WATER RESOURCES DIVISION POLICY AND PROCEDURE

DRAFT WRD-SWAS-051
Qualitative Biological and Habitat Survey Protocols for Wadeable Streams and Rivers

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ISSUE

This Water Resources Division (WRD), Great Lakes Watersheds Assessment, Restoration, and Management Section (GLWARMS) procedure establishes the process necessary to monitor the fish community, macroinvertebrate community, and habitat quality in wadeable rivers and streams in support of ambient water quality monitoring, National Pollutant Discharge Elimination System (NPDES) permit support, and other point and nonpoint source needs.

DEFINITIONS

- Foot per second (f/s)
- Functional Feeding Group (FFG)
- Great Lakes Watersheds Assessment, Restoration, and Management Section (GLWARMS)
- Large woody debris (LWD)
- Michigan Department of Environment, Great Lakes, and Energy (EGLE)
- Michigan Department of Environmental Quality (MDEQ)
- Millimeter (mm)
- Multi-metric index (MMI)
- National Pollutant Discharge Elimination System (NPDES)
- Natural Resources and Environmental Protection Act (NREPA)
- Percent (%)
- United States Environmental Protection Agency (USEPA)
- United States Geological Survey (USGS)
- Water Resources Division (WRD)

POLICY

AUTHORITY:

Section 3103(1) of Part 31, Water Resources Protection, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended (NREPA).

PROCEDURE

I. INTRODUCTION

Biological survey (biosurvey) protocols presented in this procedure consist of separate qualitative evaluations of the macroinvertebrate community, fish community, and habitat quality in wadeable lotic (flowing) streams or rivers. These evaluations may be conducted and applied independently or in combination. The results of the fish and/or macroinvertebrate community evaluations are indicators of the biological integrity of the stream.

These protocols can be used to assess the existing condition of Michigan’s wadeable streams and rivers as well as detect spatial and temporal trends. Specifically, the GLWARMS staff use these protocols to fulfill monitoring requests, assess known or potential areas of concern, achieve assessment coverage of watersheds, and provide information to support and evaluate the effectiveness of the Michigan Department of Environment, Great Lakes, and Energy (EGLE) protection programs (e.g., NPDES, nonpoint source, and site remediation), and make site-specific determinations of designated use support (per Rule 100 [R 323.1100] of the Part 4 Rules, Water Quality Standards, of the NREPA) as well as spatial and temporal designated use support determinations on statewide and watershed levels.

The physical transition between wadeable and nonwadeable rivers is not distinct. On larger rivers, the determination of the ability to adequately sample, should acknowledge the broad scale of habitat features and potential difficulties with collecting biological and habitat information representative of the entire river reach rather than simply consider the access location. The ability to safely wade the majority of the channel and adequately sample all available habitats should be considered in situations where the applicability of these protocols is questionable due to the size of the river. For large, nonwadeable rivers where it is determined that these protocols are inappropriate, the Quantitative Biological and Habitat Survey Protocols for Nonwadeable Rivers procedure (WRD-SWAS-022) (Michigan Department of Environmental Quality [MDEQ], 2013) should be used.

EGLE has conducted stream monitoring of macroinvertebrates since the early 1990s. Field methods have been consistent over time, though a revision of Procedure 51 in 2006 changed the identification subsample size from 100 to 300 organisms. Following the 2006 revision and a review of the original reference site selection for Procedure 51 (Matousek, 2017), EGLE initiated a redevelopment of the macroinvertebrate community scoring system working with an outside contractor with extensive experience developing biological indices (Tetra Tech, 2023). Field sampling methods have not been changed since the 2006 revision.

A complete data-driven redevelopment of the macroinvertebrate multi-metric index (MMI) was conducted using the following steps. First, sites with the least amount of disturbance, considered to be equivalent to reference sites, were identified to define metric expectations under optimal environmental conditions. Second, biological variability in the reference sites was examined and used to group similar macroinvertebrate communities into stream classes, within which macroinvertebrate metric expectations were specific to the natural setting of each class. Third, metrics were evaluated for precision and responsiveness to disturbance. Fourth, the MMI was composed using responsive metrics from multiple metric categories. Several index compositions were formulated and tested for responsiveness to the disturbance gradient in each stream class. The index with the best assessment performance and applicability was selected as the Michigan stream macroinvertebrate MMI for each stream class. Finally, EGLE collected additional validation data and established assessment thresholds. Additional macroinvertebrate scoring and threshold information is available in Holden et al. (2024).

