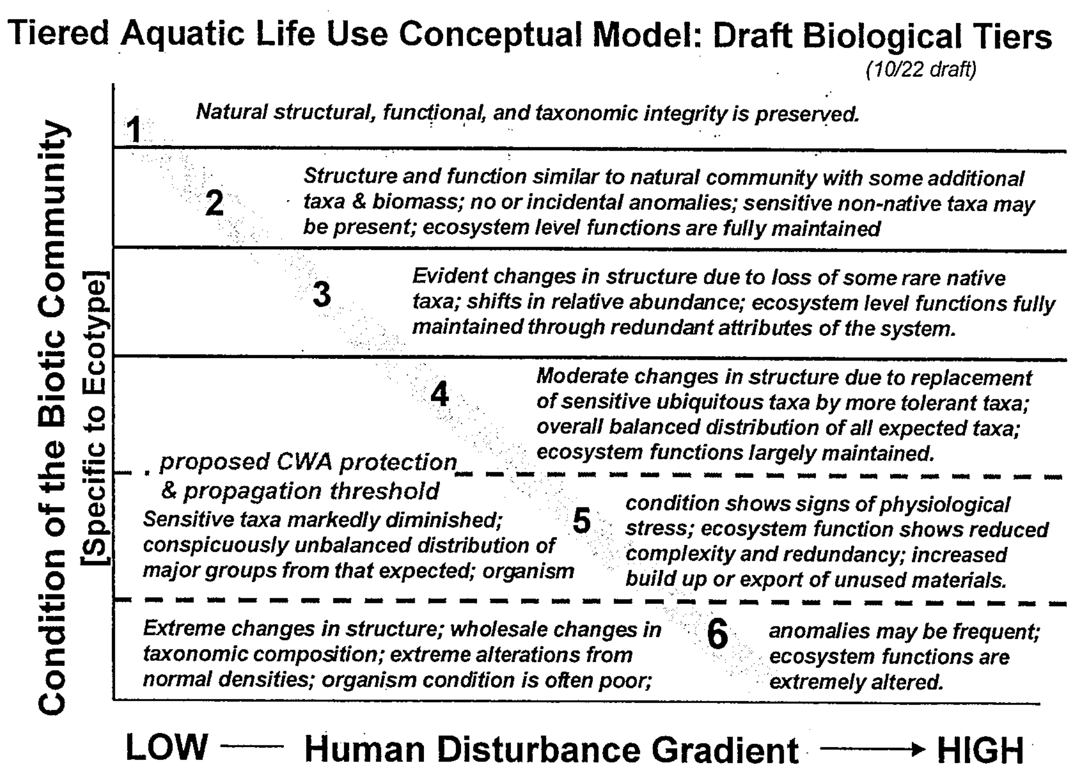

Figure 2. Tiered aquatic life use conceptual model showing a biological condition gradient and descriptive attributes of tiers along a gradient of quality and disturbance.

A.6: Project Description

The study will entail boat electrofishing at approximately 20-25 locations in the Lower Des Plaines River between Lockport to downstream from the Kankakee River (Figure 3). This will include using an intensive survey sampling design developed for non-wadeable rivers (Yoder et al. 2005).

Habitat characteristics will be recorded using a modification of qualitative, observation based methods (QHEI; Rankin 1989, 1995) under seasonal low flow conditions. Attributes of habitat include substrate diversity and composition, degree of embeddedness, cover types and amounts, classes of flow velocity, channel morphology, riparian condition and composition, and pool and run-riffle depths. Gradient will be determined from USGS 7.5' topographic maps and water clarity will be measured with a secchi disk. Water quality includes baseline field parameters such as temperature, dissolved oxygen, and conductivity. This will determined at each sampling location with portable meters and will account for the thermally affected areas by spatially stratifying the collection points within a sampling site.

Data Analyses

We expect to generate baseline data on the relative abundance and distribution of fishes in the Lower Des Plaines River. This will include raw and summarized data comprised of species enumerations, catch per unit of sampling effort (numbers and biomass), the incidence and severity of external anomalies on fish by species, total lengths for special interest and commercially and recreationally important species, basic field parameters such as temperature, conductivity, and dissolved oxygen (D.O.), and a qualitative habitat assessment. All of this information will be entered and stored in a relational database managed by CABB and made available to project sponsors and participants. Specific data that will be generated includes species relative abundance data by sampling location and river reach. From this data spatial analyses of longitudinal patterns in fish assemblage attributes (species richness, CPUE, special interest species, structural and functional guilds, IBI scores) can be accomplished and related to major natural and human-influenced changes and gradients.

A.7: Quality Objectives and Criteria

An important goal of a bioassessment method is to employ methods and equipment which are powerful enough to secure a sufficiently representative sample (accuracy), ensure reproducibility (precision), do so with a reasonable effort, and minimize potential bias induced by different operators thus making the results comparable. CABB uses large river fish sampling methods adapted from Ohio EPA (1987, 1989) and as applied by Yoder et al. (2005). This method has proven effective for fulfilling the TALU development and implementation goals and will produce data and information that will be useful to the Lower Des Plaines UAA process.

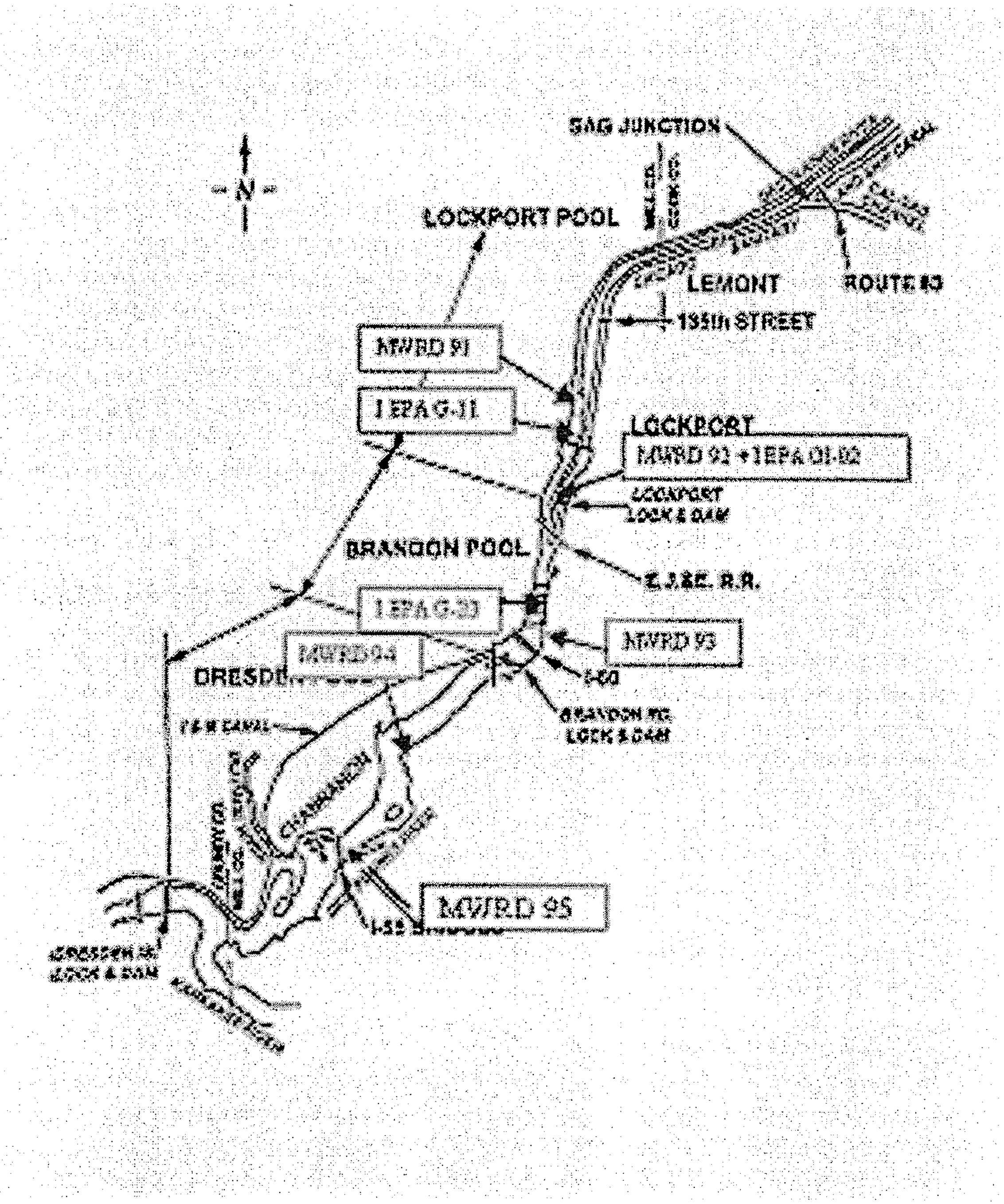

Figure 3. Lower Des Plaines study area showing historical chemical/physical sampling locations (after Hey and Associates 2003).

Data Attributes
The basic attributes of the data to be produced by the proposed study are counts and weights of fish delineated either individually or in the aggregate by species. Species level taxonomy is the minimum data quality objective and identifications to subspecies will be determined when appropriate. Scientific nomenclature will follow that adopted by the American Fisheries Society (AFS; Nelson et al. 2004). Regionally applicable ichthyology texts with keys will be used. Information will also be recorded about the occurrence of anomalies, diseases, and parasites that are observed externally on each fish that is weighed and or counted following the methods used by Ohio EPA (1989) and further described by Sanders et al. (1999). Qualitative habitat data will also be produced using a method similar to that developed by Rankin (1989; Appendix 1) modified for application to non-wadeable rivers.

Representativeness
Gammon (1973, 1976) assessed the representativeness of a standardized, pulsed D.C., large river boat electrofishing technique similar to that proposed for use in this study. Gammon determined that shoreline boat electrofishing over a distance of 500 meters sampling along the shoreline with the greatest depth and most abundant cover, was the most effective *single* method for collecting a representative cross-section of the fish assemblage. Other studies have likewise shown boat electrofishing to be the single most effective gear for obtaining fish assemblage data in Midwestern streams (Funk 1958; Larimore 1961; Boccardy and Cooper 1963; Bayley et al. 1989), large rivers (Vincent 1971; Novotny and Priegel 1974; Hendricks et al. 1980; Ohio EPA 1987), the Ohio River (Sanders 1992; Simon and Emery 1995; Simon and Sanders 1999), and the Lake Erie shoreline (Thoma 1999). While boat electrofishing does not collect all of the species present, it can collect more than 75-80% of the species that are present and approximate their relative abundances *if it is done correctly*. This meets the purposes and requirements for biological assessments and biological criteria in that sufficiently representative data is produced to provide reliable signal about the health and well-being of the resource without the need to accomplish an exhaustive faunal inventory. The collection of relative abundance data includes the use of standardized sampling procedures designed to produce a sufficiently representative sample of the fish assemblage at a site with a reasonable expenditure of effort (i.e., 1-3 hours/site). As such this type of assessment is distinguished from the much more resource intensive efforts using multiple collection gear and those required to obtain estimates of population (standing crop) or a complete inventory of all species present. The numerous and previously referenced large river IBI development studies that followed Gammon's pioneering work have substantially confirmed the utility and representativeness of the approach. Lyons et al. (2001) correctly observed that single gear assessments might not be as useful for rare or single species issues or for detailed fisheries management needs such as stock assessments of commercially or recreationally important species. However, broad agreement between overall assemblage condition assessments and the correspondence of suitable conditions for rare species and fisheries goals has been demonstrated (Hughes and Gammon 1987; Yoder and Rankin 1995).

Precision and Accuracy
Ohio EPA (1987) extensively tested the reproducibility, accuracy, and precision of their boat electrofishing sampling protocols in both wadeable streams and non-wadeable rivers. Based on a combination of data analyses from specially designed methods testing studies and the aggregate Ohio database, the reproducibility of an IBI score was determined to be 4 units out of a 12 to 60 scoring scale (Rankin and Yoder [1999] later revised the scoring range, 0-60). Rankin and Yoder (1990) showed coefficient of variations (CV) were on the order of 8-10% at least impacted and high quality sites. CVs increased at sites with lower IBI scores, presumably due to the effect of stressors at increasingly impacted sites. Fore et al. (1993) performed more extensive statistical analyses of the Ohio database and determined that IBI scores were reproducible to an error margin of 2-3 units. Their power analysis confirmed that the Ohio IBI was capable of distinguishing 6 discrete scoring ranges that approximate the delineations of the IBI scale into the qualitative descriptions of exceptional, good, fair, poor, and very poor. Angermier and Karr (1986) analyzed other statistical properties of the IBI focusing on the extent of redundancy among metrics. The results of their analysis showed that careful construction and derivation of an IBI following the original guidance of Karr et al. (1986) should produce a robust and non-redundant set of metrics.

Accuracy can also be examined in terms of the assessment produced by the subject method. Biological assessments are viewed as a direct measure of the aquatic life protection goals of the Clean Water Act (CWA) and State water quality standards (as opposed to the surrogate assessment provided by chemical water quality criteria). This has given rise to the concept and interest in biological criteria and adoption by U.S. EPA of a national program (U.S. EPA 1990), methods (Barbour et al. 1997), and the development of formal implementation procedures (U.S. EPA Aquatic Life Use Working Group). The issue at stake here is the accuracy of the delineation of waters as impaired or unimpaired for CWA purposes (e.g., TMDLs). Historically, States and U.S. EPA based these decisions on chemical water quality data and comparison to State and national water quality criteria. However, studies that compared the relative performance of chemical and biological data and their respective abilities to detect impairment showed that biological data was far superior in its ability to detect impairment and minimize type II assessment error (Rankin and Yoder 1990b; Yoder and Rankin 1998). It is implicit in these studies that the better standardized and calibrated the biological assessment method and assessment criteria, the more able the method is to detect impairment and establish a relative degree of departure from a baseline criterion.

Measurement Range and Comparability
While there is no theoretical upper limit to many of the raw data parameters that comprise the baseline data that will be produced by the proposed study, most have practically limited expectations. The practical range of these parameters is dependent on the natural attributes of the regional fish assemblage and the effectiveness of the sampling gear and

procedure. For example, in a warmwater river in Ohio we can expect boat electrofishing to produce a sample of 20-30 species and several hundred fish among those species. In exceptional quality rivers, the number of species might increase to more than 35-40 among thousands of individuals. In the large cold water rivers of the western U.S., many fewer species and individuals are usually collected. However, in terms of regional reference condition and potential, the resulting biological assessment should rate the samples from Ohio and the Western U.S. the same with respect to its similarity to or departure from a regional reference condition. This is critical to establishing biological assessments that are comparable across the U.S. Thus the derivation of reference condition is a critical step in the bioassessment process and is one of the factors that influences comparability.
The resulting assessments and biological indices have discrete scoring ranges, within which the raw data is stratified and compressed. For example, the original IBI and many of its contemporary applications used a scoring range of 12-60, i.e., metric scores of 5, 3, and 1 are assigned to each of 12 metrics. Newly developed IBIs have employed a scoring range of 0-100 (e.g., Lyons et al. 2001; Mebane et al. 2003), which is intuitively more meaningful as a theoretical scoring range and communication tool. The rigor, adequacy of the method, development, and calibration ultimately determines the accuracy, precision, and reproducibility of the index, its statistical rigor, and its resulting assessment.

Completeness
It is expected that all of the data collected by the proposed study will be used for one or more purposes. Some data may not prove to be useful for the more quantitative aspects of the planned analyses due to unforeseen or uncontrollable circumstances. However, the sampling protocols are designed to control the conditions under which sampling takes place so as to minimize these occurrences.

A.8: Training and Certification
The methods and protocols used in the proposed study require implementation by adequately trained and skilled biologists. The crew leader must be well trained and experienced in all aspects of conducting the sampling, making decisions that affect quality in the field, being familiar with the study area, and knowing how to identify all species of fish that might be encountered. This person must also be knowledgeable about safety procedures for boat electrofishing and boat and water safety. Presently, there are no formal certification requirements for such individuals except in a few instances. A biological assessment and biological criteria certification offered by the Ohio EPA is one such example. The principal investigator designed and instructed in the Ohio EPA certification course since its inception in 1997. CABB field personnel assigned to this project will be directly supervised by the principal investigator and will have been trained in an apprenticeship format. Of particular importance will be training in the electrofishing procedure, use of the modified Qualitative Habitat Evaluation Index (QHEI), and the identification of external anomalies on fish. Each will follow the procedures outlined in Ohio EPA (1989) and Rankin (1989).

There are some key "symptoms" of incomplete sampling that would lead to an under-estimate of the fish assemblage. These are the time electrofished, the sampling results (i.e., are the expected results obtained?), water clarity, conductivity, temperature, sampling distance, time of day, and the electrofishing unit settings. All of this information is recorded for each sampling site and each may yield information about a problem that could result in the later disqualification of the data.

A.9: Documents and Records

The Quality Assurance Project Plan and all updates will be maintained by CABB and provided to EPA and cooperating entities. A detailed plan of study will be developed with the sampling team and used to guide the selection of sampling sites in the field during reconnaissance and the initial sampling for each river survey.

Field Data Recording

Field data and observations will be recorded on water resistant data sheets (Figures 4 and 5). Fish assemblage data including species, numbers and weights by species, lengths for selected species, external anomalies, chemical/physical data, site name and numeration, sampling crew membership, time of day, time sampled, distance sampled, and electrofishing unit settings and electrode configurations will be recorded on the fish sampling data sheet (Figure 4). The Qualitative Habitat Evaluation Index (QHEI), with appropriate modifications for non-wadeable rivers, will also be completed at each site on a habitat assessment data sheet (Figure 4). The crew leader will also maintain a field activities log noting all circumstances related to field sampling, site access, weather, and other relevant observations. Data sheets will be retained by CABB. Voucher specimens will be collected to validate species identifications and where field identification is not possible. They will be deposited at an appropriate regional institution where curation of museum specimens is performed. As such they will provide a permanent record. These vouchers serve to validate new species distribution records and for verification of questionable field identifications. Each set of vouchers are labeled with the same location data recorded on the field sheet and they are also denoted on the field sheet. We are presently using the Ohio State University Museum of Biodiversity for depositing specimens and voucher identifications.

All data will be entered into an electronic data format maintained and supported by CABB. At this time we are using the Ohio ECOS data storage routine developed by Ohio EPA. This system is presently supported in a FoxPro format, which is translatable to other spreadsheet formats such as Access and Excel. The data analysis routines in Ohio ECOS for calculation of summarized fish assemblage information and aggregate indices such as the IBI and Modified Index of Well-Being (MIwb) will be modified appropriately in concert with the data analysis and index development outputs of the proposed study.

Figure 4. Field data sheet for recording electrofishing collection data and for entry into the Ohio ECOS database.

Midwest Biodiversity Institute **MBI**

Fish Data Sheet Mixing Zone: ☐

Field Crew: (Crew Leader, Boat Driver, Netter) ____ Time of Day: ____ Page ___ of ___

River/Stream: ____ Location: ____

Date: ____ Sampler Type: ____ Secchi Disk: ____ Time Fished: ' "

River Code: ____ Depth: ____ Color: ____ Total Seconds:

RM: ____ Data Source: ____ Temp (°C): ____ Observed Flow: ____

Distance: ____ Settings: ____ Number of Entries: ____

Anomalies: A-anchor worm; B-black spot; C-leeches; D-deformities; E-eroded fins; F-fungus; L-lesions; M-multiple DELT anomalies; N-blind; P-parasites; Y-popeye; S-emaciated; W-swirled scales; T-tumors; Z-other/. [Heavy (H) or Light (L) code may be combined with above codes]

	SPECIES	# WEIGHED							ANOMALIES
V: ☐		10X							
V: ☐		10X							
V: ☐		10X							
V: ☐		10X							
V: ☐		10X							
V: ☐		10X							
V: ☐		10X							
V: ☐		10X							

(Revised 6/01) Mass Weighing Convention: → 536 (12) ← **Number Weighed** Vouchers ☐

Figure 4. continued

Page ___ of ___

	SPECIES	# WEIGHED							ANOMALIES
V:		10X							
V:		10X							
V:		10X							
V:		10X							
V:		10X							
V:		10X							
V:		10X							
V:		10X							
V:		10X							
V:		10X							
V:		10X							

(Revised 6/01)

Figure 5. Qualitative habitat evaluation index (QHEI) field sheet – page 1.