The 2024 updated macroinvertebrate MMI, scoring, and thresholds are recommended for use on future macroinvertebrate biosurveys conducted by WRD staff; however, there may be specific needs for internal or external partners to use the 2006 scoring method. In addition, certain monitoring studies or situations may require quantitative or alternate biological or habitat collection methods or metric evaluation systems.

II. PRINCIPLES OF FISH, MACROINVERTEBRATE, AND HABITAT SURVEYS

Fish and macroinvertebrate community composition generally reflect conditions present for an extended period of time prior to sampling. However, temporary events, such as decreases in dissolved oxygen concentrations or the presence of toxicants, may cause losses of sensitive taxa either by emigration or death. Similarly, an abundance of tolerant organisms may indicate persistent degraded stream quality. Changes in fish or macroinvertebrate community structure may also occur if trophic changes occur due to pollution or perturbation.

In these protocols, analyses of the warmwater fish and macroinvertebrate communities are made according to a set of measurements or "metrics." Fish community metrics have been selected from those used in the United States Environmental Protection Agency’s (USEPA) Rapid Biological Assessment Protocols (Barbour et al., 1999), Ohio Environmental Protection Agency's protocols (Ohio Environmental Protection Agency, 1987a, 1987b, and 1987c), the state of Illinois' biological procedures, and those procedures developed specifically for Michigan and tested by EGLE.

Macroinvertebrate metrics were selected that differentiated between reference and stressed sites and chosen from several types of metrics (Tetra Tech, 2023). Metric categories include taxa richness by taxa group, composition of individuals by taxa group, richness and composition of feeding or trophic groups, richness and composition of habit types (methods of attachment or locomotion), and richness and composition of pollution tolerance groups.

The individual metrics provide information on a variety of biological attributes that, when combined, are intended to indicate overall changes in the fish and macroinvertebrate communities in response to various stream quality conditions. The accuracy of the protocols, however, depends on the selection and evaluation of appropriate reference sites used to set expectations. For both the warmwater fish and macroinvertebrate indices it is expected that high quality streams will have biological communities similar to least impacted reference sites. As environmental stressors increase in a stream, the fish and macroinvertebrate communities are expected to reflect those impacts and increasingly differ from the least impacted sites.

The reference sites used for the fish index were selected from streams recognized as excellent in quality by biologists within each of Michigan's five distinct ecoregions (Omernik, 1987). Each ecoregion has several reference sites, spanning different stream widths. The ecoregion approach provides a logical framework to use with these biological monitoring protocols because the expectations for the fish communities differ by abiotic characteristics of each ecoregion.

The reference sites used for the macroinvertebrate index were selected by identifying least impacted sites using a large suite of watershed and catchment characteristics indicative of human disturbance (Tetra Tech, 2023). This process was done separately in the north (Northern Lakes and Forests and Northern Central Harwood Forests ecoregions) and south (Eastern Corn Belt Plains, Huron/Erie Lake Plains, and Southern Michigan/Northern Indiana Drift Plains ecoregions) regions because of differences in geology, soils, and development (Omernick and Bryce, 2010; Tetra Tech, 2023). Stream classes were then developed within each region using important abiotic measures (e.g., slope or width) to account for natural variation in macroinvertebrate communities at least impacted sites. Separate macroinvertebrate indices were developed for each stream class.

Multiple metrics for coldwater fish communities are not included in this procedure. The coldwater fish community is evaluated for the presence of at least 50 fish, relative abundance of anomalies, and relative abundance of salmonids collected.

The habitat evaluation is also important in determining the nature and degree of abiotic constraints on the biological potential. This habitat evaluation is accomplished through stream characterization based on selected physical measurements and descriptive watershed features. Habitat metrics are used to assess a wide range of physical characteristics that are important to the optimum development and stability of biological communities. Ultimately, the metrics are used to rate overall habitat quality. The habitat metrics used in this protocol are based on the USEPA's Rapid Bioassessment Protocols (Barbour et al., 1999).