MBI **Qualitative Habitat Evaluation Index Field Sheet QHEI Score:** ____

River Code: ________ *RM:* ______ *Stream:* ____________
Station ID: ____________ *Location:* ____________
Date: ________ *Scorer:* ________ *Latitude:* ________ *Longitude:* ________

1] SUBSTRATE (Check ONLY Two SubstrateTYPE BOXES; Estimate % present

TYPE	POOL	RIFFLE	TYPE	POOL	RIFFLE
☐☐-BLDR /SLBS[10]	___	___	☐☐-GRAVEL [7]	___	___
☐☐-Lg BOULD. [10]	___	___	☐☐-SAND [6]	___	___
☐☐-BOULDER [9]	___	___	☐☐-BEDROCK[5]	___	___
☐☐-COBBLE [8]	___	___	☐☐-DETRITUS[3]	___	___
☐☐-HARDPAN [4]	___	___	☐☐-ARTIFICIAL[0]	___	___
☐☐-MUCK [2]	___	___	☐☐-SILT [2]	___	___

SUBSTRATE ORIGIN — Check ONE (OR 2 & AVERAGE)
☐-LIMESTONE [1]
☐-TILLS [1]
☐-WETLANDS[0]
☐-HARDPAN [0]
☐-SANDSTONE [0]
☐-RIP/RAP [0]
☐-LACUSTRINE [0]
☐-SHALE [-1]
☐-COAL FINES [-2]

SUBSTRATE QUALITY — Check ONE (OR 2 & AVERAGE)
SILT: ☐-SILT HEAVY [-2] ☐-SILT MODERATE [-1] ☐-SILT NORMAL [0] ☐-SILT FREE [1]
EMBEDDEDNESS: ☐-EXTENSIVE [-2] ☐-MODERATE [-1] ☐-NORMAL [0] ☐-NONE [1]

NUMBER OF SUBSTRATE TYPES: ☐-4 or More [2] ☐-3 or Less [0]
(High Quality Only, Score 5 or >)
COMMENTS ____________

Substrate ☐ Max 20

2] INSTREAM COVER (Give each cover type a score of 0 to 3; see back for instructions)
(Structure) TYPE: Score All That Occur
___UNDERCUT BANKS [1] ___POOLS> 70 cm [2] ___OXBOWS, BACKWATERS [1]
___OVERHANGING VEGETATION [1] ___ROOTWADS [1] ___AQUATIC MACROPHYTES [1]
___SHALLOWS (IN SLOW WATER) [1] ___BOULDERS [1] ___LOGS OR WOODY DEBRIS [1]
___ROOTMATS [1] COMMENTS: ____________

AMOUNT: (Check ONLY One or check 2 and AVERAGE)
☐-EXTENSIVE > 75% [11]
☐-MODERATE 25-75% [7]
☐-SPARSE 5-25% [3]
☐-NEARLY ABSENT < 5%[1]

Cover ☐ Max 20

3] CHANNEL MORPHOLOGY: (Check ONLY One PER Category OR check 2 and AVERAGE)

SINUOSITY	DEVELOPMENT	CHANNELIZATION	STABILITY	MODIFICATIONS/OTHER	
☐-HIGH [4]	☐-EXCELLENT [7]	☐-NONE [6]	☐-HIGH [3]	☐-SNAGGING	☐-IMPOUND.
☐-MODERATE [3]	☐-GOOD [5]	☐-RECOVERED [4]	☐-MODERATE [2]	☐-RELOCATION	☐-ISLANDS
☐-LOW [2]	☐-FAIR [3]	☐-RECOVERING [3]	☐-LOW [1]	☐-CANOPY REMOVAL	☐-LEVEED
☐-NONE [1]	☐-POOR [1]	☐-RECENT OR NO RECOVERY [1]		☐-DREDGING	☐-BANK SHAPING
		☐-IMPOUNDED [-1]		☐-ONE SIDE CHANNEL MODIFICATIONS	

COMMENTS: ____________

Channel ☐ Max 20

4]. RIPARIAN ZONE AND BANK EROSION (check ONE box per bank or check 2 and AVERAGE per bank) ? River Right Looking Downstream

RIPARIAN WIDTH — L R (Per Bank)
☐☐-VERY WIDE > 100m [5]
☐☐-WIDE > 50m [4]
☐☐-MODERATE 10-50m [3]
☐☐-NARROW 5-10 m [2]
☐☐-VERY NARROW <5 m[1]
☐☐-NONE [0]

FLOOD PLAIN QUALITY (PAST 100 Meter RIPARIAN) — L R (Most Predominant Per Bank)
☐☐-FOREST, SWAMP [3]
☐☐-SHRUB OR OLD FIELD [2]
☐☐-RESIDENTIAL,PARK,NEW FIELD [1]
☐☐-FENCED PASTURE [1]
☐☐-CONSERVATION TILLAGE [1]
☐☐-URBAN OR INDUSTRIAL [0]
☐☐-OPEN PASTURE,ROWCROP [0]
☐☐-MINING/CONSTRUCTION [0]

BANK EROSION — L R (Per Bank)
☐☐-NONE/LITTLE [3]
☐☐-MODERATE [2]
☐☐-HEAVY/SEVERE[1]

Comments: ____________

Riparian ☐ Max 10

5.]POOL/GLIDE AND RIFFLE/RUN QUALITY

MAX. DEPTH (Check 1 ONLY!)
☐- >1m [6]
☐- 0.7-1m [4]
☐- 0.4-0.7m [2]
☐- 0.2-0.4m [1]
☐- < 0.2m [POOL=0]

MORPHOLOGY (Check 1 or 2 & AVERAGE)
☐-POOL WIDTH > RIFFLE WIDTH [2]
☐-POOL WIDTH = RIFFLE WIDTH [1]
☐-POOL WIDTH < RIFFLE W. [0]
☐-IMPOUNDED [-1]
COMMENTS: ____________

CURRENT VELOCITY [POOLS & RIFFLES!] (Check All That Apply)
☐-EDDIES[1] ☐-TORRENTIAL[-1]
☐-FAST[1] ☐-INTERSTITIAL[-1]
☐-MODERATE [1] ☐-INTERMITTENT[-2]
☐-SLOW [1] ☐-VERY FAST[1]
☐-NONE [-1]

Pool/Current ☐ Max 12

CHECK ONE OR CHECK 2 AND AVERAGE

RIFFLE DEPTH	RUN DEPTH	RIFFLE/RUN SUBSTRATE	RIFFLE/RUN EMBEDDEDNESS
☐-Best Areas >10 cm [2]	☐-MAX > 50 [2]	☐STABLE (e.g.,Cobble, Boulder) [2]	☐-NONE [2]
☐-Best Areas 5-10 cm[1]	☐-MAX < 50[1]	☐MOD. STABLE (e.g.,Large Gravel) [1]	☐-LOW [1]
☐-Best Areas < 5 cm		☐UNSTABLE (Fine Gravel,Sand) [0]	☐-MODERATE [0]
☐-NO RIFFLE [Metric=0]			☐-EXTENSIVE [-1]

COMMENTS ____________

Riffle/Run ☐ Max 8

Gradient ☐ Max 10

6] GRADIENT (ft/mi): ______ DRAINAGE AREA (sq.mi.) : ______ %POOL: ☐ %GLIDE: ☐ %RIFFLE: ☐ %RUN: ☐

**Best areas must be large enough to support a population of riffle-obligate species

Modified 06/01/2005

Is Sampling Reach Representative of the Stream (Y/N)___ If Not, Explain:

Lat/Long (Beg):
Lat/Long (Mid):
Lat/Long (End):
Lat/Long(X-Loc):

Subjective Rating (1-10)

Aesthetic Rating (1-10)

Gradient: ☐ - Low, ☐ - Moderate, ☐ -High

	Gear:	Distance:	Water Clarity:	Water Stage:	Canopy -% Open
First Sampling Pass					

Stream Measurements:

Average Width	Average Depth	Maximum Depth	Av. Bankfull Width	Bankfull Mean Depth	W/D Ratio	Bankfull Max Depth	Floodprone Area Width	Entrench. Ratio

Major Suspected Sources of Impacts (Check All That Apply):
- None ☐
- Industrial ☐
- WWTP ☐
- Ag ☐
- Livestock ☐
- Silviculture ☐
- Construction ☐
- Urban Runoff ☐
- CSOs ☐
- Suburban Impacts ☐
- Mining ☐
- Channelization ☐
- Riparian Removal ☐
- Landfills ☐
- Natural ☐
- Dams ☐
- Other Flow Alteration ☐
- Other:______

Stream Drawing:

Instructions for scoring the alternate cover metric: Each cover type should receive a score of between 0 and 3, Where: 0 - Cover type absent; 1 - Cover type present in very small amounts or if more common of marginal quality; 2 - Cover type present in moderate amounts, but not of highest quality or in small amounts of highest quality; 3 - Cover type of highest quality in moderate or greater amounts. Examples of highest quality include very large boulders in deep or fast water, large diameter logs that are stable, well developed rootwads in deep/fast water, or deep, well-defined, functional pools.

Yes/No
- ☐☐ Is Stream Ephemeral (no pools, totally dry or only damp spots)?
- ☐☐ Is there water upstream? How Far:______
- ☐☐ Is There Water Close Downstream? How Far:______
- ☐☐ Is Dry Channel Mostly Natural?

Figure 5 (continued). Qualitative habitat evaluation index (QHEI) field sheet – page 2.

Reporting
A final report will be produced in accordance with the requirements of the cooperative agreement detailed work plan and grant reporting requirements.

Group B: Data Generation and Acquisition

B.1: Sampling Design Process
River locations will be sampled once or twice within a June 16 – October 15 seasonal index period as river flow, water clarity, and weather conditions permit. General reaches and sampling sites will be selected during a pre-survey planning. Specific sites will be selected prior to the initial sampling run to include representative environmental conditions and habitats available in the study area. These will match, when appropriate, historical locations that were used in the UAA study.

A longitudinal design similar to that employed by Gammon (1976), Hughes and Gammon (1987), Ohio EPA (Yoder and Smith 1999; Yoder et al. 2005), and Lyons et al. (2001) will be employed. This consists of locating sites in proximity to major sources of potential stress (major point sources, hydroelectric peaking facilities, tributary confluences), major habitat types (free-flowing, impounded, tidal estuary), and spatially so that a longitudinal profile of various fish assemblage attributes and indices can be analyzed and interpreted. Such a design represents a stratified census of the mainstem river fish assemblage and permits the demarcation of meaningful transitions that could influence the designation of TALUs.

B.2: Sampling Methods
Methods for the collection of fish will be based on appropriate modifications of those established for boat electrofishing by Ohio EPA (1989). Fish sampling procedures will be performed using boat-mounted pulsed D.C. electrofishing apparatus constructed by CABB. In addition, experimental trawling will be attempted by using an 8' Herzog Armadillo benthic trawl designed by the Missouri Department of Conservation (Herzog et al. 2005). This apparatus and method has been proven effective for the collection of benthic fishes that may not be amenable to collection by shoreline electrofishing. This method will be applied to the deeper pools and impoundments of the study area (Appendix 2). We also expect this experience to lead to more detailed methodological descriptions in future QAPP revisions.

Sampling Site Selection and Delineation
A stratified, intensive-based survey design (Yoder et al. 2005) will be used in the selection of electrofishing sites. Individual sampling sites are located along the shoreline with the most diverse habitat features in accordance with established methods (Gammon 1973, 1976; Ohio EPA 1989; Lyons et al. 2001). This is generally along the gradual outside bends of large rivers, but this is not invariable. In free-flowing habitats, a portion of each

zone should include run-riffle habitat in addition to shoal and pool habitat as each is available. Sampling distance will be measured with a GPS unit and/or a laser range finder. When using the GPS unit each zone is measured by determining lineal distance using intermediate waypoints to account for non-linear features of the river channel and the sampling track. The sampling track will also be recorded and used as an indicator of the thoroughness of the sampling at each site.

Sampling site locations are delineated using a GPS mechanism and indexed to latitude/longitude and UTM coordinates at the beginning, mid-point, and terminus of each zone and subzone if applicable. Sites will also delineated by river mile when such maps are available. The boundaries of each boat electrofishing zone or subzone are marked on stationary objects (e.g. trees, bridge piers, etc.) and fixed landmarks are geo-referenced. A detailed description of the river channel, habitat features, and sampling track is also recorded on the QHEI data sheet. This enables accurate relocation of sites in the event repeat visits are made. If the sampling zone is delineated in disjunct subzones, additional demarcations will be made. A detailed description of the sampling location should also include proximity to a fixed local landmark such as a bridge, road, discharge outfall, railroad crossing, park, tributary, dam, etc. The field crew involved with the sampling is noted on the field sheet with crew duties listed (boat driver, netters, primary I.D., etc.).

Exact sampling locations are determined in the field and include a representative proportion of reaches along the mainstem with respect to pollution sources, habitat modifications (i.e., mostly impounded sections behind dams, reaches affected by water level fluctuations below hydroelectric facilities), and relatively unmodified, free-flowing reaches.

Sampling Procedure
A boat-rigged, pulsed D.C. electrofishing apparatus is the primary gear employed in this study. This consists of a 16' john boat that is specifically constructed and modified for electrofishing. Electric current is converted, controlled, and regulated by Smith-Root 5.0 GPP alternator-pulsator that produces up to 1000 volts DC at an effective range of 8-20 amperes depending on the relative conductivity. The pulse configuration consists of a fast rise, slow decay wave that can be adjusted to 30, 60, or 120 Hz (pulses per second). Generally, electrofishing is conducted at 120 Hz, depending on which selection is producing the optimum combination of voltage and amperage output and most effectively stunning fish. This is determined on a trial and error basis at the beginning of each boat electrofishing zone and the settings will generally hold for all similar rivers and reaches. The voltage range is selected based on what percentage of the power range produces the highest amperage readings. Generally, the high range is used at conductivity readings less than 50-100 $\mu s/m^2$ and the low range is used at higher conductivities up to 1200 $\mu s/m^2$. Lower conductivities usually produce lower amperage outputs.

The electrode array consists of four 8-10' long cathodes (negative polarity; 1" diameter flexible steel conduit) which are suspended from the bow and 4 anodes (positive polarity) suspended from a retractable boom, the number used being dependent on the conductivity of the water. Each anode consists of a 3/8" woven steel cable strand 4' in length that are spaced equally on the boom cross member. Gangs of anodes can be added or detached as conductivity conditions change; anodes are increased at low conductivity and reduced at high conductivity. The anodes are suspended from a retractable boom that extends 2.75 meters in front of the bow. The width of the array is 0.9 meters. Anodes and cathodes are replaced when they are lost, damaged, or become worn.

A boat electrofishing crew consists of a boat driver and two netters. Limited access to free-flowing segments may necessitate launching at an upstream location and recovering at a downstream location. Put-in and take-out sampling is conducted where navigational barriers preclude contiguous navigation.

The accepted sampling procedure is to slowly and methodically maneuver the electrofishing boat in a *down current* direction along the shoreline maneuvering in and around submerged cover to advantageously position the netter(s) to pick up stunned and immobilized fish. This may require frequent turning, backing, shifting between forward and reverse, changing speed, etc. depending on current velocity and cover density and variability. The driver's task is to maneuver the electrofishing boat in a manner that positions the netters advantageously to pick up stunned and immobilized fish. The driver also monitors and adjusts the 5.0 GPP pulsator to provide the maximum, yet safe operational mode in terms of voltage range, pulse setting, and amperage. In areas with extensive woody debris and submergent aquatic macrophytes, it is necessary to maneuver the boat in and out of these "pockets" of habitat and wait for fish to appear within the netters field of view. In moderately swift to fast current the procedure is to electrofish with or slightly ahead of the current through the fast water sections and then return upstream to more thoroughly sample the eddies and side edges of the faster water. It is often necessary to pass over these swift water areas twice to ensure an adequate sample. Electrofishing efficiency is enhanced by keeping the boat and electric field moving with or at a slightly faster rate than the prevailing current velocity. Fish are usually oriented into the current and must turn sideways or swim into the approaching electric field to escape. As such they present an increased voltage gradient making the fish more susceptible to being immobilized by the electric current. Sampling in an upstream direction is prohibited as this compresses the electrical field towards the surface, which significantly diminishes sampling effectiveness. Although sampling effort is measured by distance, the time fished is an important indicator of adequate effort. Time fished can legitimately vary over the same distance as dictated by cover and current conditions and the number of fish encountered. In all cases, there is a minimum time that should be spent sampling each zone regardless of the catch. In our experience this is generally in the range of 2000-2500 seconds for a 0.5 km site, but could range upwards to 3500-4000 seconds where there is extensive instream cover and slack flows.

Safety features include easily accessible toggle switches on the pulsator unit and next to the driver and a foot pedal switch operated by the primary netter. The netters wear jacket style life preservers, rubber gloves, and all crew members wear chest waders. Netters are required to wear polarized sunglasses to facilitate seeing stunned fish in the water during each daytime boat electrofishing run. Boat nets with a 2.5m long handle and 7.62mm Atlas mesh knotless netting are used to capture stunned fish as they are attracted to the anode array and/or stunned. A concerted effort is made to capture every fish sighted by both the netters and driver. Since the ability of the netters to see stunned and immobilized fish is partly dependent on water clarity, sampling is conducted only during periods of "normal" water clarity and flows. Periods of high turbidity and high flows are avoided due to their negative influence on sampling efficiency. If high flow conditions prevail, sampling will be delayed until flows and water clarity return to seasonal, low flow norms. Other potential hazards in the Lower Des Plaines include commercial barge traffic and cable and line crossings. These will be dealt with by yielding to river traffic and commonly accepted navigational rules.

General Cautions Concerning Field Conditions

Electrofishing should be conducted only during "normal" summer-fall water flow and clarity conditions. What constitutes normal can vary considerably from region to region. Generally normal water conditions in the Midwest occur during below annual average river flows. Under these conditions the surface of the water generally will have a placid appearance. Abnormally turbid conditions are to be avoided as are high water levels and elevated current velocities. In addition to safety concerns, any of these conditions can adversely affect sampling efficiency and may rule out data applicability for bioassessment purposes. Since the ability of the netter to see and capture stunned fish is crucial, sampling should take place only during periods of normal water clarity and flow. Floating debris such as twigs, tree limbs, flotsam, and other trash are usually visible on the surface during elevated flow events. Such conditions should be avoided and sampling delayed until the water returns to a "normal" flow and clarity. High flows should also be avoided for obvious safety reasons in addition to the reductions in sampling efficiency. Boat mounted methods are particularly susceptible as it becomes more difficult to maneuver the boat into areas of cover and the fish assemblage is locally displaced by the elevated flow events. It may take several days or even weeks for the assemblage to return to their normal summer-fall distribution patterns. Thus sampling may need to be delayed by a similar time period if necessary. Knowing this requires local knowledge and a familiarity with flow gage readings and conditions. Generally, these conditions coincide with low flow durations of approximately 80% or greater, i.e., flows that are exceeded 80% of the time for the period of record. These statistics are available for most Midwest rivers from the U.S. Geological Survey at: http://waterdata.usgs.gov/.

Field Sample Processing Procedures

Captured fish are immediately placed in an on-board live well for processing. Water is replaced regularly in warm weather to maintain adequate dissolved oxygen levels in the water and to minimize mortality. Aeration will be provided to further minimize stress and mortality. Special handling procedures may be necessary for species of special concern. Fish not retained for voucher or other purposes are released back into the water after they are identified to species, examined for external anomalies, weighed and, if necessary, measured for total length. Every effort is made to minimize holding and handling times. The majority of captured fish are identified to species in the field; however, any uncertainty about the field identification of individual fish requires their preservation for later laboratory identification. Fish are preserved for future identification in borax buffered 10% formalin and labeled by date, river or stream, and geographic identifier (e.g., river mile). Large specimens (>50-100 mm) require visceral incision (lower right abdominal) to permit proper preservation of internal spaces and organs. After an initial fixation period of 3-4 weeks, specimens are washed in plain water and then transferred to increasing dilutions of non-denatured ethyl alcohol and water (35%, 50%) with a final solution of 70% ethyl alcohol. This process takes approximately 4-5 weeks to complete. Identification is performed to the species level at a minimum and it may be necessary to the sub-specific level in certain instances. Regional ichthyology keys are used. Assistance with the verification of voucher specimens has been provided by The Ohio State University Museum of Biodiversity (OSUMB). Representative fish voucher specimens are retained at CABB for the purpose of confirming later identifications and at the OSUMB to serve as a permanent record. Photographs may also used to record species occurrences, particularly larger species that are not as easily preserved and stored. Photographs are maintained by CABB in an archived electronic file.

The sample from each zone or subzone is processed by enumerating and recording weights by species or by species age class when this is distinguished. Fish weighing less than 1000 grams are weighed to the nearest gram on a spring dial scale (1000 g x 2g) or a 1000 g hand held spring scale. Fish weighing more than 1000 grams are weighed to the nearest 25 grams on a 12 kg spring dial scale (12 kg x 50 g) or a 50 kg hand held spring scale. Scales are periodically checked with National Bureau of Standards check weights and adjusted accordingly. Samples comprised of two or more distinct size classes of fish (e.g., y-o-y, juveniles, and adults) are processed separately. These are recorded on the field data sheet by designating an A (adult), B (1+ year), or Y (young-of-year) to the numeric species code. For example, if both adult and juvenile white suckers occur in the same sample the adult numbers and weights are recorded as family-species code 40-016A with juvenile numbers and weights recorded as 40-016B. Although each is listed separately on the fish data sheet they can be treated in the aggregate as a single sample of the same species in any subsequent data analyses or as distinct size class entities. The data management programs used by CABB are designed to calculate relative numbers and biomass data based on the input of weighted subsamples. Total lengths may be recorded for important commercial, recreational, ecological, and special interest species. Larval and/or post-larval fish measuring less than 15-20 mm in length are generally not included in the data recording as a matter of practice following the recommendations of Angermeier and Karr (1986).

The incidence of external anomalies is recorded following procedures outlined by Ohio EPA (1989) and refinements made by Sanders et al. (1999). The frequency of DELT anomalies (deformities, eroded fins and body parts, lesions, and tumors) is a good indication of chronic stress caused by biological agents, intermittent stresses, and chemical contaminants. The percentage of DELT anomalies is a metric that is included in most of the large river fish assemblage IBIs that have been developed across the U.S.

A qualitative habitat assessment using an appropriate modification of the Qualitative Habitat Evaluation Index (QHEI; Ohio EPA 1989; Rankin 1989) is completed by the crew leader at each 1.0 km site. The QHEI is a physical habitat index designed to provide an empirical, qualitative evaluation of the lotic macrohabitat characteristics that are important to fish assemblages. The QHEI was developed as a rapid assessment tool and in recognition of the constraints associated with the practicalities of conducting a large-scale monitoring program, i.e., the need for a rapid assessment tool that yields meaningful information and which takes advantage of the knowledge and insights of experienced field biologists who are conducting biological assessments. This index has been used widely outside of Ohio and parallel habitat evaluation techniques are in widespread existence throughout the U.S. The QHEI incorporates the types and quality substrate, the types and amounts of instream cover, several characteristics of channel morphology, riparian zone extent and quality, bank stability and condition, and pool-run-riffle quality and characteristics. Slope or gradient is also factored into the QHEI score. We followed the guidance and scoring procedures outlined in Ohio EPA (1989) and Rankin (1989) with some minor modifications made during 2002 and 2003. A QHEI users guide appears in Appendix 1. A QHEI habitat assessment form is completed by the crew leader for each 1.0 km site (see example in Figure 5).

Method Performance Evaluation
The principal investigator will be responsible for evaluating the performance of the methods used in this project and for making decisions about appropriate modifications to those described in this section. In some cases an evaluation will be made based on preliminary data analyses conducted during the field sampling part of the project. In other instances, the assessment of method performance will be a part of the data analysis conducted following the field season. This latter information will be used to better develop and refine the methods prior to their wider application to other rivers.

B.3: Sampling Handling and Custody
The principal sample product produced by this project will be completed field forms for the boat electrofishing results and the qualitative habitat assessment. All completed field data sheets are logged by the field crew leader to prevent loss and assure that all sites are sampled according to the detailed plan of study. Data is then entered into the Ohio ECOS data management system, which was developed by Ohio EPA for the purpose of storing and analyzing fish relative abundance data. Data are entered in the format presented in the field data sheet (Figures 4 and 5). Each data entry contains the basin-river code, date of

entry, GPS coordinates, river mile, and date of sampling. The data sheets are assembled in a notebook along with site description sheets, maps of the sampling sites, the QHEI field sheet, and the final study plan. Each entry is checked and initialed; any subsequent changes that are made to the fish data sheets are also initialed and dated. After all data have been entered into Ohio ECOS the entries are proofread by the data entry analyst for accuracy. All corrections or updates are then entered into the database. The initialed data sheets also serve as a chain-of-custody for the data collection process.

B.4: Analytical Methods
The principal analytical tools used in this project are those associated with data analysis and the biological indices. This will be performed on personal computers using relational databases such as FoxPro, Access, and Excel. CABB currently uses the data storage, retrieval, and calculation routines available in the Ohio ECOS system developed and used by Ohio EPA. Appropriate modifications to those routines have been made as an outcome of the data analysis part of the project.

B.5: Quality Control
Quality control of boat electrofishing includes monitoring the power output variables, which is performed by the crew leader during the sampling. These output variables are recorded on the field sheet and are described in more detail in B.2. Other important measures of adequate effort include time electrofished and the effort made by the netters to capture stunned and immobilized fish. There is an inherent degree of judgment involved in the assessment of individual crew member performance and this will be performed by the principal investigator. The quality of identifications made in the field will be evaluated by the principal investigator and also based on the retention of voucher specimens that will be verified independent of the field crew. Any samples that are deemed unacceptable will either be repeated or denoted in the database. This latter denotation may limit or disqualify the use of the data in some of the analyses and computations that will be performed later.

B.6: Instrument/Equipment Testing, Inspection, and Maintenance
The electrofishing equipment is evaluated for performance during all phases of sampling as described previously in B.2. All connections and switches must be in good condition to ensure acceptable performance and are inspected several times each day by the sampling crew. Malfunctioning and worn parts are replaced immediately. All engines undergo maintenance as prescribed by the manufacturer for intensive use. Analytical field meters used by the sampling crew are maintained in accordance with the manufacturer's specifications.

B.7: Instrument/Equipment Calibration and Frequency
The electrofishing equipment is calibrated to local water conditions at the beginning of each sampling zone (see B.2). Field meters are calibrated in accordance with the

manufacturer's recommendations and specifications and in accordance with the specifications in Table 3.

B.8: Inspection/Acceptance of Supplies and Consumables

All supplies used in this project undergo an initial inspection for usability and suitability. No chemical reagents or analytical sensitive supplies will be used in this project.

B.9: Non-direct Measurements

We will make an effort to access historical information about the fish fauna of the study rivers. This will be especially valuable in constructing the qualitative attributes of the Biological Condition Gradient. Some expert judgment may be necessary to evaluate the quality and accuracy of this information. It is unlikely that historical data will support the analyses envisioned by this project and its use will likely be restricted to qualitative uses.

B.10: Data Management

CABB uses an adaptation of the Ohio ECOS data management system developed to store, retrieve, and analyze biological and habitat assessment data and information. Fish assemblage data are entered directly via the electronic data entry routine from the field sheets (Figures 4 and 5). All data entry codes follow those specified in Ohio EPA (1987) and those added by CABB for non-Ohio fish species. All entries are proofread by the data entry analyst and corrections are made in the electronic database. All corrections are noted and initialed by the data entry operator and confirmed by the project manager. Other checks on data entry accuracy are made via the routine processing and analysis of the data. The procedure for retaining and filing of data sheets and field notes was described in B.2.

Group C: Assessment and Oversight

C.1: Assessments and Response Actions

Due to the scope and experimental character of the project, much of the assessment and oversight will be the responsibility of the principal investigator and the lead scientist for the contractor. However, the stakeholder organizations will be afforded an opportunity to make inspections and audits of the field sampling, the equipment, and the results. This will be coordinated by the principal investigator.

Table 3. Field analytical instrument calibration specifications.

Instrument	Calibration Activity	Frequency of Calibration	Acceptance Criteria	Corrective Action
Temperature	Check against NIST certified Thermometer	Check prior to beginning of survey	± 1 EC of NIST thermometer	Adjust or replace probe/meter
D.O.	Calibrate with saturated moist air; check with 0.0 D.O. std.	Daily prior to use; check at end of day	±0.5 mg/l from 0.0 std.	If D.O. exceeds criteria prepare fresh 0.0 std., clean probe, change membrane; recalibrate; qualify data.
Conductivity	Calibrate with single point standard; check with standard in range of samples.	Daily prior to use; check calibration at end of day.	10% of true value of check standard	If conductivity exceeds criteria prepare fresh Standard and re-Calibrate; qualify data accordingly.
Secchi Disk	Check reading with second sampler.	10% of locations.	±0.2 meters	Check second sampler readings until agreement is reached; qualify data accordingly.

C.2: Reports to Management

The principal investigator will include a report on this project in the final grant report to the U.S. EPA project officer with distribution to all parties listed in A.3. Recipients may comment directly to the principal investigator or the EPA project officer.

Group D: Data Validation and Usability

D.1: Data Review, Validation, and Verification

Data acceptance will initially be evaluated in the field using the processes described in B.2 and B.5. However, later inspection of the data may also raise issues of acceptance such as identification problems and issues. An attempt will be made to reconcile any inconsistencies or issues prior to disqualifying data.

D.2: Verification and Validation of Methods

Most of the raw data will be field validated in accordance with the processes described in B.2, B.3, B.4, and B.10. Post-sampling validation will entail verification of identifications made in the field and later in the laboratory.

Analyses have already been performed to determine the minimum sampling distance required to generate data and information adequate for producing a consistent assessment of the health and well-being of the fish assemblage (Gammon 1976; Yoder and Smith 1999). This entailed an analysis of the effect of increasing distance on assemblage parameters such as species richness and catch per unit effort both in terms of fish numbers and biomass. This was performed by sequentially adding data from 0.25 km subzones over 1.5 km long test zones and analyzing the effect of the cumulative addition of information on selected assemblage attributes. The influence of time electrofished and variations in physical parameters such as conductivity, temperature, and zone depths was also analyzed by these studies.

D.3: Reconciliation with User Requirements

The sampling and analytical approach used in this project are designed to provide the opportunity to adjust and modify methods as appropriate to obtain results that meet the project goals and objectives. The initial scoping and shakedown sampling produced the data necessary to make adjustments, modifications, and refinements to the methods described in B.2. Other changes and modifications may not be apparent until later during the project and the data are more fully analyzed and discussed. These changes will be documented in periodic reports and will include a detailed description of all data analyses used.

References

Angermier, P.L. and J.R. Karr. 1986. Applying an index of biotic integrity based on stream-fish communities: considerations in sampling and interpretation. N. Am. J. Fish. Mgmt. 6: 418-427.

Bayley, P.B., Larimore, R.W., and Dowling, D.C. 1989. Electric seine as a fish-sampling gear in streams. Trans. Am. Fish. Soc. 118: 447-453.

Blocksom, K.A. and J.E. Flotemersch. 2004. Comparison of macroinvertebrate sampling methods for non-wadeable streams. Env. Mon. Assess. (xxx): 1-20.

Boccardy, J.A. and E.L. Cooper. 1963. The use of rotenone and electrofishing in surveying small streams. Trans. Am. Fish. Soc. 92: 307-310.

Emery, E. B., T. P. Simon, F. H. McCormick, P. A. Angermeier, J. E. DeShon, C. O. Yoder, R. E. Sanders, W. D. Pearson, G. D. Hickman, R. J. Reash, J. A. Thomas. 2003. Development of a Multimetric Index for Assessing the Biological Condition of the Ohio River. Trans. Am. Fish. Soc. 132:791-808.

Davis, W.S. and T.P. Simon. 1995. Biological criteria and assessment: tools for water resource planning and decision making. Lewis Publishers, Boca Raton, FL. 415 pp.

Fausch, K. D., J. R. Karr, and P. R. Yant. 1984. Regional application of an index of biotic integrity based on stream fish communities. Trans. Am. Fish. Soc. 113: 39-55.

Fore, L.S., J.R. Karr, and L.L. Conquest. 1993. Statistical properties of an index of biotic integrity used to evaluate water resources. Can. J. Fish. Aquatic Sci. 51: 1077-1087.

Funk, J.L. 1958. Relative efficiency and selectivity of gear used in the study of stream fish populations. 23rd N.Am. Wildl. Conf. 23: 236-248.

Gammon, J.R., Spacie, A., Hamelink, J.L., and R.L. Kaesler. 1981. Role of electrofishing in assessing environmental quality of the Wabash River, in Ecological assessments of effluent impacts on communities of indigenous aquatic organisms, in Bates, J. M. and Weber, C. I., Eds., ASTM STP 730, 307 pp.

Gammon, J.R. 1980. The use of community parameters derived from electrofishing catches of river fish as indicators of environmental quality. pp. 335-363 in Seminar on water quality management trade-offs (point source vs. diffuse source pollution). EPA-905/9-80-009.

Gammon, J.R. 1976. The fish populations of the middle 340 km of the Wabash River, Purdue Univ. Water Res. Research Cen. Tech. Rep. 86. 73 p.

Gammon, J.R. 1973. The effect of thermal inputs on the populations of fish and macroinvertebrates in the Wabash River. Purdue Univ. Water Res. Research Cen. Tech. Rep. 32. 106 pp.

Hendricks, M.L., C.H. Hocutt, and J.R. Stauffer. 1980. Monitoring of fish in lotic habitats, pp. 205-231. in C.H. Hocutt and J.R. Stauffer (eds.). Biological Monitoring of Fish. Heath, Lexington, MA.

Herzog, D.P., V.A. Barko, J.S. Scheibe, R.A. Hrabik, and D.E. Ostendorf. 2005. The efficacy of a benthic trawl for sampling small-bodied fishes in large river systems. N. Am. J. Fish. Mgmt. 25: 594-603.

Hey and Associates. 2003. Lower Des Plaines river use attainability analysis (draft). Prepared for Illinois Environmental Protection Agency. 8 chapters + appendices.

Hughes, R.M. and J.R. Gammon. 1987. Longitudinal changes in fish assemblages and water quality in the Willamette River, Oregon. Trans. Am. Fish. Soc., 116: 196-209.

Karr, J. R. 1991. Biological integrity: A long-neglected aspect of water resource management. Ecological Applications 1(1): 66-84.

Karr, J. R., K. D. Fausch, P. L. Angermier, P. R. Yant, and I. J. Schlosser. 1986. Assessing biological integrity in running waters: a method and its rationale. Illinois Natural History Survey Special Publication 5: 28 pp.

Larimore, R.W. 1961. Fish populations and electrofishing success in a warmwater stream. J. Wildl. Mgmt. 25(1): 1-12.

Lyons, John, R.R. Piette, and K.W. Niermeyer. 2001. Development, validation, and application of a fish-based index of biotic integrity for Wisconsin's large warmwater rivers. Trans. Amer. Fisheries Society: Vol. 130, No. 6, pp. 1077–1094.

Mebane, C.A., T.R. Maret, and R.M. Hughes. 2003. An index of biotic integrity (IBI) for Pacific Northwest rivers. Trans. Am. Fish. Soc. 132: 239-261.

Midwest Biodiversity Institute. 1999. Application for a cooperative agreement between the U.S Environmental Protection Agency and the Midwest Biodiversity Institute for technical assistance, concept development and application, conferences, symposia, training, and other activities on biological monitoring and assessment and biological criteria issues. MBI, Columbus, OH. 11 pp.

Nelson,J.S. and 6 others. 2004. Common and Scientific Names of Fishes from the United States, Canada, and Mexico. Sixth Edition. American Fisheries Society Spec. Publ. 29. 386 pp.

Novotny, D.W. And G.R. Priegel. 1974. Electrofishing boats, improved designs, and operational guidelines to increase the effectiveness of boom shockers. Wisc. DNR Tech. Bull. No. 73, Madison, WI. 48 pp.

Ohio Environmental Protection Agency. 1989. Biological criteria for the protection of aquatic life. volume III: standardized biological field sampling and laboratory methods for assessing fish and macroinvertebrate communities, Division of Water Quality Monitoring and Assessment, Surface Water Section, Columbus, Ohio.

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

Rankin, E.T. 1995. Habitat indices in water resource quality assessments, *in* W.S. Davis and T.P. Simon (Eds.), Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making, Lewis Publishers, Boca Raton, FL, 181-208.

Rankin, E.T. and C.O. Yoder. 1999. Adjustments to the Index of Biotic Integrity: a summary of Ohio experiences and some suggested modifications, pp. 625-638. . *in* T.P. Simon (ed.), Assessing the Sustainability and Biological Integrity of Water Resources Using Fish Communities. CRC Press, Boca Raton, FL.

Sanders, R.S. 1992. Day versus night electrofishing catches from near-shore waters of the Ohio and Muskingum Rivers. Ohio J. Sci. 92: 51-59.

Simon, T.P. and R.E. Sanders. 1999. Applying an index of biotic integrity based on great river fish communities: considerations in sampling and interpretation, pp. 475-506. *in* T.P. Simon (ed.), Assessing the Sustainability and Biological Integrity of Water Resources Using Fish Communities. CRC Press, Boca Raton, FL.

Simon, T.P. and E.B. Emery. 1995. Modification and assessment of an index of biotic integrity to quantify water resource integrity in great rivers. Regulated Rivers Research and Management, 11: 283-298.

Simon, T.P. and J. Lyons. 1995. Application of the index of biotic integrity to evaluate water resource integrity in freshwater ecosystems, pp. 245-262. *in* W.S Davis and T.P. Simon (eds.). Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Thoma, R.F. 1999. Biological monitoring and an index of biotic integrity for Lake Erie's nearshore waters, pp. 417-462. *in* T.P. Simon (ed.), Assessing the Sustainability and Biological Integrity of Water Resources Using Fish Communities. CRC Press, Boca Raton, FL.

U.S. Environmental Protection Agency. 1995b. Biological criteria: technical guidance for streams and small rivers. EPA 822-B-94-001, U. S. EPA, Office of Water (WH 4304), Washington, D. C. 20460. 162 pp.

U.S. Environmental Protection Agency. 1990. Biological Criteria, national program guidance for surface waters. U. S. EPA, Office of Water Regulations and Standards, Washington, D. C. EPA-440/5-90-004.

Vincent, R. 1971. River electrofishing and fish population estimates. Prog. Fish Cult. 33(3): 163-169.

Yoder, C.O. and 9 others. 2005. Changes in fish assemblage status in Ohio's non-wadeable rivers and streams over two decades. *in* R. Hughes and J. Rinne (eds.). Historical changes in fish assemblages of large rivers in the America's. American Fisheries Society Symposium Series (in press).

Yoder, C.O. and M.A Smith. 1999. Using fish assemblages in a state biological assessment and criteria program: essential concepts and considerations, pp. 17-56. *in* T.P. Simon (ed.), Assessing the Sustainability and Biological Integrity of Water Resources Using Fish Communities. CRC Press, Boca Raton, FL.

Yoder, C.O. and E.T. Rankin. 1998. The role of biological indicators in a state water quality management process. J. Env. Mon. Assess. 51(1-2): 61-88

Yoder, C.O. and E.T. Rankin. 1995. Biological criteria program development and implementation in Ohio, pp. 109-144. in W. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Appendix 1

Methods for Assessing Habitat in Flowing Waters: Using the Qualitative Habitat Evaluation Index (QHEI)

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Methods for Assessing Habitat in Flowing Waters: Using the Qualitative Habitat Evaluation Index (QHEI)

Introduction

This document summarizes the methodology for completing a general evaluation of macrohabitat, generally done by the fish field crew leader while sampling each location using the Ohio EPA Site Description Sheet - Fish (Appendix 1). This form is used to tabulate data and information for calculating the Qualitative Habitat Evaluation Index (QHEI). The following guidance should be used when completing the site evaluation form.

Header/Geographical Information

Complete site identification information is critical to making field data useful. Figure 1 illustrates the location information required for the QHEI.

OhioEPA Qualitative Habitat Evaluation Index and Use Assessment Field Sheet QHEI Score:

Stream & Location: ________ RM: ___._ Date: __/__/ 06

________ Scorers Full Name & Affiliation: ________

River Code: __-___-___ STORET #: ______ Lat./ Long.: (NAD 83 - decimal °) __._____ /8_._____ Office verified location ☐

Figure 1. Header of Ohio EPA QHEI Sheet

1) Stream & Location, River Mile (RM), Date. The official stream name may be found in the Gazetteer of Ohio Streams (Ohio DNR 2001) or on USGS 7.5 minute topographic maps. If the stream is unnamed, a name and stream code is assigned by the Ohio ECOS Database Coordinator. Usually the name of a nearby landmark is used for the stream name. The River Mile (RM) designations used are found on 7.5 minute topo maps stored at the Ohio EPA, Division of Surface Water, Lazarus Government Center, Front Street (PEMSO RMI maps), one of five Ohio EPA District offices (maps for that district), and the Ohio EPA, Ecological Assessment Section at Grove City. These maps should soon be available as Adobe PDF files. A brief description of the sampling location should include proximity to a local landmark such as a bridge, road, discharge outfall, railroad crossing, park, tributary, dam, etc.

2) QHEI Scorers Full Name/Institution. The full name of the person who filled out the sheet are listed, along with the institution, company etc. QHEI information is to be completed someone who has successfully completed the QHEI training (e.g., crew leader). Ohio EPA will track the level of qualifications for each scorer. Level 2 QHEI practitioners have completed the two day training and successfully scored an additional site in a manner similar to EPA staff; Level 3 practitioners have additional training and have submitted three sites scored independently which will be verified as similar to EPA staff.

3) River Code, STORET, and Lat/Long. The River Code is Ohio EPA river code (PEMSO system) and the STORET # is the official unique Station Identifier used to link all data collected at a given "site" or "station" deemed to be similar for assessment purposes within a certain spatial area.

Habitat Characteristics: QHEI Metrics

The Qualitative Habitat Evaluation Index (QHEI) is a physical habitat index designed to provide an empirical, quantified evaluation of the general lotic macrohabitat characteristics that are important to fish communities. A detailed analysis of the development and use of the QHEI is available in Rankin (1989) and Rankin (1995). The QHEI is composed of six principal metrics each of which are described below. The maximum possible QHEI site score is 100. Each of the metrics are scored individually and then summed to provide the total QHEI site score. This is completed at least once for each sampling site during each year of sampling. An exception to this convention would be when substantial changes to the macrohabitat have occurred between sampling passes. Standardized definitions for pool, run, and riffle habitats, for which a variety of existing definitions and perceptions exist, are essential for accurately using the QHEI. For consistency the following definitions are taken from Platts et al. (1983). It is recommended that this reference also be consulted prior to scoring individual sites.

Riffle and Run Habitats:

Riffle - areas of the stream with fast current velocity and shallow depth; the water surface is visibly broken.

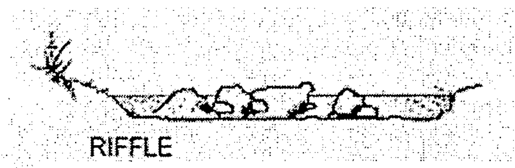


Figure 2. Riffle cross-section.

Run - areas of the stream that have a rapid, non-turbulent flow; runs are deeper than riffles with a faster current velocity than pools and are generally located downstream from riffles where the stream narrows; the stream bed is often flat beneath a run and the water surface is not visibly broken.

Figure 3. Run cross-section.

Pool and Glide Habitats:

Pool - an area of the stream with slow current velocity and a depth greater than riffle and run areas; the stream bed is often concave and stream width frequently is the greatest; the water surface slope is nearly zero.

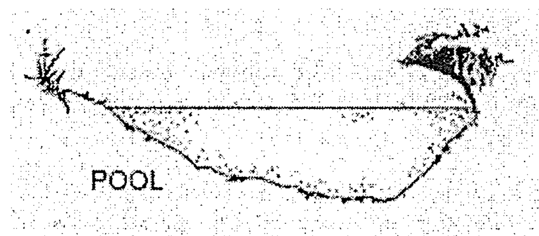


Figure 4. Pool cross-section.

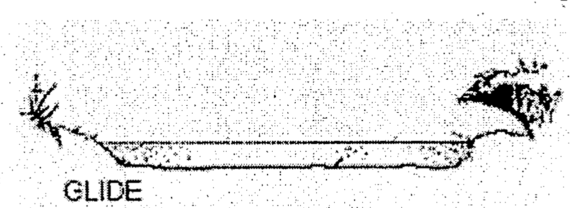


Figure 5. Glide cross-section.

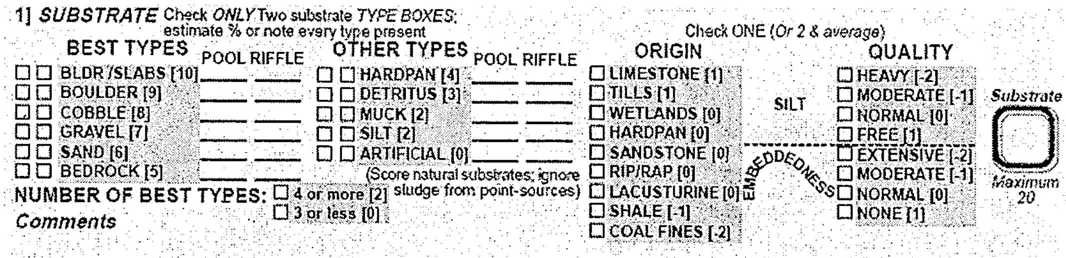
Glide - this is an area common to most modified stream channels that do not have distinguishable pool, run, and riffle habitats; the current and flow is similar to that of a canal; the water surface gradient is nearly zero. HINT: These habitat types typically grade into one another. For example a run gradually changes into a pool. When measuring typical depths of these features take measurements where the feature is clearly of that type, not where they are grading from one type to another. The following is a description of each of the six QHEI metrics and the individual metric components. Guidelines on how to score each is presented. Generally, metrics are scored by checking boxes. In certain cases the biologist completing the QHEI sheet may interpret a habitat characteristic as being intermediate between the possible choices; in cases where this is allowed (denoted by the term "Double-Checking") two boxes may be checked and their scores averaged.

Metric 1: Substrate (Figure 6).