III. GENERAL SAMPLING CONSIDERATIONS

1. Sampling should occur between June 1 and September 30 during periods of stable discharge and at times of low or moderate flow. This sampling period helps to ensure consistency between sampling studies by reducing variability due to seasonality and flow fluctuations within years or between years.

2. For basin investigations or long-term studies, stations should be sampled during the same time frame, or similar environmental conditions, to minimize seasonal variability in fish and macroinvertebrate distribution or abundance.

3. Maximum impact of a municipal or industrial discharge usually occurs during summer low stream flow and maximum temperature conditions. Dilution is minimal for pollutants during low flow conditions, while elevated stream temperatures and productivity produce maximum fluctuations in diurnal oxygen concentrations. High temperatures also increase fish and macroinvertebrate metabolic rates, which may amplify toxics effects.

4. Consideration must be given to the sampling sequence at a site to ensure the least disruption of the communities to be sampled. Sampling should generally occur in the following order: fish, macroinvertebrates, and habitat.

5. Record all data on the Field Sheet (available upon request) or alternate digital data collection application, including a sketch of the station location to assist future sampling.

The following channel modifications should be noted by checking the appropriate box(es) on the Field Sheet:

- None - natural stream channel, no evidence of modifications.
- Dredged - stream channel has been excavated (widened, deepened, straightened), evidence of dredge spoils along stream banks.
- Canopy removal - woody riparian vegetation has been removed from 1 or both banks either by physical removal or with the use of defoliant sprays.
- Snagging - removal of logs, deadfalls, and other large woody debris (LWD) from the stream channel.

- Impounded - station is located either directly upstream of an impoundment or directly downstream of a dam.
- Relocated - stream channel has been completely rerouted from the original channel usually to follow a roadway, railway, or has been redirected for industrial purposes (e.g., mill race) or has been rerouted to another watershed.
- Bank stabilization - this includes engineered cattle access points, or the stream bank has been armored with rip-rap, sheet piling, revetments, etc.
- Habitat improvement - identified by the presence of artificial banks (lunker structures), wing deflectors, half-logs, rock dams, etc.

Instream features should be recorded that characterize average stream conditions in the sampling reach. It is recommended that flow is estimated by following appropriate protocols such as the neutrally buoyant object method (EGLE, 2023a).

6. The presence or absence of bacterial slimes, rooted emergent, rooted submergent, rooted floating, or free floating plants and suspended or attached algae should be noted, along with the dominant species if known. Estimates of the spatial coverage at the site of both algae and macrophytes should also be made. Additional notes on any possible concerns with nutrient expression should be recorded. Additional assessment of nutrient expression can be made using draft internal guidance on stream nutrient expression assessment.

7. Presence and extent of inorganic and organic substrate components in the sampling reach should be recorded. Inorganic substrate percentages should add up to 100 percent (%) and could include bedrock, boulder, cobble, gravel, sand, silt, or clay. Organic substrates do not need to add up to 100% and include coarse particulate organic material (sticks, wood, coarse plant) and fine particulate organic material (black, fine). The proportion of the reach represented by stream morphology types should also be recorded (riffle, run, pool). Additional structure available for macroinvertebrate colonization should be recorded (undercut banks, overhanging vegetation, LWD, aquatic macrophytes, rootwads).

IV. SITE SELECTION

Sites may be selected for assessment using a targeted approach and/or a randomized approach. Sites may be selected using a targeted approach to investigate specific concerns. Sites should be randomly selected using the Macroinvertebrate Community Status and Trend Monitoring Procedure (WRD-SWAS-027; MDEQ, 2015) to evaluate spatial and temporal biological trends and attainment status on a watershed and statewide levels.

These biological and habitat survey protocols are intended for use in wadeable portions of perennial streams that flow between well-defined stream banks. Streams that become lentic or lose all perception of flow due to impoundment or other hydrologic modification or are intermittent or ephemeral are not suitable for assessment using this procedure.