This metric includes two components, substrate type[1] and substrate quality. **Substrate type** Check the two most common substrate types in the stream reach. If one substrate type predominates (greater than approximately 75- 80% of the bottom area OR what is clearly the most functionally predominant substrate) then this substrate type should be checked twice. **DO NOT CHECK MORE THAN TWO BOXES.** Note the category for artificial substrates. Spaces are provided to note the presence (by check marks, or estimates of % if time allows) of all substrate types present in pools (includes pools and glides) and riffles (includes riffles and runs) that each comprise sufficient quantity to support species that may commonly be associated with

[1] We suggest that QHEI practitioners should conduct some pebble count assessments which help calibrate an investigators ability to identify predominant substrates.

that substrate type. This section must be filled out completely to permit future analyses of this metric. If there are more than four or more high quality substrate types in the zone that are present in sufficient amounts (see above) then check the appropriate box for number of best types. This metrics award points to those sites with a diversity of high quality substrate types. Substrate origin refers to the parent material from which the substrate type(s) originated. This can be double-checked if two origin types are common (e.g., tills & limestone). See end of this section for some definitions.



1] SUBSTRATE Check ONLY Two substrate TYPE BOXES; estimate % or note every type present

BEST TYPES	POOL	RIFFLE	OTHER TYPES	POOL	RIFFLE
☐☐ BLDR /SLABS [10]	___	___	☐☐ HARDPAN [4]	___	___
☐☐ BOULDER [9]	___	___	☐☐ DETRITUS [3]	___	___
☐☐ COBBLE [8]	___	___	☐☐ MUCK [2]	___	___
☐☐ GRAVEL [7]	___	___	☐☐ SILT [2]	___	___
☐☐ SAND [6]	___	___	☐☐ ARTIFICIAL [0]	___	___
☐☐ BEDROCK [5]	___	___	(Score natural substrates; ignore sludge from point-sources)		

NUMBER OF BEST TYPES: ☐ 4 or more [2] ☐ 3 or less [0]

Comments

Check ONE (Or 2 & average)

ORIGIN: ☐ LIMESTONE [1] ☐ TILLS [1] ☐ WETLANDS [0] ☐ HARDPAN [0] ☐ SANDSTONE [0] ☐ RIP/RAP [0] ☐ LACUSTURINE [0] ☐ SHALE [-1] ☐ COAL FINES [-2]

QUALITY

SILT: ☐ HEAVY [-2] ☐ MODERATE [-1] ☐ NORMAL [0] ☐ FREE [1]

EMBEDDEDNESS: ☐ EXTENSIVE [-2] ☐ MODERATE [-1] ☐ NORMAL [0] ☐ NONE [1]

Substrate

Maximum 20

Figure 6. QHEI substrate metric.

Substrate quality.

Substrate origin refers to the "parent" material that the stream substrate is derived from. Check ONE box under the substrate origin column unless the parent material is from multiple sources (e.g., limestone and tills).

Embeddedness is the degree that cobble, gravel, and boulder substrates are surrounded, impacted in, or covered by fine materials (sand and silt). Substrates should be considered embedded if >50% of surface of the substrates are embedded in fine material. Embedded substrates cannot be easily dislodged. This also includes substrates that are concreted or "armor-plated". Naturally sandy streams are not considered embedded; however, a sand predominated stream that is the result of anthropogenic activities that have buried the natural coarse substrates is considered embedded. This can be very difficult to perceive. One help is to examine fresh point bars and look at the most common large materials that have been recently moved. According to Kappesser (1993), for gravel-bed rivers, the median of these large pieces should be equivalent to the median of the pieces on a riffle (based on a Wolman pebble count). If the riffles are finer than this, then sediment is aggrading in the reach and is evidence of embedded conditions. In some cases one can dig though the fine surface materials and fine coarser materials buried below. In this metric we are estimating the

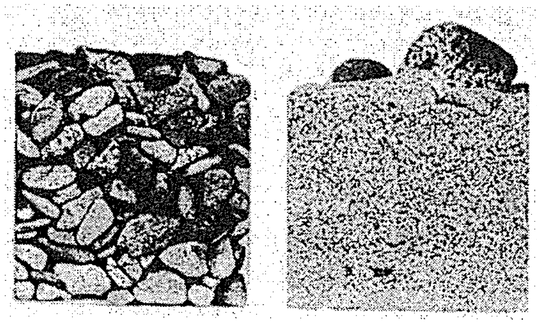


Figure 7. Side view of clearly un-embedded and embedded substrates.

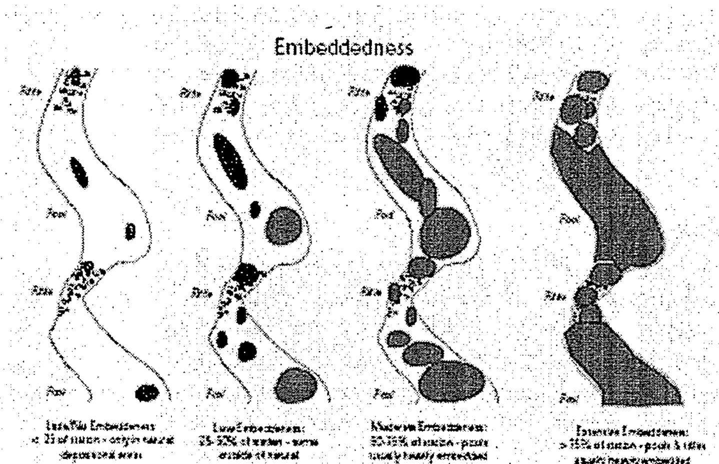


Figure 8. Illustration of example of degrees of pervasiveness of embeddedness for this QHEI component.

<u>pervasiveness</u> of embedded conditions through-out a station. Boxes are checked for extensiveness (*i.e.*, pervasiveness throughout the area of the sampling zone) of the embedded substrates as follows: Extensive – > 75% of site area, Moderate – 50-75%, Normal[2] – 25-50%, None[3] – < 25%.

Silt Cover is the extent that substrates are covered by a silt layer (*i.e.*, a 1 inch thick or obviously affecting aquatic habitats). Silt cover differs from the embeddedness metric in that it only considers the fine silt size particles whereas fine gravels, sands, and other fines are considered in assessing embedded conditions. **Silt Heavy** means that nearly the entire stream bottom is layered with a deep covering of silt. (pool/glides and all but the fastest areas of riffle/runs). **Moderate** means extensive covering by silts, but with some areas of cleaner substrate (*e.g.*, riffles). **Normal** silt cover includes areas where silt is deposited in small amounts along the stream margin or is present as a "dusting" that appears to have little functional significance. If substrates are exceptionally clean the **Silt Free** box should be checked.

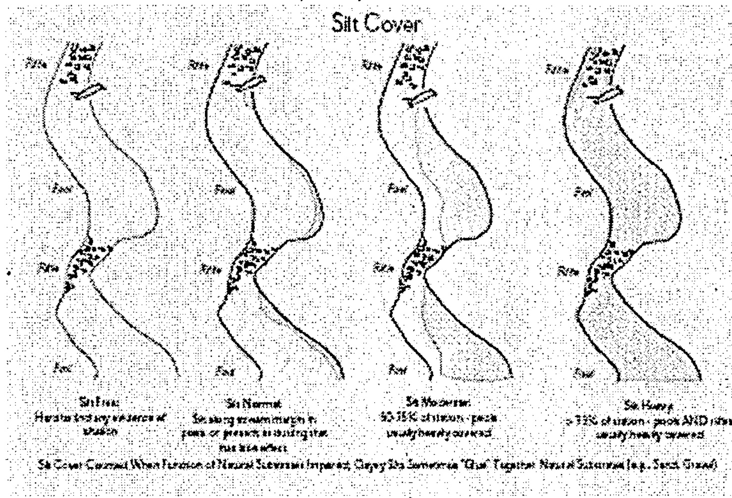


Figure 9. Illustration of example of degrees of pervasiveness of silt cover.

Substrate types are defined as:

a) **Bedrock** - solid rock forming a continuous surface.

b) **Boulder** - rounded stones over 256 mm in diameter (10 in.) or large "slabs" more than 256 mm in length (Boulder slabs)[4].

c) **Cobble** - stones from 64- 256 mm (2 1/2 - 10 in.) in diameter.

d) **Gravel** - mixture of rounded course material from 2-64 mm (1/12 - 2 1/2 in.) in diameter. Note the wide range of sizes included under gravel. In the riffle metric we distinguish between large and fine gravels

e) **Sand** - materials 0.06 - 2.0 mm in diameter, gritty texture when rubbed between fingers.

f) **Silt** - 0.004 - 0.06 mm in diameter, generally this is fine material which feels "greasy" when rubbed between fingers.

g) **Hardpan** - particles less than 0.004 mm in diameter, usually clay, which forms a dense, gummy surface that is difficult to penetrate.

h) **Marl** - calcium carbonate; usually grayish-white; often contains fragments of mollusk shells.

i) **Detritus** - dead, unconsolidated organic material covering the bottom which could include sticks, wood and other partially or un-decayed coarse plant material.

j) **Muck** - black, fine, flocculent, completely decomposed organic matter (does not include sewage sludge).

k) **Artificial** - substrates such as rock baskets, gabions, bricks, trash, concrete etc., placed in the stream for reasons OTHER than habitat mitigation.

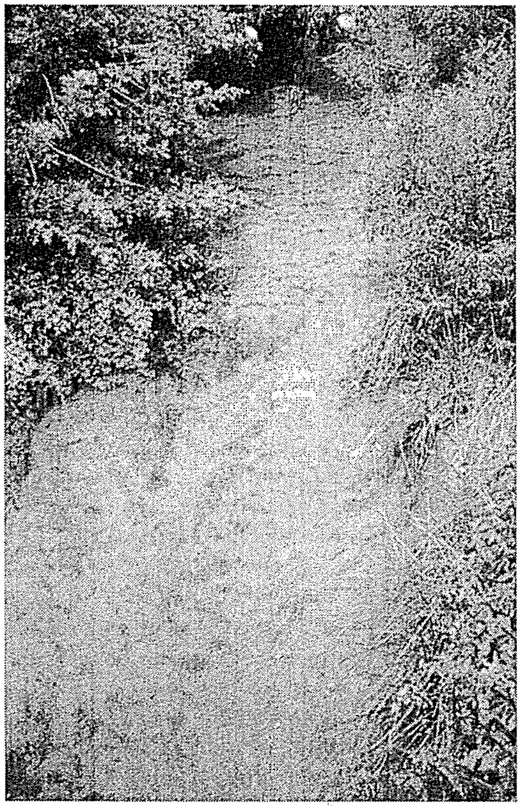
Sludge is defined as a thick layer of organic matter that is decidedly of human or animal origin. NOTE: SLUDGE THAT ORIGINATES FROM POINT SOURCES IS NOT INCLUDED; THE SUBSTRATE SCORE IS BASED ON THE UNDERLYING MATERIAL. This scenario is rare today and was done to prevent underestimating stream habitat potential affect by discharges.

Substrate Metric Score: Although the sum of the individual metric scores can be greater than 20 the maximum substrate core allowed for this metric is 20 points.

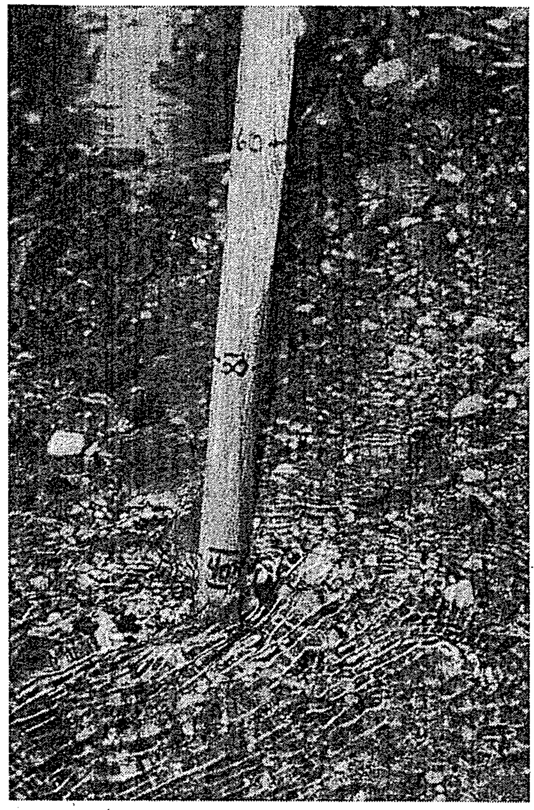
[2] In some earlier training materials "normal" was described as "low" (e.g., see Figure 7).

[3] In some earlier training materials "None" was described as "little-no" (e.g., see Figure 7).

[4] A version of the QHEI used in Maine distinguishes large boulders.



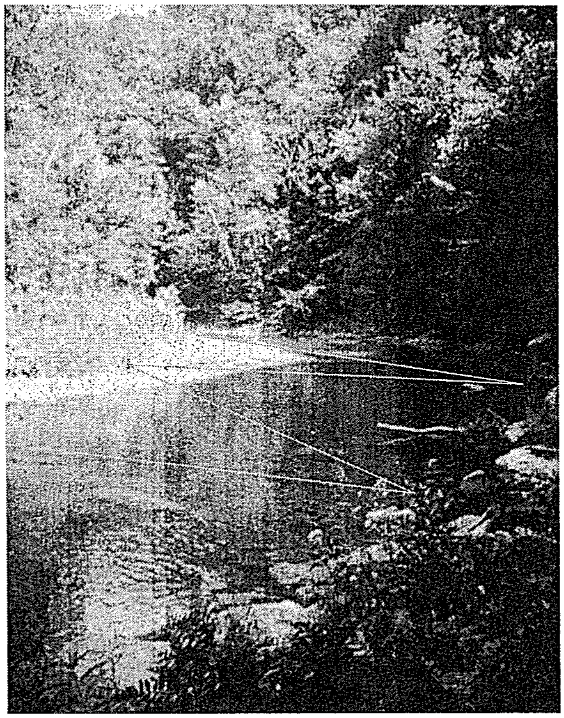
Example of stream with heavily embedded substrates.



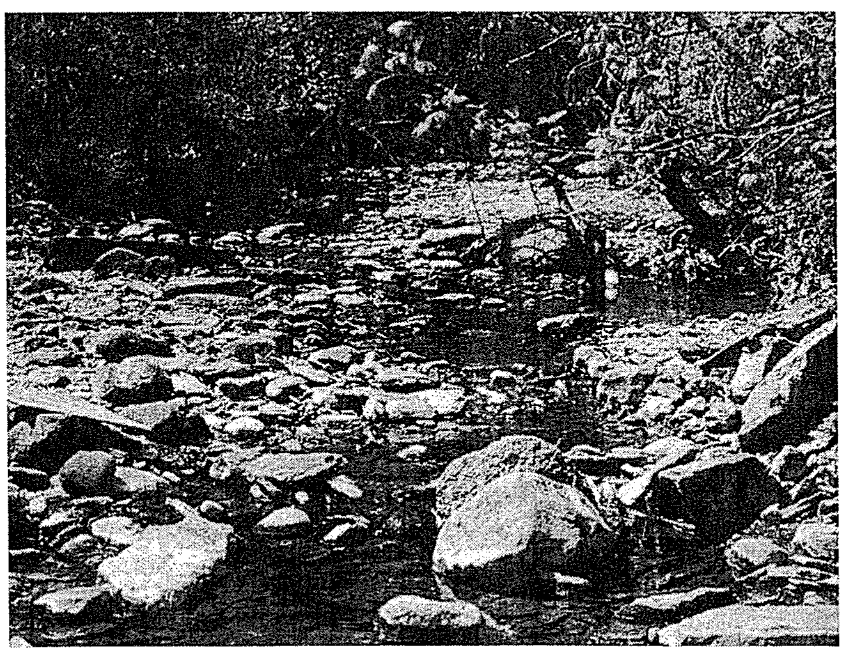
Example of spongy deposits of fine gravels and sands from recent erosion activities.

Substrate Origin Identification Tips:

- Limestone: Often contains fossils, easily scratched with knife, usually bedrock or flat boulders and cobbles
- Tills: Sediments deposited by glaciers; particles often rounded. Can be carried into non-glaciated areas
- Wetlands: Usually organic muck and detritus
- Hardpan: Clay – smooth, usually slippery
- Sandstone: Contains rounded fragment of sand "cemented" together
- Rip/Rap: Artificial boulders
- Lacustrine: Old lake bed sediments
- Shale: "Claystone," sedimentary rock made of silt/clay, soft and cleaves easily
- Coal Fines: Black fragments of coal, generally SE Ohio only



We suggest that QHEI practitioners gain some experience in pebble count procedures. Conducting Wolman or Zig-Zag pebble counts helps to improve the ability to visually estimate predominant substrate sizes and size categories.



Stream characterized by cobble and boulder-size substrates.

2] *INSTREAM COVER* Indicate presence 0 to 3: 0-Absent; 1-Very small amounts or if more common of marginal quality; 2-Moderate amounts, but not of highest quality or in small amounts of highest quality; 3-Highest quality in moderate or greater amounts (e.g., very large boulders in deep or fast water, large diameter log that is stable, well developed rootwad in deep / fast water, or deep, well-defined, functional pools.

AMOUNT
Check ONE (*Or 2 & average*)

____ UNDERCUT BANKS [1] ____ POOLS > 70cm [2] ____ OXBOWS, BACKWATERS [1] ☐ EXTENSIVE >75% [11]
____ OVERHANGING VEGETATION [1] ____ ROOTWADS [1] ____ AQUATIC MACROPHYTES [1] ☐ MODERATE 25-75% [7]
____ SHALLOWS (IN SLOW WATER) [1] ____ BOULDERS [1] ____ LOGS OR WOODY DEBRIS [1] ☐ SPARSE 5-<25% [3]
____ ROOTMATS [1] ☐ NEARLY ABSENT <5% [1]

Comments *Cover Maximum 20*

Figure 10. Instream cover (structure) metric.

Metric 2: Instream Cover (Figure 10).

This metric scores presence of instream cover types and amount of overall instream cover. Ohio EPA has been phasing in an alternative scoring system for this metric, but for this 2006, the total scoring still follows the existing methods. The changes will be discussed later.

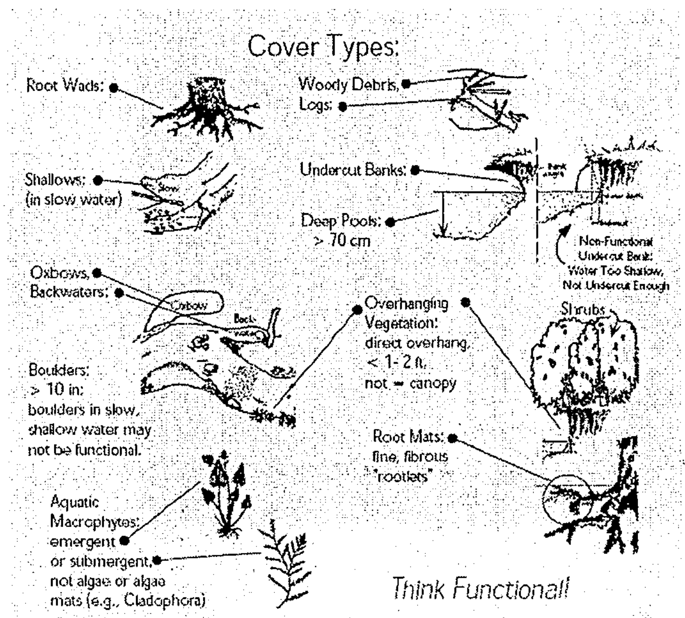


Figure 11. Examples of major cover/structure types measured with QHEI.

Existing Scoring Method:
Each cover type that is present in an amount occurs in sufficient quantity to support species that may commonly be associated with the habitat type should be scored.[5] Cover should not be counted when it is in areas of the stream with insufficient depth (usually < 20 cm) to make it useful. For example a logjam in 5 cm of water contributes very little, if any cover, and at low flow may be dry. Other cover types with limited function in shallow water include undercut banks and overhanging vegetation, boulders, and rootwads. Under amount, one or two boxes may be checked. Extensive cover is that which is present throughout the sampling area, generally greater than about 75% of the stream reach sampled. Cover is moderate when it occurs over 25- 75% of the sampling area. Cover is sparse when it is present in less than 25% of the stream margins (sparse cover usually exists in one or more isolated patches). Cover is nearly absent when no large patch of any type of cover exists anywhere in the sampling area. This situation is usually found in recently channelized streams or other highly modified reaches (e.g. ship channels). If cover is thought to be intermediate in amount between two categories, check two boxes and average their scores. For wide streams cover amount is estimated along the swath of stream sampled (or that would be sampled) with an electrofisher. In smaller streams

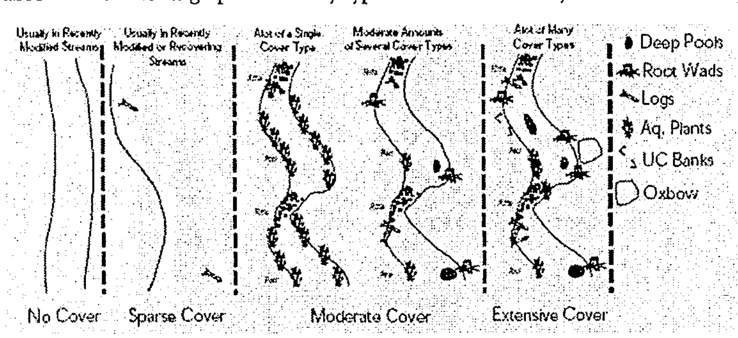


Figure 12. Illustration of the four categories of cover amounts.

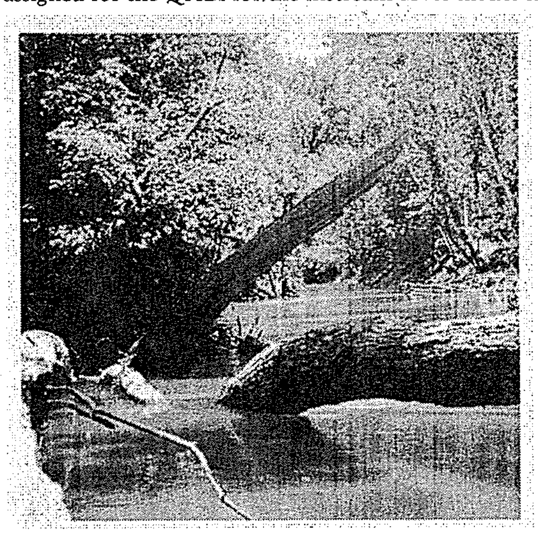
[5] We had mentioned a 5% rule of thumb for an amount threshold if biological experience is low – this would be as a linear, not an areal amount.

(smaller wadeable and headwater streams) this generally covers most of the stream width. If a single type of cover is extensive and others are absent or uncommon then the total is scored as moderate because of the low diversity of types.

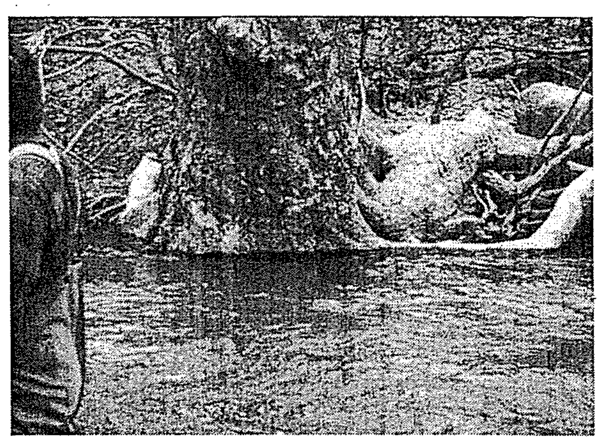
A desire to investigate and measure variation in amount and quality of individual cover types lead to a change in scoring of this metric. Over the next year or so the existing scoring method (each cover type scored on an presence/absence rating and a cumulative cover amount score) will be replaced with the following scoring method that focuses on scoring each cover type on a gradient of amount and quality. Each cover type would receive a score of 0-3 where:

> 0 - Absent;
> 1 - Very small amounts or if more common of marginal quality;
> 2 - Moderate amounts, but not of highest quality or in small amounts of highest quality;
> 3 - Highest quality in moderate or greater amounts (e.g., very large boulders in deep or fast water, large diameter logs that are stable, well developed rootwads in deep/fast water, or deep, well-defined, functional pools.

The cover ratings have been collected for about the last five years and an assessment of their relation to biological measures will be used to adjust a final scoring for this metric. At present, continue scoring these as present/absent and use the overall cover metric score. Cover types include: 1) undercut banks, 2) overhanging vegetation, 3) shallows (in slow water)[6], 4) logs or woody debris, 5) deep pools (> 70 cm), 6) oxbows, backwaters, or side channels, 7) boulders, 8) aquatic macrophytes, and 9) rootwads (tree roots that extend into stream). Do not check undercut banks AND rootwads unless undercut banks exist along with rootwads as a major component. Although the theoretical maximum score is > 20 the maximum score assigned for the QHEI for the instream cover metric is limited to 20 points.



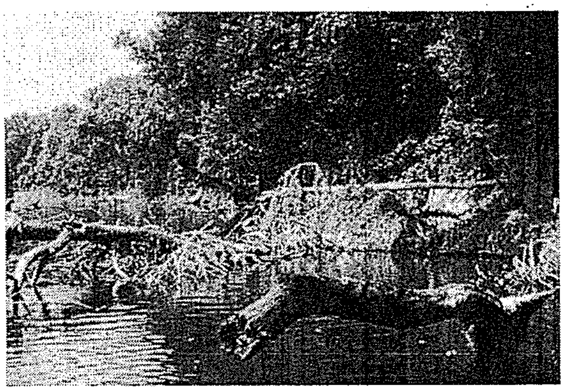
High quality logs and woody debris in deep water.

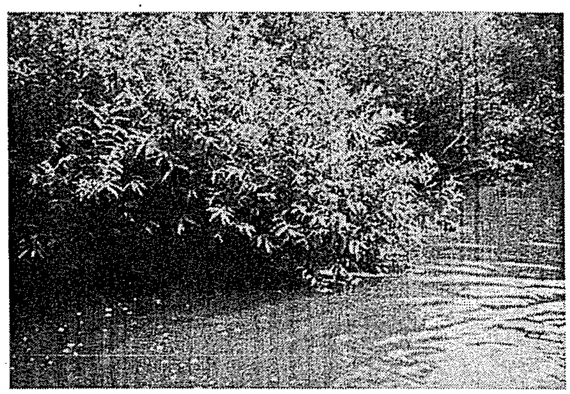


High quality rootwad in deep, fast water.

[6] Shallows are habitats that provide nursery areas for small fish.


Root Mats


Importance of logs and woody debris in large rivers.


Functional overhanging vegetation

Metric 3: Channel Morphology (Figure 13)

This metric emphasizes the quality of the stream channel that relates to the creation and stability of macrohabitat. It includes channel sinuosity (i.e. the degree to which the stream meanders), channel development, channelization, and channel stability. One box under each should be checked unless conditions are considered to be intermediate between two categories; in these cases check two boxes and average their scores.

3] *CHANNEL MORPHOLOGY* Check ONE in each category (*Or 2 & average*)

SINUOSITY	DEVELOPMENT	CHANNELIZATION	STABILITY
☐ HIGH [4]	☐ EXCELLENT [7]	☐ NONE [6]	☐ HIGH [3]
☐ MODERATE [3]	☐ GOOD [5]	☐ RECOVERED [4]	☐ MODERATE [2]
☐ LOW [2]	☐ FAIR [3]	☐ RECOVERING [3]	☐ LOW [1]
☐ NONE [1]	☐ POOR [1]	☐ RECENT OR NO RECOVERY [1]	

Comments

Channel Maximum 20

Figure 13. Channel morphology metric.

a) *Sinuosity* - **No sinuosity** is a straight channel. **Low sinuosity** is a channel with only 1 or 2 poorly defined outside bends in a sampling reach, or perhaps slight meandering within modified banks. **Moderate sinuosity** is more than 2 outside bends, with at least one bend well defined. **High sinuosity** is more than 2 or 3 well defined outside bends with deep areas outside and shallow areas inside. Sinuosity may be more conceptually described by the ratio of the stream distance between two points on the channel of a stream and the straight-line distance between these same two points, taken from a topographic map. This metric measures the formation of pools and increased habitat area as the primary "functions" of sinuosity as related to aquatic life. Check one box or select two and average.

b) *Development* - This refers to the development of riffle/pool complexes. **Poor** means riffles are absent, or if present, shallow with sand and fine gravel substrates; pools, if present are shallow. Glide habitats, if predominant, receive a **Poor** rating. **Fair** means riffles are poorly developed or absent; however, pools are more developed with greater variation in depth. **Good** means better defined riffles present with larger substrates (gravel, rubble or boulder); pools have variation in depth and there is a distinct transition between pools and riffles. **Excellent** means development is similar to the **Good** category except the following characteristics must be present: pools must have a maximum depth of >1 m and deep riffles and runs (>0.5 m) must also be present. In streams sampled with wading methods, a sequence of riffles, runs, and pools must occur more than once in a sampling zone. Check one box or check two and average.

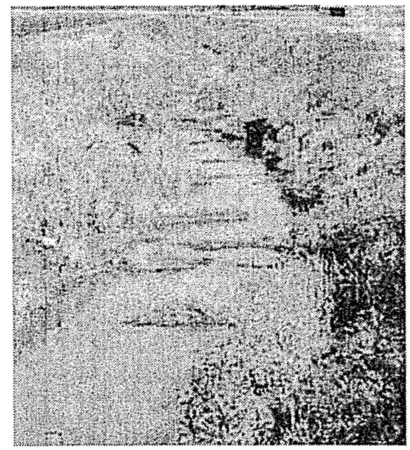
Table 1: Scoring criteria for pool/riffle development metric.

	Excellent	Good	Fair	Poor
Pool	> 1 m deep, well defined	0.7-1.0 m deep, well defined	Some depth variation	Shallow, if present
Glide	Not common	Not common	Common	Predominant
Riffle	Deep, well defined riffles, large substrates	Defined riffles, large substrates	Poorly defined riffles or riffles absent	Absent of shallow with fine substrates
Run	> 0.5 m deep, well defined	Deep, well defined	Usually absent	Absent

This metric can be double-checked. For situations, for example where riffles are excellent and pools are only fair, it is advantageous to check the excellent and the fair box rather than checking the good box as an average to keep information on the variance in quality.

Note how well defined (i.e., distinct) the riffle and pool are in this high quality headwater stream pictured on the left. Also note the large tree in the riparian

c) *Channelization* - This refers to anthropogenic channel modifications. **Natural** refers to no obvious direct moving or alteration of the channel and a natural appearance. **Recovered** refers to streams that have been channelized in the past, but which have recovered most of their natural channel characteristics. **Recovering** refers to channelized streams which are still in the process of regaining their former, natural however, these habitats are still degraded. This category also applies to those streams, especially in the Huron/ Erie Lake Plain ecoregion (NW Ohio), that were channelized long ago and have a riparian border of mature trees, but still have Poor channel characteristics. **Recent** or **No Recovery** refers to streams that were recently channelized or those that show no significant recovery of habitats (e.g. drainage ditches, grass lined or rock rip-rap banks, etc.). The specific type of habitat modification is checked in the last two columns but not scored.



A channelized stream channel starting to revert towards more natural channel features.

Unstable channel features and low stability.

d) *Stability* - This refers to channel stability. Artificially stable (concrete) stream channels receive a High score. Even though they generally have a negative influence on fish assemblages, the negative effects are related to features other than their stability. Channels with **Low stability** are usually characterized by fine substrates in riffles that often change location, have unstable and severely eroding banks, and a high bedload that slowly creeps downstream. Sometimes these unstable riffles form diagonally across the channel (see figure, right). Channels with **Moderate stability** are those that appear to maintain stable riffle/ pool and channel characteristics, but which exhibit some symptoms of instability, e.g. high bedload, eroding or false banks, or shows the effects of wide fluctuations in water level. Channels with **High stability** have stable banks and substrates, and little or no erosion and bedload. e) *Modifications/Other* - Check the appropriate box if impounded, islands present, or leveed (these are not included in the QHEI scoring) as well as the appropriate source of habitat modifications. The maximum QHEI metric score for Channel Morphology is 20 points.

Metric 4: Riparian Zone and Bank Erosion (Figure 14)

This metric emphasizes the quality of the riparian buffer zone and quality of the floodplain vegetation. This includes riparian zone width, floodplain quality, and extent of bank erosion. Each of the three components requires scoring the left and right banks (looking downstream). The average of the left and right banks is taken to derive the component value. One box per bank should be checked unless conditions are considered to be intermediate between two categories; in these cases check two boxes and average their scores.

4] *BANK EROSION AND RIPARIAN ZONE* Check ONE in each category for *EACH BANK* (*Or 2 per bank & average*)

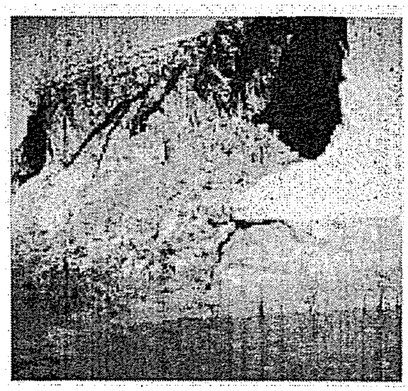
River right looking downstream

L R EROSION	L R RIPARIAN WIDTH	L R FLOOD PLAIN QUALITY	L R
☐ ☐ NONE / LITTLE [3]	☐ ☐ WIDE > 50m [4]	☐ ☐ FOREST, SWAMP [3]	☐ ☐ CONSERVATION TILLAGE [1]
☐ ☐ MODERATE [2]	☐ ☐ MODERATE 10-50m [3]	☐ ☐ SHRUB OR OLD FIELD [2]	☐ ☐ URBAN OR INDUSTRIAL [0]
☐ ☐ HEAVY / SEVERE [1]	☐ ☐ NARROW 5-10m [2]	☐ ☐ RESIDENTIAL, PARK, NEW FIELD [1]	☐ ☐ MINING / CONSTRUCTION [0]
	☐ ☐ VERY NARROW < 5m [1]	☐ ☐ FENCED PASTURE [1]	*Indicate predominant land use(s) past 100m riparian.*
	☐ ☐ NONE [0]	☐ ☐ OPEN PASTURE, ROWCROP [0]	*Riparian Maximum 10*

Comments

Figure 14. Bank erosion and riparian zone metric.

a) *Bank Erosion* - A modified Streambank Soil Alteration Ratings from Platts et al. (1983) is used here; check one box for each side of the stream and average the scores. False banks are used in the sense of Platts et al. (1983) to mean banks that are no longer adjacent to the normal flow of the channel but have been moved back into the floodplain most commonly as a result of livestock trampling. 1) **None** - streambanks are stable and not being altered by water flows or animals (e.g. livestock) - Score 3. 2) **Little** - streambanks are stable, but are being lightly altered along the transect line; less than 25% of the streambank is receiving any kind of stress, and if stress is being received it is very light; less than 25% of the streambank is false, broken down or eroding - Score 3. 3) **Moderate** - streambanks are receiving moderate alteration along the transect line; at least 50 percent of the streambank is in a natural stable condition; less than 50% of the streambank is false, broken down or eroding; false banks are rated as altered - Score 2. 4) **Heavy** - streambanks have received major alterations along the transect line; less than 50% of the streambank is in a stable condition; over 50% of the streambank is false, broken down, or eroding - Score 1. 5) **Severe** - streambanks along the transect line are severely altered; less than 25% of the streambank is in a stable condition; over 75% of the streambank is false, broken down, or eroding - Score 1

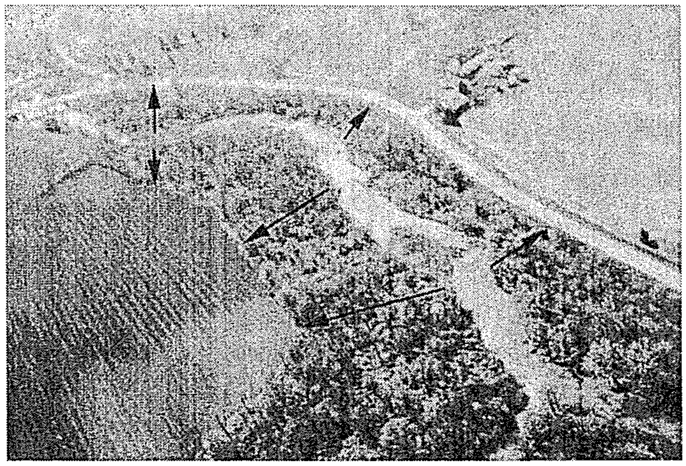


Severe bank erosion.

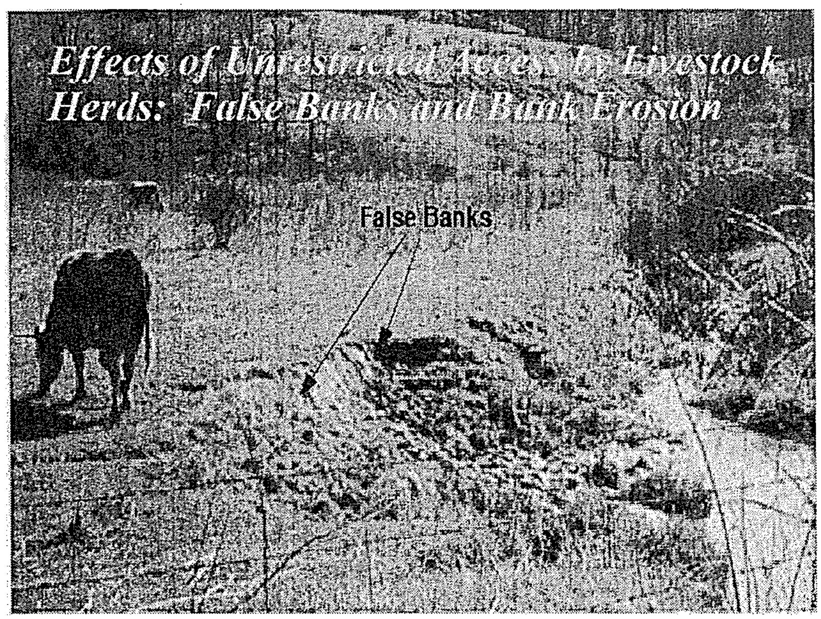
b) *Riparian Width* - This is the width of the riparian (stream side) vegetation. Width estimates are only done for **forest, shrub, swamp,** and **old field vegetation** if it has **woody** components (*e.g.*, willows). Old field refers to a fairly mature successional field that has stable, woody plant growth; this generally does not include weedy urban or industrial lots that often still have high runoff potential. Two boxes, one each for the left and right bank (looking downstream), should be checked and then averaged.

c) *Floodplain Quality* - The two most predominant floodplain quality types should be checked, one each for the left and right banks (includes urban, residential, etc.), and then averaged. By floodplain we mean the areas immediately outside of the riparian zone or greater than 100 meters from the stream, whichever is wider on each side of the stream. The concept is to identify land uses that might deliver harmful runoff to the stream. These are areas adjacent to the stream that can have direct runoff and erosion effects during normal wet weather. This is considered a ground truthing exercise and we suggest those interested in estimating of the effects of adjacent or riparian land uses use now well-developed GIS approaches. We do not limit it to the riparian zone and it is much less encompassing than the stream basin.

The maximum score for Riparian Zone and Erosion metric is 10 points.



Estimating riparian zone width.



Example of un-restricted livestock access and the formation of "false" banks.

Metric 5: Pool/Glide and Riffle-Run Quality (Figure 15)

This metric emphasizes the quality of the pool, glide and/or riffle-run habitats. This includes pool depth, overall diversity of current velocities (in pools and riffles), pool morphology, riffle-run depth, riffle-run substrate, and riffle-run substrate quality.

5] *POOL / GLIDE AND RIFFLE / RUN QUALITY*

MAXIMUM DEPTH Check ONE (*ONLY!*)	CHANNEL WIDTH Check ONE (*Or 2 & average*)	CURRENT VELOCITY Check ALL that apply		Recreation Potential
☐ > 1m [6]	☐ POOL WIDTH > RIFFLE WIDTH [2]	☐ TORRENTIAL [-1]	☐ SLOW [1]	*Primary Contact*
☐ 0.7-<1m [4]	☐ POOL WIDTH = RIFFLE WIDTH [1]	☐ VERY FAST [1]	☐ INTERSTITIAL [-1]	*Secondary Contact*
☐ 0.4-<0.7m [2]	☐ POOL WIDTH > RIFFLE WIDTH [0]	☐ FAST [1]	☐ INTERMITTENT [-2]	(circle one and comment on back)
☐ 0.2-<0.4m [1]		☐ MODERATE [1]	☐ EDDIES [1]	
☐ < 0.2m [0]		*Indicate for reach - pools and riffles.*		*Pool / Current Maximum 12*

Comments

Figure 15. Pool/glide and riffle/run metric

A) Pool/Glide Quality

1) *Maximum depth* of pool or glide; check one box only (Score 0 to 6). Pools or glides with maximum depths of less than 20 cm are considered to have lost their function and the total metric is scored a 0. No other characteristics need be scored in this case.

2) *Current Types* - check each current type that is present in the stream (including riffles and runs; score -2 to 4), definitions are: **Torrential** - extremely turbulent and fast flow with large standing waves; water surface is very broken with no definable, connected surface; usually limited to gorges and dam spillway tailwaters. **Very Fast** - turbulent flow that may make it difficult to stand and creates pulsating effect again leg. **Fast** - mostly non-turbulent flow with small standing waves in riffle/run areas; water surface may be partially broken, but there is a visibly connected surface. Fast current has sufficient energy to flow forcefully over objects. Sharp drop evident on depth rod. **Moderate** - non-turbulent flow that is detectable and visible (i.e. floating objects are readily transported downstream); water surface is visibly connected. With moderate current water flows around rather than over objects. Little drop around depth rod. **Slow** - water flow is perceptible, but very sluggish. **Eddies** - small areas of circular current motion usually formed in pools immediately downstream from riffle-run areas. **Interstitial** - water flow that is perceptible only in the interstitial spaces between substrate particles in riffle-run areas. **Intermittent** - no flow is evident anywhere leaving standing pools that are separated by dry areas. The role of bank erosion in sediment delivery to streams is often underestimated. Higher gradient stream showing typical locations of fast, moderate, and slow areas and eddies.

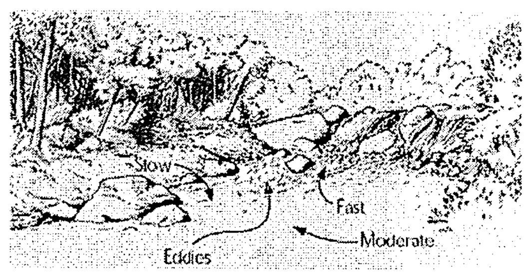


Figure 16. Typical locations of various current velocity types in a stream.

4) *Morphology* - Check **Wide** if pools are wider than riffles, **Equal** if pools and riffles are the same width, and **Narrow** if the riffles are wider than the pools (Score 0 to 2, see Figure 17). If the morphology varies throughout the site average the types. If the entire stream area (including areas outside of the sampling zone) is pool or riffle, then check riffle = pool.

Although the theoretical maximum score for the pool metric is greater than 12 the maximum score assigned for the QHEI for the Pool Quality metric is limited to 12 points.

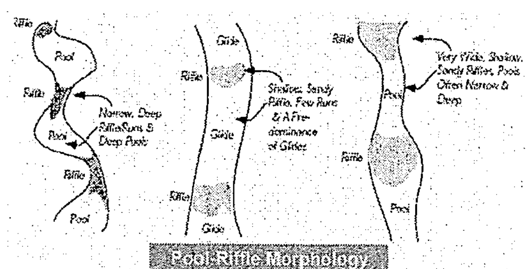
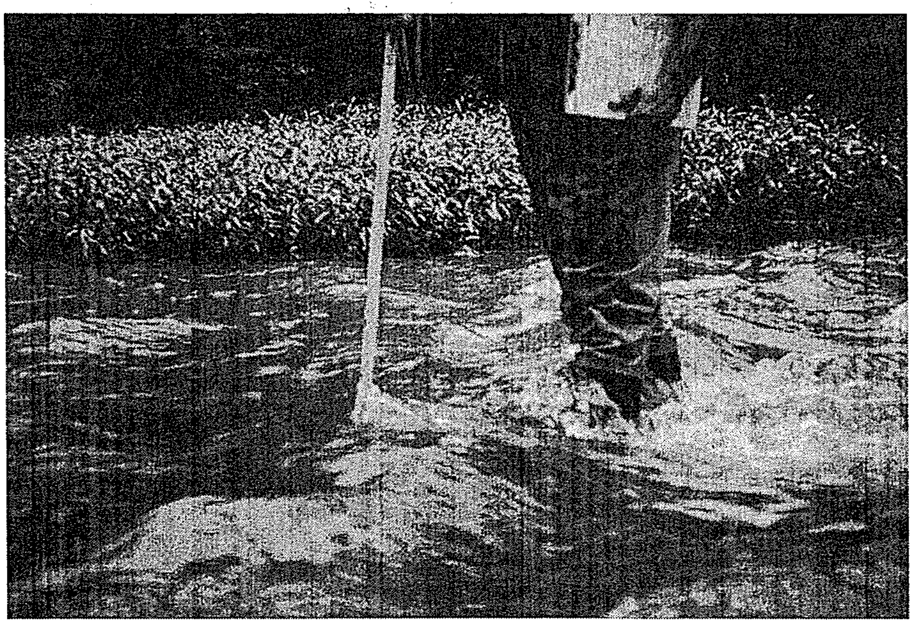


Figure 17. Pool morphology metric categories.