When the sampling station is located at a road crossing, sampling should occur upstream to avoid direct influence of the roadway when possible or may be shifted downstream of the road in an area without visible road impact. Locally-modified sites, such as small impoundments and bridge areas, should be avoided unless data are needed to assess their effects on the water body. In addition, areas located immediately downstream of lentic water bodies (e.g., lake outlets) should be avoided. Sampling near the mouths of tributaries entering large water bodies should also be avoided, if possible, since these areas will have habitat more typical of the larger water body (Karr et al., 1986).

V. QUALITATIVE FISH SAMPLING PROCEDURE AND DATA ANALYSIS

A. Fish Sampling Procedures

1. The stream barge shocking unit is the preferred fish sampling device except where physically impractical. Backpack shocking units may be used when sampling smaller streams or headwaters. All safety procedures must be observed when using these units (Procedure WRD-SWAS-005; EGLE, 2023b).

2. Fish shocking must always be done in an upstream direction.

3. The sampling effort expended should be sufficient to ensure that all fish species present are sampled in proportion to their occurrence in the stream reach chosen. As a goal, at least 100 individual fish should be examined from each station. This will generally require approximately 30 minutes of electrofishing per station, encompassing 100-300 feet with sufficient sampling to include all significant available habitat. In small streams (10 feet wide), the length of the sampling station should be approximately 100 feet. In moderate size streams (30 feet wide), the length should be approximately 300 feet. In larger streams and rivers, the length of the sampling station should be about 5-10 channel widths. If necessary, increase the length of the selected sampling area. If the number of fish collected is no greater than 100 individuals after 45 minutes, discontinue further sampling and calculate metrics based on reduced sample size.

4. All collected fish should be placed immediately in water-filled tubs. Care should be taken to keep fish alive by replenishing the holding tub water and processing the fish as quickly as possible. Tubs may be placed in the stream barge shocking unit or along the stream banks. A live box may also be placed directly in the stream to hold collected fish. Portable battery-operated aerators may also be used.

B. Data to be Recorded

When sampling has been completed at each station, the following information should be recorded:

1. The location of the sampling stations should be specifically indicated on the Field Sheet so that future studies can be repeated at the same station. Latitude and longitude coordinates should be obtained using appropriate methods and quality control (EGLE, 2023a). The station reaches should be identified on a detailed map of the study area together with any necessary comments or descriptions on the Field Sheet.

2. Record the names and number of each species collected with a length greater than 1 inch and determine the total number of fish collected. If unsure of correct field identification, return representatives to the lab for later identification. Regional keys have been chosen for their ease of use and elimination of extraneous taxa. Hubbs and Lagler (1964) should be used as the primary key when identifying all gamefish. For nongame fish, Smith (1988) may be used but identification verification should use Hubbs and Lagler (1964). Additional information on Petromyzonidae (lampreys) can be found in Vladykov and Kott (1980).

3. The following externally observable anomalies should be noted as total number of individuals afflicted: bent spine (scoliosis), open lesions, severely eroded fins, fungus patches, growths on skin or fins, tumors, and poor physical condition indicated by severe emaciation, excessive mucus coating, and hemorrhaging. This measurement is meant to apply only to extreme or

obvious conditions. Common external parasites, such as copepods (anchorworms), and common visible internal parasites, such as black spot and yellow grub should not be considered anomalies unless extreme or very severe infestations are present. All determinations of anomalies should be compared to those illustrated and presented in Allison et al. (1977).

4. Record the amount of time spent electrofishing at each station including the number of passes through the sampling station and the number of shocking probes used. Also record average stream width (wetted stream channel width at time of sampling) and distance of reach electrofished. Catch per unit effort will be calculated as the total number of fish collected divided by the number of minutes spent shocking at each station (catch per minute), and as the number of fish per stream area (catch per square meter).

5. Record the length of all fish listed in Appendix G to inch group or size range. These data may be used for additional biomass or productivity estimates.

C. Data Analysis Techniques

Following sample analyses, a Fish Score will be calculated for each warmwater station based on the sum of each of the 10 metrics listed below. Each metric score for an individual station is contrasted to the ecoregional reference sites. A biosurvey category describing the degree of similarity to the reference sites will be given to each station based on the total metric point score calculated. These contrasts and categories are described in a separate report (Creal et al., 1996).