Illustration of the importance of pool depth to aquatic life



Estimating current velocity, Sharp drop from front to back of rod and boot indicates fast current velocities.

B) Riffle-Run Quality (Figure 18)

This entire metric is scored 0 if no riffles are present.

Indicate for functional riffles; Best areas must be large enough to support a population of riffle-obligate species: Check ONE (*Or 2 & average*). ☐ NO RIFFLE [metric=0]

RIFFLE DEPTH	RUN DEPTH	RIFFLE / RUN SUBSTRATE	RIFFLE / RUN EMBEDDEDNESS
☐ BEST AREAS > 10cm [2]	☐ MAXIMUM > 50cm [2]	☐ STABLE (e.g., Cobble, Boulder) [2]	☐ NONE [2]
☐ BEST AREAS 5-10cm [1]	☐ MAXIMUM < 50cm [1]	☐ MOD. STABLE (e.g., Large Gravel) [1]	☐ LOW [1]
☐ BEST AREAS < 5cm [metric=0]		☐ UNSTABLE (e.g., Fine Gravel, Sand) [0]	☐ MODERATE [0]
			☐ EXTENSIVE [-1]

Comments

Riffle / Run Maximum 8

Figure 18. Riffle-run metric.

1)Riffle - select one box that most closely describes the depth characteristics of the best riffle in the zone (Score 0 to 2). The best riffle is selected because we want to identify bottlenecks during harsh periods (*e.g.*, drought). Estimate depths in areas that are clearly riffle, not transitional between a riffle and a run. If the riffle is generally less than 5 cm in depth, riffles are considered to have loss their function and the entire riffle metric is scored a 0.

2) *Run Depth* - select one box that most closely describes the depth characteristics of the runs (Score 0 to 2). Estimate depth in areas that are clearly run, not transitional between a pool and a run or a riffle and a run.

3) *Riffle/Run Substrate Stability*— select one box from each that best describes the substrate type and stability of the riffle habitats (Score 0 to 2).

4) *Riffle/Run Embeddedness*— Embeddedness is the degree that cobble, gravel, and boulder substrates are surrounded or covered by fine material (sand, silt); here in the riffle/runs only. We consider substrates embedded if >50% of surface of the substrates are embedded in fine material—these substrates cannot be easily dislodged. This also includes substrates that are concreted.. Boxes are checked for pervasiveness of (riffle/ run area of sampling zone) embedded substrates: **Extensive** — > 75% of stream area, **Moderate** — 50-75%, **Sparse** — 25- 50%, **Low** — < 25%. The maximum score assigned for the QHEI for the Riffle/Run Quality metric is 8 points.

Metric 6: Map Gradient

Local or map gradient is calculated from USGS 7.5 minute topographic maps by measuring the elevation drop through the sampling area. This is done by measuring the stream length between the first contour line upstream and the first contour line downstream of the sampling site and dividing the distance by the contour interval. If the contour lines are closely "packed" a minimum distance of at least one mile should be used. Some judgment may need to be exercised in certain anomalous areas (e.g. in the vicinity of waterfalls, impounded areas, etc.) and this can be compared to an infield, visual estimate which is recorded next to the gradient metric on the front of the sheet. Scoring for ranges of stream gradient takes into account the varying influence of gradient with stream size, preferably measured as drainage area in square miles or stream width. Gradient classifications (Table V-4-3) were modified from Trautman (p 139, 1981) and scores were assigned, by stream size category, after examining scatter plots of IBI vs. natural log of gradient in feet/mile (see Rankin 1989). Scores are listed in Table 2. The maximum QHEI metric score for Gradient is 10 points

6] *GRADIENT* (ft/mi) ☐ VERY LOW - LOW [2-4]
DRAINAGE AREA ☐ MODERATE [6-10]
(mi²) ☐ HIGH - VERY HIGH [10-6]

Figure 19. QHEI Stream gradient metric.

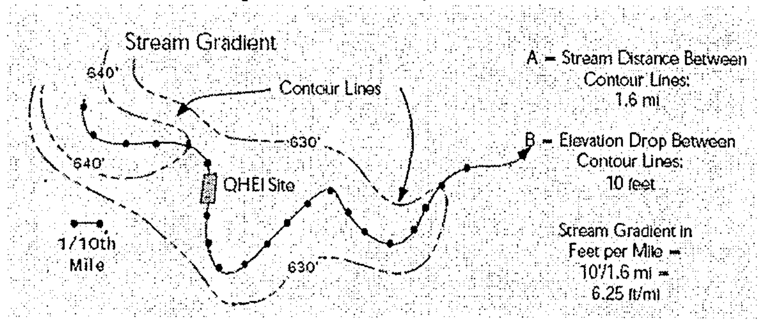


Figure 20. Illustration of methodology for determining stream gradient from topographic maps.

Table 2 Classification of stream gradients for Ohio by stream size. Modified from Trautman (p 139, 1981). Scores were derived from plots of IBI versus stream gradient for each stream size category.

Stream Width	Drainage Area (sq mi)	Gradient (feet/mile)						
		Very Low	Low	Low-Moderate	Moderate	Moderate-High	High	Very High[1]
≤4.7	<9.2	0 - 1.0 **2**	1.1 - 5.0 **4**	5.1 - 10.0 **6**	10.1 - 15.0 **8**	15.1 - 20 **10**	20.1 - 30 **10**	30.1 - 40 **8**
4.8 - 9.2	9.2 - 41.6	0 - 1.0 **2**	1.1 - 3.0 **4**	3.1 - 6.0 **6**	6.1 - 12.0 **10**	12.1 - 18 **10**	18.1 - 30 **8**	30.1 - 40 **6**
9.3 - 13.8	41.7 - 103.7	0 - 1.0 **2**	1.1 - 2.5 **4**	2.6 - 5.0 **6**	5.1 - 7.5 **8**	7.6 - 12 **10**	12.1 - 20 **8**	20.1 - 30 **6**
13.9 - 30.6	103.8 - 622.9	0 - 1.0 **4**	1.1 - 2.0 **6**	2.1 - 4.0 **8**	4.1 - 6.0 **10**	6.1 - 10 **10**	10.1 - 15 **8**	15.1 - 25 **6**
>30.6	>622.9		0 - 0.5 **6**	0.6 - 1.0 **8**	1.1 - 2.5 **10**	2.6 - 4.0 **10**	4.1 - 9 **10**	>9 **8**

[1]Any site with a gradient greater than the upper bound of the "very high" gradient classification is assigned a score of 4.

Computing the Total QHEI Score: To compute the total QHEI score, add the components of each metric to obtain the metric scores and then sum the metric scores to obtain the total QHEI score. The QHEI metric scores cannot exceed the Metric Maximum Score indicated below.

QHEI SCORING (Maximum = 100)

QHEI Metric	Metric Component	Component Scoring Range	Metric Max. Score
1) Substrate	a) Type	0 to 21	20
	b) Quality	-5 to 3	
2) Instream Cover	a) Type	0 to 10	20
	b) Amount	1 to 11	
3) Channel Morphology	a) Sinuosity	1 to 4	20
	b) Development	1 to 7	
	c) Channelization	1 to 6	
	d) Stability	1 to 3	
4) Riparian Zone	a) Width	0 to 4	10
	b) Quality	0 to 3	
	c) Bank Erosion	1 to 3	
5a) Pool Quality	a) Max. Depth	0 to 6	12
	b) Current	-2 to 4	
	c) Morphology	0 to 2	
5b) Riffle Quality	a) Depth	0 to 4	8
	b) Substr Stab.	0 to 2	
	c) Substr Embd.	-1 to 2	
6) Gradient		2 to 10	10

Narrative ranges of QHEI scores

For communicating general habitat quality to the public general narrative categories have been assigned to QHEI scores. Habitat influences on aquatic life, however, occur at multiple spatial scales and these narrative ranges are general and not always definitely predictable of aquatic assemblages are any given site.

Table 2. General narrative ranges assigned to QHEI scores. Ranges vary slightly in headwater (≤ 20 sq mi) vs. larger waters.

Narrative Rating	QHEI Range: Headwaters	QHEI Range: Larger Streams
Excellent	≥ 70	≥ 75
Good	55 to 69	60 to 74
Fair	43 to 54	45 to 59
Poor	30 to 42	30 to 44
Very Poor	< 30	< 30

Additional Information/Back of QHEI Sheet

Additional information is recorded on the reverse side of the Site Description Sheet. Several versions of the reverse of the QHEI sheet have been produced over the past 10 years, but this description is based on the most recent revision of the Ohio EPA sheet (Figure 21).

A] SAMPLED REACH Check ALL that apply

Comment RE: Reach consistency/ Is reach typical of steam?, Recreation/ Observed - Inferred, Other/ Sampling observations, Concerns, Access directions, etc.

METHOD: ☐ BOAT ☐ WADE ☐ L. LINE ☐ OTHER

STAGE (1st –sample pass– 2nd): ☐ HIGH ☐ ☐ UP ☐ ☐ NORMAL ☐ ☐ LOW ☐ ☐ DRY ☐

DISTANCE: ☐ 0.5 Km ☐ 0.2 Km ☐ 0.15 Km ☐ 0.12 Km ☐ OTHER ____ meters

CLARITY (1st –sample pass– 2nd): ☐ < 20 cm ☐ ☐ 20-<40 cm ☐ ☐ 40-70 cm ☐ ☐ > 70 cm/ CTB ☐ ☐ SECCHI DEPTH ☐ 1st ____ cm 2nd ____ cm

CANOPY: ☐ > 85%- OPEN ☐ 55%-<85% ☐ 30%-<55% ☐ 10%-<30% ☐ <10%- CLOSED

B] AESTHETICS: ☐ NUISANCE ALGAE ☐ INVASIVE MACROPHYTES ☐ EXCESS TURBIDITY ☐ DISCOLORATION ☐ FOAM / SCUM ☐ OIL SHEEN ☐ TRASH / LITTER ☐ NUISANCE ODOR ☐ SLUDGE DEPOSITS ☐ CSOs/SSOs/OUTFALLS

C] RECREATION AREA DEPTH *POOL:* ☐ >100ft² ☐ >3ft

D] MAINTENANCE (Circle some & *COMMENT*): PUBLIC / PRIVATE / BOTH / NA; ACTIVE / HISTORIC / BOTH / NA; YOUNG-SUCCESSION-OLD; SPRAY / SNAG / REMOVED; MODIFIED / DIPPED OUT / NA; LEVEED / ONE SIDED; RELOCATED / CUTOFFS; MOVING-BEDLOAD-STABLE; ARMOURED / SLUMPS; ISLANDS / SCOURED; IMPOUNDED / DESICCATED; FLOOD CONTROL / DRAINAGE

E] ISSUES: WWTP / CSO / NPDES / INDUSTRY; HARDENED / URBAN / DIRT&GRIME; CONTAMINATED / LANDFILL; BMPs-CONSTRUCTION-SEDIMENT; LOGGING / IRRIGATION / COOLING; BANK / EROSION / SURFACE; FALSE BANK / MANURE / LAGOON; WASH H_20 / TILE / H_20 TABLE; ACID / MINE / QUARRY / FLOW; NATURAL / WETLAND / STAGNANT; PARK / GOLF / LAWN / HOME; ATMOSPHERE / DATA PAUCITY

F] MEASUREMENTS: $\bar{x}$ width; $\bar{x}$ depth; max. depth; $\bar{x}$ bankfull width; bankfull $\bar{x}$ depth; W/D ratio; bankfull max. depth; floodprone x^2 width; entrench. ratio; *Legacy Tree:*

Stream Drawing:

A – Sampling Characteristics

1) *Methods Used* – A series of check boxes to record the type of sampling completed in the reach.

2) *Distance* – Distance assessed for the QHEI and/or fish assessment.

3) *Stage* – Estimate of flow stage during assessment. Since some sites are sampled twice, a box is included for each sampling effort.

4) *Clarity* – Estimate of water clarity during assessment. Since some sites are sampled twice, a box is included for each sampling effort. There are also two places to record Secchi depths, if taken.

5) *Canopy* – Estimate of average width of canopy

B. Aesthetics

1) Check all of the boxes that apply in terms of aesthetic characteristics of the site

C. Recreation
1) Record whether there exists, within the area, greater than 100 ft^2 of water greater than three feet in depth. This is used to estimate whether full body immersion is possible or likely.

D. Maintenance
1) Record what types of stream maintenance activities or special features occur in the sampling zone. Some of this information was previously on the front of the sheet and is used as an aid when determining aquatic life uses (e.g., existing on ongoing channel maintenance).

E. Issues
1) Record various potential sources of impact that may occur in or near the site.

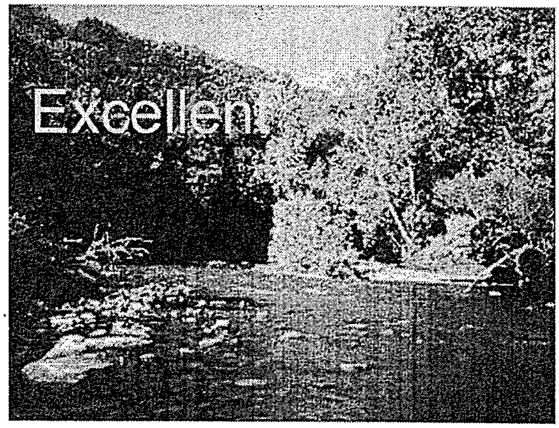
F. Measurements
1) If some quantitative measurements of stream channel characteristics are collected they may be recorded here. It is likely, however, that more detailed stream measurements (e.g., geomorphic assessment) will be recorded on separate forms.

G) *Stream Maps and Diagram*
Stream maps for each site can be very important. The act of drawing a map usually helps to identify habitat types scored with the QHEI. It can also help later samples identify sampling sites and determine whether changes have occurred. The level of detail of the drawings will likely vary with the objective. For example, sites assessed for 401 purposes should have as much detail as possible to help in later decisions of habitat limitations or high potential. Two or three cross-sections of the stream can provide useful information on the stream bank, stream bottom, stream channel, and floodplain characteristics.

QHEI Pool/Riffle Development Metric

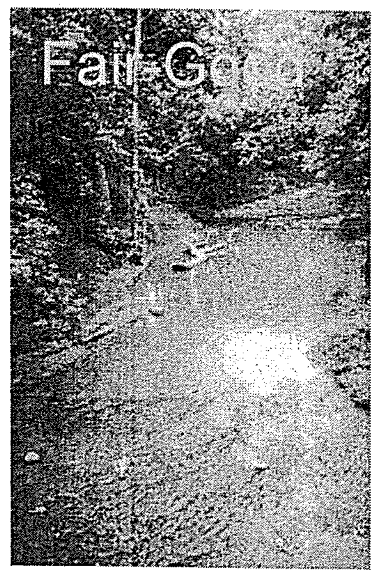
ExcellentP ool/Riffle Development:

Pools - > 1 m Deep
Glides - Only Transitional Habitats
Runs - > 0.5 m Deep
Riffles - Deep, Large Substrates
Morphology - All Habitats Easily Definable, Riffles Narrow and Deep, Pools Wide with Deep and Shallow Sections



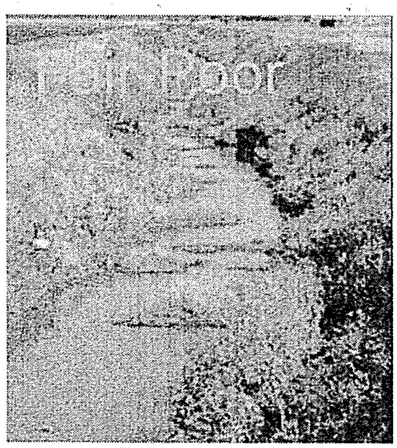
Good Pool/Riffle Development:

Pools - > 0.7 m Deep
Glides - Mostly Transitional Habitats
Runs - Deep,b ut < 0.5 m
Riffles - Some Deep Areas, Large Substrates (At Least Large Gravels)
Morphology - All Habitats Fairly Well Definable, Riffles Typically Narrower Than Most Pools



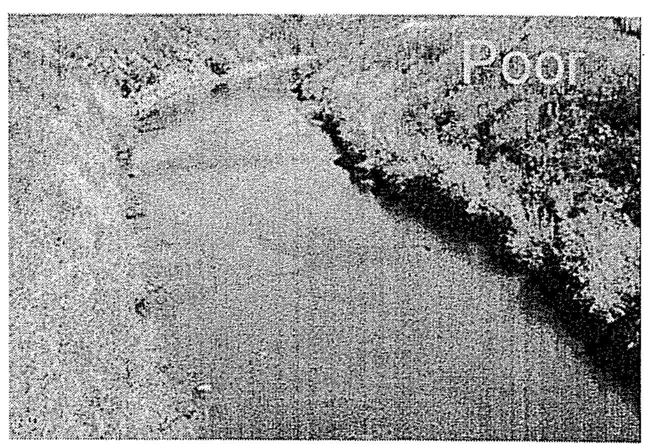
Fair Pool/Riffle Development:

Pools - Show Some Depth Variation
Glides - Common
Runs - Typically Absent
Riffles - Poorly Defined, Shallow
Morphology - HabitatT ypes Not As Distinct, Glides Typically Difficult to
Separate From Pools and Riffles



Poor Pool/Riffle Development:

Pools - Shallow if Present
Glides - Predominant
Runs - Absent
Riffles - Absent, Or if Present Unstable and Shallow With Fine Substrates
Morphology - Mostly Glide Characteristics, Riffles Ephemeral if Present



OhioEPA

Qualitative Habitat Evaluation Index and Use Assessment Field Sheet

QHEI Score: ☐

Stream & Location: ______________________ *RM:* ___.__ *Date:* __/__/ 06

______________________ *Scorers Full Name & Affiliation:* ______________________

River Code: __-___-___ *STORET #:* ______ *Lat./Long.:* (NAD 83 - decimal °) __.____ /8_.____ *Office verified location* ☐

1] SUBSTRATE

Check *ONLY* Two substrate *TYPE BOXES*; estimate % or note every type present

BEST TYPES	POOL	RIFFLE	OTHER TYPES	POOL	RIFFLE
☐ ☐ BLDR /SLABS [10]	___	___	☐ ☐ HARDPAN [4]	___	___
☐ ☐ BOULDER [9]	___	___	☐ ☐ DETRITUS [3]	___	___
☐ ☐ COBBLE [8]	___	___	☐ ☐ MUCK [2]	___	___
☐ ☐ GRAVEL [7]	___	___	☐ ☐ SILT [2]	___	___
☐ ☐ SAND [6]	___	___	☐ ☐ ARTIFICIAL [0]	___	___
☐ ☐ BEDROCK [5]	___	___	(Score natural substrates; ignore sludge from point-sources)		

NUMBER OF BEST TYPES: ☐ 4 or more [2] ☐ 3 or less [0]

Comments

Check ONE (*Or 2 & average*)

ORIGIN
- ☐ LIMESTONE [1]
- ☐ TILLS [1]
- ☐ WETLANDS [0]
- ☐ HARDPAN [0]
- ☐ SANDSTONE [0]
- ☐ RIP/RAP [0]
- ☐ LACUSTURINE [0]
- ☐ SHALE [-1]
- ☐ COAL FINES [-2]

QUALITY

SILT
- ☐ HEAVY [-2]
- ☐ MODERATE [-1]
- ☐ NORMAL [0]
- ☐ FREE [1]

EMBEDDEDNESS
- ☐ EXTENSIVE [-2]
- ☐ MODERATE [-1]
- ☐ NORMAL [0]
- ☐ NONE [1]

Substrate ☐ *Maximum 20*

2] INSTREAM COVER

Indicate presence 0 to 3: **0**-Absent; **1**-Very small amounts or if more common of marginal quality; **2**-Moderate amounts, but not of highest quality or in small amounts of highest quality; **3**-Highest quality in moderate or greater amounts (e.g., very large boulders in deep or fast water, large diameter log that is stable, well developed rootwad in deep / fast water, or deep, well-defined, functional pools.

___ UNDERCUT BANKS [1]	___ POOLS > 70cm [2]	___ OXBOWS, BACKWATERS [1]
___ OVERHANGING VEGETATION [1]	___ ROOTWADS [1]	___ AQUATIC MACROPHYTES [1]
___ SHALLOWS (IN SLOW WATER) [1]	___ BOULDERS [1]	___ LOGS OR WOODY DEBRIS [1]
___ ROOTMATS [1]		

AMOUNT

Check ONE (*Or 2 & average*)
- ☐ EXTENSIVE >75% [11]
- ☐ MODERATE 25-75% [7]
- ☐ SPARSE 5-<25% [3]
- ☐ NEARLY ABSENT <5% [1]

Comments

Cover ☐ *Maximum 20*

3] CHANNEL MORPHOLOGY

Check ONE in each category (*Or 2 & average*)

SINUOSITY	DEVELOPMENT	CHANNELIZATION	STABILITY
☐ HIGH [4]	☐ EXCELLENT [7]	☐ NONE [6]	☐ HIGH [3]
☐ MODERATE [3]	☐ GOOD [5]	☐ RECOVERED [4]	☐ MODERATE [2]
☐ LOW [2]	☐ FAIR [3]	☐ RECOVERING [3]	☐ LOW [1]
☐ NONE [1]	☐ POOR [1]	☐ RECENT OR NO RECOVERY [1]	

Comments

Channel ☐ *Maximum 20*

4] BANK EROSION AND RIPARIAN ZONE

Check **ONE** in each category for ***EACH BANK*** (*Or 2 per bank & average*)

River right looking downstream

EROSION (L R)	RIPARIAN WIDTH (L R)	FLOOD PLAIN QUALITY (L R)	(L R)
☐ ☐ NONE / LITTLE [3]	☐ ☐ WIDE > 50m [4]	☐ ☐ FOREST, SWAMP [3]	☐ ☐ CONSERVATION TILLAGE [1]
☐ ☐ MODERATE [2]	☐ ☐ MODERATE 10-50m [3]	☐ ☐ SHRUB OR OLD FIELD [2]	☐ ☐ URBAN OR INDUSTRIAL [0]
☐ ☐ HEAVY / SEVERE [1]	☐ ☐ NARROW 5-10m [2]	☐ ☐ RESIDENTIAL, PARK, NEW FIELD [1]	☐ ☐ MINING / CONSTRUCTION [0]
	☐ ☐ VERY NARROW < 5m [1]	☐ ☐ FENCED PASTURE [1]	*Indicate predominant land use(s) past 100m riparian.*
	☐ ☐ NONE [0]	☐ ☐ OPEN PASTURE, ROWCROP [0]	

Comments

Riparian ☐ *Maximum 10*

5] POOL / GLIDE AND RIFFLE / RUN QUALITY

MAXIMUM DEPTH

Check **ONE** (*ONLY!*)
- ☐ > 1m [6]
- ☐ 0.7-<1m [4]
- ☐ 0.4-<0.7m [2]
- ☐ 0.2-<0.4m [1]
- ☐ < 0.2m [0]

CHANNEL WIDTH

Check ONE (*Or 2 & average*)
- ☐ POOL WIDTH > RIFFLE WIDTH [2]
- ☐ POOL WIDTH = RIFFLE WIDTH [1]
- ☐ POOL WIDTH > RIFFLE WIDTH [0]

CURRENT VELOCITY

Check ALL that apply

☐ TORRENTIAL [-1]	☐ SLOW [1]
☐ VERY FAST [1]	☐ INTERSTITIAL [-1]
☐ FAST [1]	☐ INTERMITTENT [-2]
☐ MODERATE [1]	☐ EDDIES [1]

Indicate for reach - pools and riffles.

Recreation Potential
Primary Contact
Secondary Contact
(circle one and comment on back)

Comments

Pool / Current ☐ *Maximum 12*

Indicate for functional riffles; Best areas must be large enough to support a population of riffle-obligate species: Check ONE (*Or 2 & average*).

☐ NO RIFFLE [metric=0]

RIFFLE DEPTH	RUN DEPTH	RIFFLE / RUN SUBSTRATE	RIFFLE / RUN EMBEDDEDNESS
☐ BEST AREAS > 10cm [2]	☐ MAXIMUM > 50cm [2]	☐ STABLE (e.g., Cobble, Boulder) [2]	☐ NONE [2]
☐ BEST AREAS 5-10cm [1]	☐ MAXIMUM < 50cm [1]	☐ MOD. STABLE (e.g., Large Gravel) [1]	☐ LOW [1]
☐ BEST AREAS < 5cm [metric=0]		☐ UNSTABLE (e.g., Fine Gravel, Sand) [0]	☐ MODERATE [0]
			☐ EXTENSIVE [-1]

Comments

Riffle / Run ☐ *Maximum 8*

6] GRADIENT (ft/mi)

DRAINAGE AREA (mi²)

- ☐ VERY LOW - LOW [2-4]
- ☐ MODERATE [6-10]
- ☐ HIGH - VERY HIGH [10-6]

%POOL: ☐ %GLIDE: ☐

%RUN: ☐ %RIFFLE: ☐

Gradient ☐ *Maximum 10*

A] SAMPLED REACH
Check ALL that apply

Comment RE: Reach consistency/ Is reach typical of steam?, *Recreation/* Observed - Inferred, *Other/* Sampling observations, Concerns, Access directions, etc.

METHOD
- ☐ BOAT
- ☐ WADE
- ☐ L. LINE
- ☐ OTHER

STAGE
1st -sample pass- 2nd
- ☐ HIGH ☐
- ☐ UP ☐
- ☐ NORMAL ☐
- ☐ LOW ☐
- ☐ DRY ☐

DISTANCE
- ☐ 0.5 Km
- ☐ 0.2 Km
- ☐ 0.15 Km
- ☐ 0.12 Km
- ☐ OTHER

_______ meters

CLARITY
1st --sample pass-- 2nd
- ☐ < 20 cm ☐
- ☐ 20-<40 cm ☐
- ☐ 40-70 cm ☐
- ☐ > 70 cm/ CTB ☐
- ☐ SECCHI DEPTH ☐

pass 1st_________ cm
2nd_________ cm

CANOPY
- ☐ > 85%- OPEN
- ☐ 55%-<85%
- ☐ 30%-<55%
- ☐ 10%-<30%
- ☐ <10%- CLOSED

B] AESTHETICS
- ☐ NUISANCE ALGAE
- ☐ INVASIVE MACROPHYTES
- ☐ EXCESS TURBIDITY
- ☐ DISCOLORATION
- ☐ FOAM / SCUM
- ☐ OIL SHEEN
- ☐ TRASH / LITTER
- ☐ NUISANCE ODOR
- ☐ SLUDGE DEPOSITS
- ☐ CSOs/SSOs/OUTFALLS

C] RECREATION
AREA DEPTH
POOL: ☐ >100ft² ☐ >3ft

D] MAINTENANCE Circle some & *COMMENT*

PUBLIC / PRIVATE / BOTH / NA
ACTIVE / HISTORIC / BOTH / NA
YOUNG-SUCCESSION-OLD
SPRAY / SNAG / REMOVED
MODIFIED / DIPPED OUT / NA
LEVEED / ONE SIDED
RELOCATED / CUTOFFS
MOVING-BEDLOAD-STABLE
ARMOURED / SLUMPS
ISLANDS / SCOURED
IMPOUNDED / DESICCATED
FLOOD CONTROL / DRAINAGE

E] ISSUES

WWTP / CSO / NPDES / INDUSTRY
HARDENED / URBAN / DIRT&GRIME
CONTAMINATED / LANDFILL
BMPs-CONSTRUCTION-SEDIMENT
LOGGING / IRRIGATION / COOLING
BANK / EROSION / SURFACE
FALSE BANK / MANURE / LAGOON
WASH H_20 / TILE / H_20 TABLE
ACID / MINE / QUARRY / FLOW
NATURAL / WETLAND / STAGNANT
PARK / GOLF / LAWN / HOME
ATMOSPHERE / DATA PAUCITY

F] MEASUREMENTS
- $\bar{x}$ width
- $\bar{x}$ depth
- max. depth
- $\bar{x}$ bankfull width
- bankfull $\bar{x}$ depth
- W/D ratio
- bankfull max. depth
- floodprone x^2 width
- entrench. ratio

Legacy Tree:

Stream Drawing:

Appendix 2

Experimental Benthic Trawling Method

North American Journal of Fisheries Management 25:594–603, 2005

DOI: 10.1577/M03-157.1

[Article]

Efficacy of a Benthic Trawl for Sampling Small-Bodied Fishes in Large River Systems

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Abstract.—We conducted a study from 1998 to 2001 to determine the efficacy of a benthic trawl designed to increase species detection and reduce the incidence of zero catches of small-bodied fishes. We modified a standard two-seam slingshot balloon trawl by covering the entire trawl with a small-mesh cover. After completing 281 hauls with the modified (Missouri) trawl, we discovered that most fish passed through the body of the standard trawl and were captured in the cover. Logistic regression indicated no noticeable effect of the cover on the catch entering the standard portion of the modified trawl. However, some fishes (e.g., larval sturgeons *Scaphirhynchus* spp. and pallid sturgeon *S. albus*) were exclusively captured in the small-mesh cover, while the catch of small-bodied adult fish (e.g., chubs *Macrhybopsis* spp.) was significantly improved by use of the small-mesh cover design. The Missouri trawl significantly increased the number and species of small-bodied fishes captured over previously used designs and is a useful method for sampling the benthic fish community in moderate- to large-size river systems.

Trawling has been used to sample aquatic organisms in coastal marine systems (Matsushita and Shida 2001), reservoirs (Michaletz et al. 1995), and rivers (Dettmers et al. 2001). Trawl size and design vary depending on the intended use. For example, researchers often target an individual species and use a trawl that is known to capture that group (Van Den Avyle et al. 1995; Pine 2000; Madsen and Holst 2002). During many trawl surveys, the loss of other species is unimportant and at times, because of catch regulations, is considered beneficial (Kelley 1994). Therefore, many trawl surveys use large-mesh trawls because they tend to capture larger fish and reduce bycatch. Large-mesh trawls also reduce drag while in tow and are noted for fuel efficiency (Dickson 1962; Naidu et al. 1987; Mous et al. 2002). In addition, shape, configuration, and environmental factors can also influence trawl catch (Glass and Wardle 1989; Kunjipalu et al. 1992; Chopin and Arimoto 1994; Kim and Wardle 1997; Godo and Walsh 1998; Dahm 2000; Ryer and Olla 2000; Matsushita and Shida 2001). Furthermore, catch is affected by trawl design components. For example, the cod end (i.e., distal end) is where most of the trawl catch is collected. Millar (1992) modeled trawl selectivity based on total catch, which he determined was influenced by size and shape of the mesh openings in the cod end. Therefore, the cod end is often modified to capture a particular size of organism (Lowry and Robertson 1996), although many factors can affect catch entering the cod end. For example, the escape of organisms through the body of a trawl may result in variable cod end retention (Dremiere et al. 1999; Polet 2000). The covered cod end method has been used to determine efficacy of mesh cod ends (Madsen and Holst 2002). However, the body of the trawl also determines total catch. Therefore, the whole catch of a trawl is determined by the sum of catches made in the trawl components.

Trawl gear are probably the most commonly used sampling gear in oceanic and estuarine habitats but are only occasionally used in large rivers (Hayes et al. 1996). Trawl gear have been used to sample the Mississippi River, but techniques var-

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ied among researchers (Pitlo 1992; Dettmers et al. 2001). From 1991 to 1997, we used a standard two-seam balloon trawl to sample benthic fishes for the Long Term Resource Monitoring Program (LTRMP; Gutreuter et al. 1995). However, total catch was often zero (D. Herzog, unpublished data), and small benthic fishes (e.g., chubs *Macrhybopsis* spp.) and larval or juvenile fishes (e.g., sturgeons *Scaphirhynchus* spp.) were not well represented in the total catch. Therefore, the objective of this study was to design a trawl to increase species detection while reducing the incidence of zero catch and improving catch of small-bodied fishes. To accomplish this, we modified a two-seam slingshot balloon trawl—both the body and the cod end—by use of a dual-mesh design (i.e., pass-through technique). We covered the entire standard trawl with small mesh to determine capture probability.

Study Site

This study was conducted in the unimpounded section of the upper Mississippi River between river kilometers (RK) 48.3 and 128.7 (see Herzog 2004). This reach is located between the Missouri (RK314) and Ohio River (RK0) confluences, contains few side channels, and has been channelized for commercial navigation. Water surface elevations in this reach rise and fall annually by approximately 8 m. Channel maintenance structures (e.g., wing dikes) occur throughout this reach, and vast expanses of limestone rock (i.e., revetment) cover much of the riverbank.

Methods

Sample sites were selected by use of a stratified random design developed for the LTRMP (Gutreuter 1993; Gutreuter et al. 1995); subjectively chosen fixed sites were also used. The study reach was stratified into four physical habitat classes (e.g., wing dike, main-channel border, side channel, and tributary; see Barko et al. 2004 for habitat descriptions), which were delineated in a geographical information systems database (Owens and Ruhser 1996). Each potential study site was represented on a 50 × 50-m grid indexed by universal transverse mercator coordinates on 1989 infrared photos (e.g., basemap). Annual site locations (e.g., primary sites) were randomly chosen within each physical habitat. If a stratified random site was deemed unsafe due to snags or other conditions, then a stratified random alternate site was chosen. These sites were randomly chosen from the 50 × 50-m grids and were located within 1 km^2 of the center of the primary site. Subjectively chosen sites were selected based on unique habitat features within the study area (e.g., island tips and gravel bars). Site selection for this study (1998–2001) and for previous work that used another trawl design (1991–1997) remained consistent over time.

The modified trawl (hereafter referred to as the Missouri trawl; Figure 1) was made of a two-seam (i.e., standard) slingshot balloon trawl (Gutreuter et al. 1995) completely covered with 4.76-mm, heavy, delta-style mesh. Experiments involving covered cod ends address the effect of capture in the cod end of the net (Madsen and Holst 2002). However, we were also interested in the effect of capture by the trawl body. Therefore, we modified the standard approach to covering the cod end by instead covering the entire net. The standard trawl body was made of 1-mm-diameter nylon twine with 19.05-mm bar mesh. Bar measure was the length measured from the beginning of a knot to the beginning of an adjacent knot (Hayes et al. 1996). The headrope was 4.87 m long; four floats (3.81 cm wide × 6.35 cm high) were spaced every 0.91 m along the headrope. The quoted approximate buoyancy of each float was 124.7 g. The width of the standard trawl narrowed from 4.87 m at the headrope to 0.91 m at the mid-section to 0.38 m at the cod end (Figure 2a). The standard trawl's cod end was made of 1.67-m-long, 1.5-mm-diameter nylon twine with 19.05-mm bar mesh and was lined with 3.18-mm ace-style mesh. Therefore, we added the same 3.18-mm mesh size to the cover's cod end, which was 2.14 m long and 1.52 m wide. The footrope was 5.48 m long, and a 4.76-mm-diameter chain was attached to it. The chain helped the footrope maintain contact with the substrate during conditions of heavy current, fast tow speeds, or undulating bottom surfaces (e.g., sand waves). The 4.76-mm-delta-mesh cover was attached directly to the headrope of the standard trawl by use of 1-mm-diameter nylon twine. The cover was large enough to keep space between the cover and the standard trawl, minimize influence on the mesh of the standard trawl, and allow ballooning of the standard trawl (Figure 2b). The Missouri trawl was attached to the boat with 30.48–60.96-m towlines. Towline length was dependent on water depth (i.e., deeper water required longer towlines; Brabant and Nedelec 1979). In water depths of 5 m or less, 30.48-m towlines were used, whereas 60.96-m towlines were used in water depths over 5 m and up to 10 m. Water depth during each tow varied by less than 2 m and was moni-

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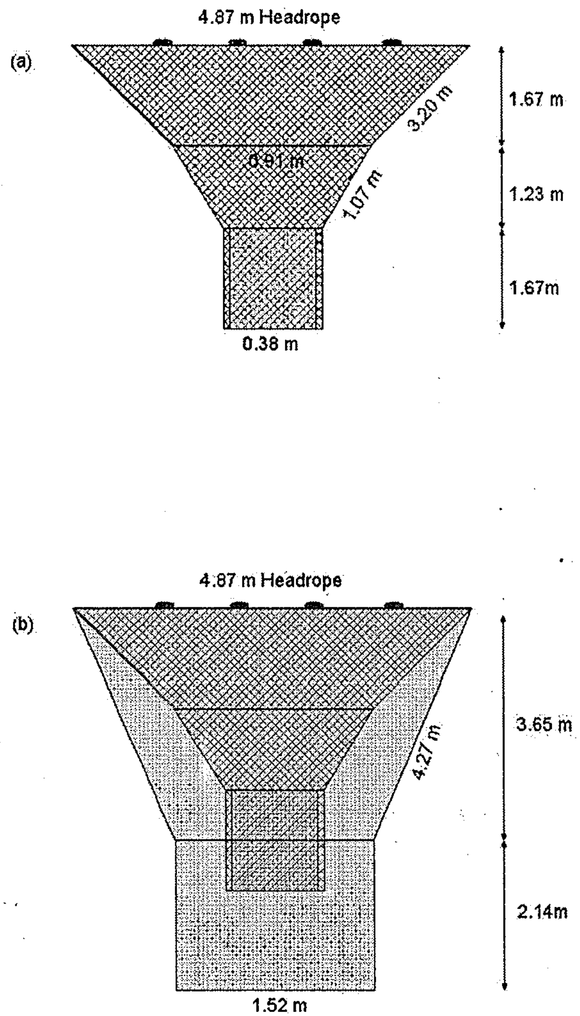

FIGURE 2.—Trawl designs for (a) a standard two-seam balloon trawl (used to sample the upper Mississippi River in 1991–1997) and (b) a modified (Missouri) trawl (used for sampling in 1998–2001).

thula and sturgeons, which were measured to fork length (FL). All common and scientific names follow Nelson et al. (2004). To compare abundances of species captured in the standard portion and cover of the Missouri trawl, we used chi-square tests for equal proportions (Steel and Torrie 1980; SAS Institute. 1988; $P \leq 0.05$) because we assumed that the cod end of the standard trawl was nonselective for size.

Trawl effect on capture probability for fish of a given length was assessed by use of logistic regression (SAS Institute. 1988). Logistic regression was used to characterize catch response of the standard trawl versus the cover rather than as a selectivity prediction tool. The cumulative probability of capturing a fish was linearized with the logit transformation

$$p' = \log_e\left(\frac{p}{1-p}\right) \tag{1}$$

where p is the cumulative probability of capturing a fish of a given length or shorter. Thus, the linear regression model had the form

$$p' = \beta_0 + \beta_1 X. \tag{2}$$

where X represents fish length. Transforming the linearized cumulative probabilities back to their original form resulted in the logistic regression model

$$E(Y) = \frac{e^{(\beta_0+\beta_1 X)}}{1 + e^{(\beta_0+\beta_1 X)}}, \tag{3}$$

With this formulation, the dependent axis was the expected cumulative probability of capturing a fish with a length of at least X cm, and varied from 0 to 1. The regression was performed four times. Cumulative probability of capture was regressed against length based on the 1998–2001 data, first for the standard trawl portion and second for the cover of the Missouri trawl. The maximum fish length that passed through the trawl body to the cover was 28 cm, and therefore this length was used in the models. Hence, fish larger than 28 cm were not represented and subsequently were not used in the comparison between the cover and the standard trawl portion. To determine the effect of the cover, the cumulative probability of capture was regressed against all fish lengths for the unmodified standard trawl (1991–1997 data) and for the standard trawl portion of the Missouri trawl (1998–2001).

Species data from the standard trawl without the cover (1991–1997) were compared to the Missouri trawl data set (1998–2001). We estimated the rate of species capture by randomly selecting 100 observations from both the 1991–1997 and 1998–2001 data sets. The data were randomized by assigning a random number to each sample. The data were then sorted by random number. The first sample listed was plotted by the number of species captured in that sample or haul. We continued plotting samples until 100 observations were reached. A logarithmic trend line was used to plot each "sample" for both trawls.

Results

Two-hundred eighty-one Missouri trawl hauls were completed over the 4-year period from 1998 to 2001. We sampled at depths that ranged from 0.6 to 10 m; mean depth was 3.2 m. Water surface velocity ranged from 0.02 to 1.94 m/s, and the mean was 0.81 m/s. Secchi disk transparency averaged 28 cm and ranged from 2 to 61 cm. Sample area substrates varied but were mostly comprised of sand. We captured 3,217 fish (32 species) in the standard trawl portion of the Missouri trawl and 10,549 fish (43 species; 77% of the total catch) in the 4.76-mm-mesh cover. Chi-square tests indicated that abundances of 18 of the 45 species captured were significantly higher (df = 1, $P \leq 0.05$) in the cover than in the standard trawl portion. However, shovelnose sturgeon *S. platorynchus* had significantly higher abundance in the standard trawl portion than in the cover (Table 1). Five percent of the hauls (15/281) had zero catch in both the standard trawl portion and the cover. The standard trawl portion of the Missouri trawl had zero catch in 21% (60/281) of the hauls, whereas the cover had zero catch in 6% (18/281) of the hauls.

Larval sturgeons and pallid sturgeon were captured only in the cover of the Missouri trawl. Several additional species were captured exclusively in the cover (e.g., bullhead minnow, inland silverside, Mississippi silvery minnow) or exclusively in the standard trawl portion (e.g., shortnose gar) and were represented by more than one occurrence (Table 1). The remaining species did not have significantly different abundance in the standard trawl portion versus the cover of the Missouri trawl. Sturgeon chub and larval sturgeons were captured in the Missouri trawl but had not been captured by Missouri Department of Conservation Open Rivers Field Station researchers during 1991–1997, when the unmodified standard trawl was used. Two-hundred eighteen standard trawl hauls were completed over the 7-year period, 1991–1997. During 1991–1997, 2,966 fish representing 30 species were captured in the standard trawl. Twenty-four percent of the hauls (52/218) had zero catch.

All four logistic regression models were significant at the 0.05 level ($P \leq 0.0001$) and explained 82.33% (standard trawl portion of Missouri trawl: $p = 0.5 + 0.08 \cdot \text{Length}$; $F_{1,77} = 266.20$), 90.27% (standard trawl without cover: $p = 0.34 + 0.09 \cdot \text{Length}$; $F_{1,77} = 677.14$), 91.51% (cover of Missouri trawl, fish lengths up to 28 cm: $p = -0.82 + 0.41 \cdot \text{Length}$; $F_{1,25} = 269.57$), and 87.8% (standard trawl portion of Missouri trawl, fish lengths up to 28 cm: $p = -1.36 + 0.28 \cdot \text{Length}$; $F_{1,25} = 180.56$) of the variance in cumulative capture probability (Figures 3, 4). Fish larger than 28 cm were not captured in the cover because they did not pass through the body of the standard trawl portion. Therefore, regressions for the cover and the standard trawl portion were based only on fish lengths up to 28 cm (Figure 3). The slopes of the regression models for fish up to 28 cm differed markedly between the standard trawl portion and cover; the regression for the cover had a steeper slope (Figure 3). Use of the cover resulted in greater probability of capture for fish lengths up to 23 cm, and for fish longer than 15 cm the cumulative probability of capture approached 1.0 (Figure 3). The standard trawl portion of the Missouri trawl accumulated captures at a slower rate, and the cumulative probability of capture approached 1.0 for fish longer than 26 cm.

The slopes of the regression models were similar between the standard trawl portion of the Missouri trawl (1998–2001) and the standard trawl without the cover (1991–1997). Use of the cover did not affect the cumulative capture probability of fish in the standard trawl portion of the Missouri trawl (Figure 4). Therefore, the cumulative probability of capturing fish in the standard trawl portion of the Missouri trawl was the same as that of the standard trawl without the cover.

Species detection was higher in the Missouri trawl than in the unmodified standard trawl. Random sampling of the data indicated quicker response time of species detection by use of the Missouri trawl (Figure 5). After eight samples, the Missouri trawl captured 50% of the overall detected species, whereas it took the standard trawl 56 samples to reach the same level of species detection.

Discussion

Our data show that many small fishes passed through the trawl body. Previous negligible catch of small benthic fishes in the standard trawl (1991–1997) was because of the trawl body. We used a small-mesh cod end in the standard trawl for 7 years before implementing the Missouri trawl. We detected fewer individuals and species in the standard trawl than in the Missouri trawl. Seventy-seven percent of the total fish captured passed through the standard trawl's mesh and failed to reach the cod end of the standard trawl, including young and larval fish (e.g., sturgeons) and smaller-bodied adult species (e.g., chubs). The lack of several historically common species (e.g., sturgeon chub, sicklefin chub) in community samples during 1991–1997 was previously troublesome. Both fish species were candidates for federal endangered status during this study.

The standard trawl design did not effectively

TABLE 1.—Fish species captured by use of a modified two-seam balloon trawl (i.e., Missouri trawl) in the upper Mississippi River during 1998–2001. Species abundances in the standard (std.) trawl portion and cover were compared by use of the chi-square statistic. Species with significantly different abundances ($P \leq 0.05$) are denoted by asterisks.

Family and species	Total catch		χ^2	P
	Cover	Std. trawl		
Acipenseridae				
Pallid sturgeon *Scaphirhynchus albus*	2	0	0	
Shovelnose sturgeon *S. platorynchus*	22	83	35.44	<0.001*
Larval sturgeon *Scaphirhynchus* spp.	26	0	0	
Polyodontidae				
Paddlefish *Polyodon spathula*	181	24	120.24	<0.001*
Lepisosteidae				
Shortnose gar *Lepisosteus platostomus*	0	4	0	
Clupeidae				
Goldeye *Hiodon alosoides*	22	8	6.53	<0.001*
Mooneye *H. tergisus*	11	3	4.57	0.033*
Skipjack herring *Alosa chrysochloris*	1	2	0.33	0.564
Gizzard shad *Dorosoma cepedianum*	40	39	0.01	0.91
Threadfin shad *D. petenense*	3	3	0	1.0
Cyprinidae				
Grass carp *Ctenopharyngodon idella*	7	1	4.5	0.033*
Red shiner *Cyprinella lutrensis*	1	0	0	
Blacktail shiner *C. venusta*	1	0	0	
Common carp *Cyprinus carpio*	35	19	4.74	0.029*
Mississippi silvery minnow *Hybognathus nuchalis*	2	0	0	
Bighead carp *Hypophthalmichthys nobilis*	39	6	24.2	<0.001*
Shoal chub *Macrhybopsis hyostoma*	3,070	396	2,062.98	<0.001*
Sturgeon chub *M. gelida*	198	36	112.15	<0.001*
Sicklefin chub *M. meeki*	144	40	58.78	<0.001*
Silver chub *M. storeriana*	28	5	16.03	<0.001*
Emerald shiner *Notropis atherinoides*	26	1	23.15	<0.001*
River shiner *N. blennius*	1	0	0	
Bigeye shiner *N. boops*	1	0	0	
Silverband shiner *N. shumardi*	36	1	33.11	<0.001*
Channel shiner *N. wickliffi*	893	91	653.66	<0.001*
Bluntnose minnow *Pimephales notatus*	1	0	0	
Bullhead minnow *P. vigilax*	2	0	0	
Catostomidae				
River carpsucker *Carpiodes carpio*	5	10	1.67	0.197
Blue sucker *Cycleptus elongatus*	1	1	0	1.0
Black buffalo *Ictiobus niger*		1	0	
Shorthead redhorse *Moxostoma macrolepidotum*	1	1	0	1.0
Ictaluridae				
Yellow bullhead *Ameiurus natalis*	1	0	0	
Blue catfish *Ictalurus furcatus*	602	347	68.52	<0.001*
Channel catfish *I. punctatus*	4,376	1,762	1,113.23	<0.001*
Stonecat *Noturus flavus*	12	3	5.4	<0.02*
Freckled madtom *N. nocturnus*	4	2	0.67	0.414
Flathead catfish *Pylodictis olivaris*	2	5	1.29	0.257
Atherinopsidae				
Inland silverside *Menidia beryllina*	2	0	0	
Moronidae				
White bass *Morone chrysops*	5	4	0.111	0.739
Striped bass *M. saxatilis*	1	0	0	
Centrarchidae				
Bluegill *Lepomis macrochirus*	2	2	0	1.0
Percidae				
Logperch *Percina caprodes*	1	0	0	
River darter *P. shumardi*	9	2	4.46	0.035*
Sauger *Sander canadensis*	4	9	1.92	0.166
Sciaenidae				
Freshwater drum *Aplodinotus grunniens*	728	306	172.23	<0.001*
All species	10,549	3,217	5,938.65	<0.001*

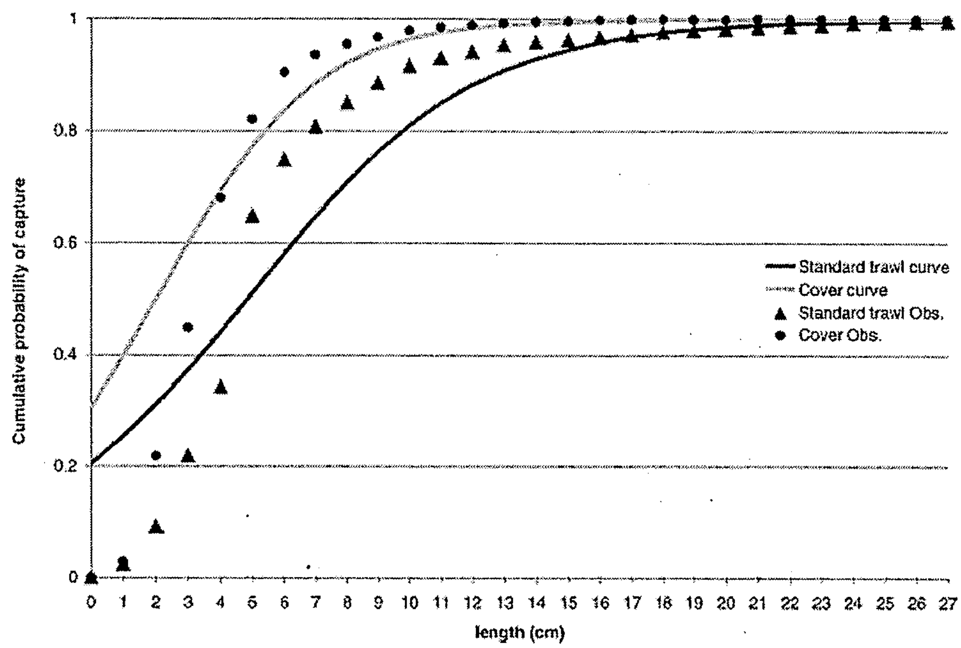

FIGURE 3.—Results of the logistic regression plotting the cumulative probability of capture against fish length for the standard trawl portion and cover of the Missouri trawl (triangle = standard trawl, observed; circle = cover, observed). Standard trawl and cover curves are indicated by solid lines.

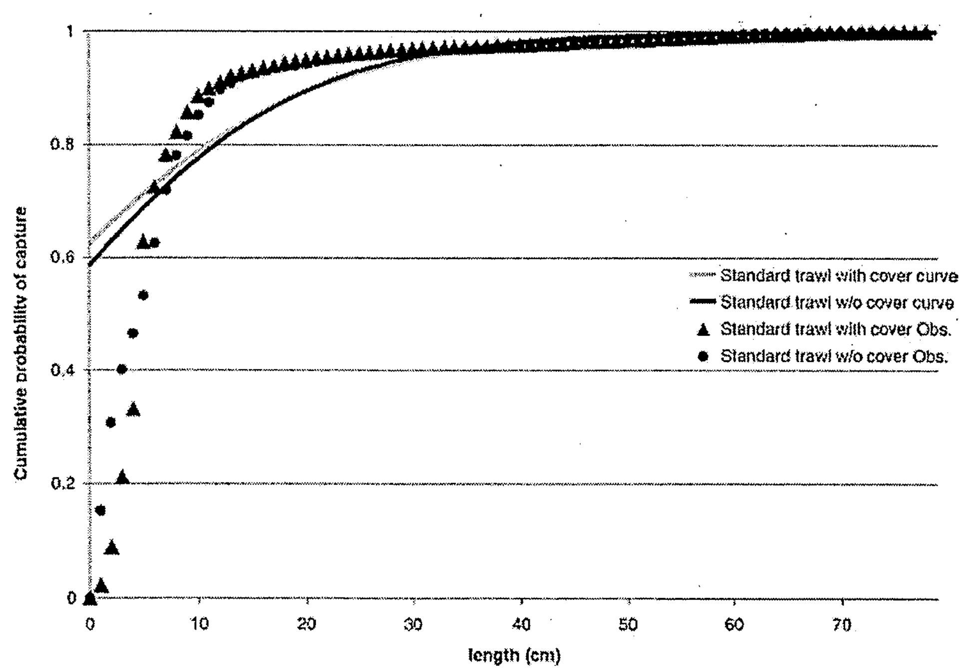

FIGURE 4.—Results of the logistic regression plotting the cumulative probability of capture against fish length for the standard trawl without a cover (used to sample the upper Mississippi River in 1991–1997) and the standard trawl portion of the Missouri trawl (used for sampling in 1998–2001) (triangle = standard trawl with cover, observed; circle = standard trawl without cover, observed). Curves for standard trawls with and without a cover are indicated by solid lines.

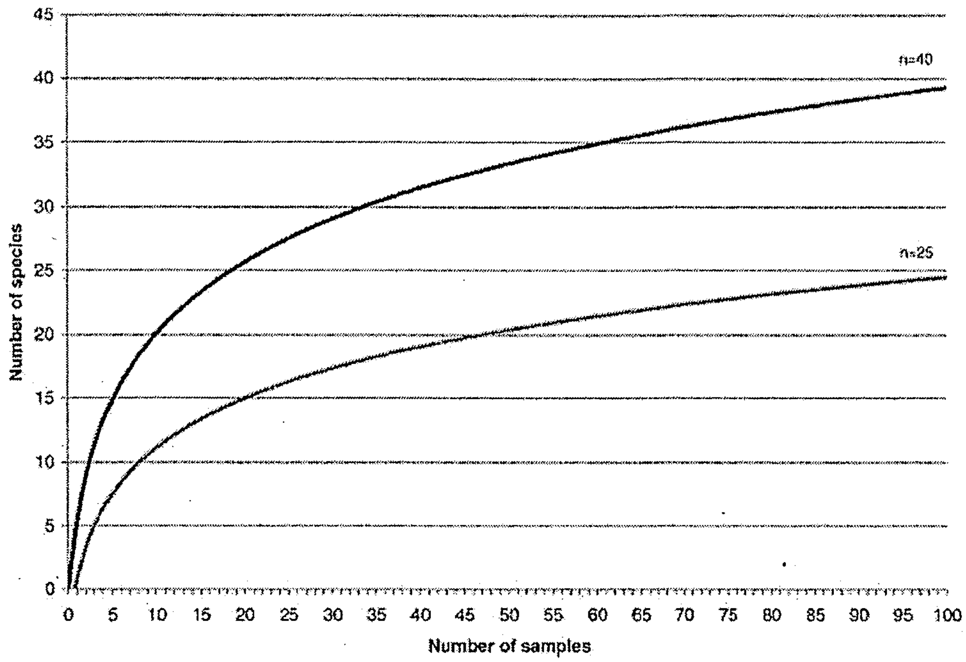

FIGURE 5.—Comparison of the rate of fish species captured after 100 samples by use of the unmodified standard trawl (gray line) and the Missouri trawl (black line) in the unimpounded reach of the upper Mississippi River. Solid lines represent cumulative numbers of fish species captured at selected sampling intervals.

capture small fish, and the design could have contributed to escape through the trawl body because the fish may have impinged against the mesh prior to entering the cod end. Although the standard trawl is generally funnel-shaped, the attack angle of the trawl body may have caused the trawl to act more like a sieve rather than as a funnel for directing fish to the cod end. We speculate that fish have a higher tendency to pass through the netting when the attack angle is abrupt than when the angle is gradual. Unfortunately, no studies on this subject have been published for freshwater systems, and additional research should be conducted to clarify this issue. However, trawling procedures were consistent throughout the study for both trawls (i.e., Missouri and standard). Therefore, any changes to catch composition that occur through use of the Missouri trawl should be attributed to the cover.

When a trawl with a cover is used, mesh interactions may affect the catch. Cover effects were not identified when the cumulative capture probabilities from the standard trawl portion of the Missouri trawl (1998–2001) and the standard trawl without the cover (1991–1997) were compared. Cumulative capture probabilities were nearly identical across all length ranges. These results are similar to findings of Madsen and Holst (2002), who found no obvious masking effects caused by a covered cod end on catch of a single species. However, fish larger than the mesh cannot pass through to the small mesh. This explains the significantly higher abundance of shovelnose sturgeon in the standard portion of the Missouri trawl. A fish's shape, texture, behavioral response (e.g., predator avoidance), and size are important factors in determining its susceptibility to fishing gear (Pope et al. 1975). Shovelnose sturgeon are not strong swimmers and use substrate appression to maintain themselves in the current (Adams et al. 1997). Thus, this species is less likely to escape an encounter with a bottom trawl. Conversely, larval sturgeons pass through large mesh because of their size and shape. Gunderson (1993) addressed differences in trawl capture based on fish size and ability to out-swim the trawl. Also, because of habitats they occupy, some fish (e.g., pelagic species) will not be captured by bottom trawling. All 18 species that were significantly more abundant in the small-mesh cover than in the standard portion of the Missouri trawl were either small or had streamlined bodies.

Although there was no apparent effect of the cover on cumulative probability of catch, there was an effect on drag. The small-mesh cover of the Missouri trawl increases the power required by the motor to pull the trawl and requires substantially more manpower to retrieve than does an unmodified standard trawl. In addition, the small-mesh cover is susceptible to damage because it is on the outside of the trawl. However, the utility of the cover for community sampling outweighs any negative aspects like higher drag or maintenance, and the cover may reduce catch mortality of small fish. For example, although large-mesh trawls capture larger fish, reduce drag, and allow for reduced bycatch (Dickson 1962; Naidu et al. 1987), they may injure or kill fish. Fish escapement through large-mesh trawls may cause delayed mortality because of the trauma of pass-through or impingement on the trawl body (Chopin and Arimoto 1994). However, because there were two mesh sizes in the Missouri trawl, smaller fish that passed through the standard trawl portion remained separate from large debris and larger fish. This design prevented unnecessary damage to smaller fish by impingement on larger fish or debris. Matsushita and Shida (2001) noted that separation of marine debris by selective gear (i.e., bycatch exclusion window) avoided much damage to the catch. This is extremely important when there is potential for encountering a federally endangered species (e.g., pallid sturgeon) while trawling. The Missouri trawl design improves small fish capture and decreases the likelihood of delayed mortality caused by capture stress.

When a single gear is used to sample a fish community, it is important to address how many species are being captured as well as the total number of individuals of each species. Many sampling protocols are designed to capture species-specific information by use of best methods and are effective tools for resource managers. However, a sampling gear that is effective for multiple species and diverse areas provides more utility per unit effort. We have shown that the Missouri trawl is a practical method for sampling fish communities in different-size river systems. The advantages of this trawl include low equipment cost, simple operation, and improved capture of fish species and abundance in comparison to that of a two-seam slingshot balloon trawl with a 19.05-mm-mesh body and a 3.18-mm-mesh cod end. Researchers continue to modify cod end specifications to study and capture specific sizes of fish (Mous et al. 2002). The modifications are usually not associated with community sampling, but rather are used to increase catch of large fish and reduce catch of small or unwanted fish. Our study supports the idea that the body of the trawl can affect capture as much as or more than the cod end. This methodology will improve the effectiveness of benthic fish community sampling in moderate to large river systems.

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References

Adams, S. R., G. R. Parsons, J. J. Hoover, and K. J. Killgore. 1997. Observations of swimming ability in shovelnose sturgeon (*Scaphirhynchus platorynchus*). Journal of Freshwater Ecology 12:631–633.

Barko, V. A., M. W. Palmer, D. P. Herzog, and B. S. Ickes. 2004. Influential environmental gradients and spatiotemporal patterns in fish assemblages in the unimpounded upper Mississippi River. American Midland Naturalist 152(2):369–385.

Brabant, J. C., and C. Nedelec. 1979. Bottom trawls for small-scale fishing. FAO Fisheries Technical Paper 189.

Chopin, F. S., and T. Arimoto. 1994. The condition of fish escaping from fishing gears: a review. Fisheries Research 21:315–327.

Dahm, E. 2000. Changes in length compositions of some fish species as a consequence of alterations in the ground gear of the GOV-trawl. Fisheries Research 49:39–50.

Dettmers, J. M., S. Gutreuter, D. H. Wahl, and D. A. Soluk. 2001. Patterns and abundance in main channels of the upper Mississippi River system. Canadian Journal of Fisheries and Aquatic Sciences 58: 933–942.

Dickson, W. 1962. Modern fishing gear of the world, volume 2. Fishing News Books, Farnham, UK.

Dremiere, P., L. Fiorentini, G. Cosimi, I. Leonori, A. Sala, and A. Spagnolo. 1999. Escapement from the main body of the bottom trawl used for the Mediterranean international trawl survey (MEDITS). Aquatic Living Resources 12:207–217.

Glass, C. W., and C. S. Wardle. 1989. Comparison of the reactions of fish to a trawl gear at high and low light intensities. Fisheries Research 7:249–266.

Godo, O. R., and S. J. Walsh. 1998. Escapement of fish during bottom trawl sampling: implications for resource assessment. Fisheries Research 13:281–292.

Gunderson, D. R. 1993. Surveys of fisheries resources. Wiley, New York.

Gutreuter, S. 1993. The need for spatially randomized sampling of fishes in the Long Term Resource Monitoring Program. U.S. Fish and Wildlife Service, Environmental Management Technical Center, Technical Report 92-T001, Onalaska, Wisconsin.

Gutreuter, S., R. W. Burkhardt, and K. Lubinski. 1995. Long Term Resource Monitoring Program procedures: fish monitoring. National Biological Service, Environmental Management Technical Center, Technical Report 95-P002-1, Onalaska, Wisconsin.

Hayes, D. B., C. P. Ferreri, and W. W. Taylor. 1996. Active fish capture methods. Pages 193–220 *in* B. R. Murphy and D. W. Willis, editors. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Herzog, D. P. 2004. Capture efficiency and habitat use of sturgeon chub (*Macrhybopsis gelida*) and sicklefin chub (*Macrhybopsis meeki*) in the Mississippi River. Master's thesis. Southeast Missouri State University, Cape Girardeau.

Kelley, K. 1994. Fish behavior is key to reducing unwanted species. National Fisherman 74(4):1–30.

Kim, Y. H., and C. S. Wardle. 1997. Measuring brightness contrast of fishing gear: the visual stimulus for fish capture. Fisheries Research 34:151–164.

Kunjipalu, K. K., N. S. Pillai, M. R. Boopendranath, and K. K. Rao. 1992. Effect of horizontal opening of bottom trawl on fish catch. Fishery Technology 29: 91–94.

Lowry, N., and J. H. B. Robertson. 1996. The effect of twine thickness on cod end selectivity of trawls for haddock in the North Sea. Fisheries Research 26: 353–363.

Madsen, N., and R. Holst. 2002. Assessment of the cover effect in trawl cod end selectivity experiments. Fisheries Research 56:289–301.

Matsushita, Y., and M. Shida. 2001. Comparison of catches between selective and conventional otter trawl for a coastal fishery. Reviews in Fisheries Science 9:33–42.

Michaletz, P., J. Boxrucker, S. Hale, and J. R. Jackson. 1995. Comparison of four trawls for sampling juvenile shad. North American Journal of Fisheries Management 15:918–923.

Millar, R. B. 1992. Estimating the size selectivity of fishing gear by conditioning on the total catch. Journal of the American Statistical Association 87:962–969.

Mous, P. J., W. L. T. van Densen, and M. A. M. Machiels. 2002. The effect of smaller mesh sizes on catching larger fish with trawls. Fisheries Research 54:171–179.

Naidu, R. M., S. V. S. Ramarao, G. Narayanappa, A. V. V. Satyanarayana, J. Sitaramarao, and A. K. K. Nair. 1987. Effect of variation in mesh size on trawl efficiency. Fishery Technology 24:80–82.

Nelson, J. S., E. J. Crossman, H. Espinoza-Perez, L. T. Findley, C. R. Gilbert, R. N. Lea, and J. D. Williams. 2004. Common and scientific names of fishes from the United States, Canada, and Mexico. American Fisheries Society, Special Publication 29, Bethesda, Maryland.

Owens, T., and J. J. Ruhser. 1996. Long Term Resource Monitoring Program operating procedures: aquatic database production. National Biological Service, Environmental Management Technical Center, Report 95-P008-6, Onalaska, Wisconsin..

Pine, W. E., III 2000. Comparison of two otter trawls of different sizes for sampling black crappies. North American Journal of Fisheries Management 20: 819–821.

Pitlo, J. 1992. An evaluation of the effect of a change in commercial harvest regulations on the channel catfish populations inhabiting the upper Mississippi River. Iowa Department of Natural Resources, Federal Aid in Sport Fish Restoration, Project F-109-R, Des Moines.

Polet, H. 2000. Cod end and whole trawl selectivity of a shrimp beam trawl used in the North Sea. Fisheries Research 48:167–183.

Pope, J. A., A. R. Margetts, J. M. Hamley, and E. F. Akyuz. 1975. Manual of methods for fish stock assessment, part3. Selectivity of fishing gear. FAO Fisheries Technical Paper 41.

Ryer, C. H., and B. L. Olla. 2000. Avoidance of an approaching net by juvenile walleye pollock *Theragra chalcogramma* in the laboratory: the influence of light intensity. Fisheries Research 45:195–199.

SAS Institute. 1998. SAS/STAT user's guide, release 6.03. SAS Institute, Cary, North Carolina.

Steel, R. G. D., and J. H. Torrie. 1980. Principles and procedures of statistics, 2nd edition. McGraw-Hill, New York.

Van Den Avyle, M. J., J. Boxrucker, P. Michaletz, B. Vondracek, and G. R. Ploskey. 1995. Comparison of catch rate, length distribution, and precision of six gears used to sample reservoir shad populations. North American Journal of Fisheries Management 15:940–955.