There are some overriding considerations in this interpretation. When fewer than 50 fish are collected, or when the percent of fish with anomalies exceeds 2%, the site will not be scored following the metrics, but will be considered below acceptable quality.

In addition, for coldwater designated streams, significant populations of salmonids should be present. Therefore, for coldwater designated streams, relative abundance of salmonids is the metric used (i.e., relative abundance of salmonids equal to or exceeding 1% as described in separate reports (Creal et al., 1996).

Metric Description

Metric 1. Total Number of Fish Species. This is the total number of fish species collected at each sampling station. For a given watershed size and type of stream (warmwater), total number of fish species decreases with environmental degradation. This metric is scored by comparison to excellent sites of similar size.

Metric 2. Number of Darter Species. This is the number of species in the genera Ammocrypta, Etheostoma, and Percina (Percidae: Etheostomatinae), and the number of species of Sculpins (Cottidae) and of Madtoms (genus Noturus). These species are sensitive to habitat degradation due to the unique habitats they require for reproduction. Such habitats are degraded by siltation, dredging, or reductions in oxygen content. The presence of 1 or 2 taxa may indicate good water quality so care should be taken during sampling to collect all small fish.

Metric 3. Number of Sunfish Species. This is the total number of species in the family Centrarchidae exclusive of largemouth and smallmouth basses (Micropterus sp.). They are particularly responsive to declines in pool habitats and habitat structure such as instream cover (Gammon et al., 1981; Angermeier, 1983).

Metric 4. Number of Sucker Species. This is the total number of species in the family Catostomidae. Many species are not tolerant of habitat and chemical degradation, due to habitat specificity and dominance of benthic insects in their diet. In addition, large size and long lives provide a multiyear integrative perspective.

Metric 5. Number of Intolerant Species. This is the total number of species classified as intolerant (Appendix A). Intolerant fish are those that are sensitive to many types of environmental degradation and tend to be absent from degraded surface water bodies.

Metric 6. Percentage of Total Sample as Omnivores. This is the ratio of the number of omnivores to the total number of fish collected. Omnivorous fishes are those species that routinely take significant quantities of both plant and animal material (often including detritus) and have the ability, usually indicated by the presence of a long gut and dark peritoneum, to utilize both. Appendix B contains a list of omnivorous fishes commonly found in Michigan. The common omnivores of small midwestern streams are Pimephales notatus and P. promelas, while Cyprinus carpio and Dorosoma cepedianum, also omnivores, are found over a wider range of stream sizes.

Omnivores can become dominant in degraded conditions, apparently as a result of irregular supply of both plants and invertebrate foods. Irregularity in plant or invertebrate availability results in declining abundances for fish that specialize on 1 food type or the other.

Metric 7. Percentage of Total Sample as Insectivorous Fish. This metric measures the ratio of the number of insectivorous fish to the total number of fish collected and tends to vary inversely with Metric 6. Most cyprinids are insectivores (Carlander, 1969 and 1977); besides the omnivores mentioned above (Pimephales), some other minnow species are strict herbivores and a few are piscivores. Although a dominant trophic group in Midwestern streams, relative abundance of insectivorous fish decreases with degradation, perhaps in response to variability in supply or production of insects, which in turn may decline in response to alteration of water quality, energy sources, or instream habitat. Appendix C contains a list of insectivorous fish commonly found in Michigan.

Metric 8. Percentage of Total Sample as Piscivores. This metric is a ratio of the number of all species that are predominantly piscivores as adults to the total number of fish collected. Some opportunistic fish species may feed on invertebrates as well as fish, including both fry and juveniles. Do not include species, such as creek chub, that may opportunistically include some fish in their diet only when very large (Fraser and Sise, 1980). Viable and healthy populations of top carnivore species such as smallmouth bass, walleye, northern pike, grass pickerel, and others indicate a healthy, trophically diverse community. Appendix D contains a list of piscivorous fishes commonly found in Michigan.

Metric 9. Percentage of Total Sample as Tolerant Species. This metric is a ratio of the number of tolerant fish to the total number of fish collected. Tolerant fish are those species able to adapt to a wide range of environmental conditions and are often common in highly degraded surface water bodies. Appendix E provides a list of tolerant species.

Metric 10. Percentage of Total Sample as Simple Lithophilic Spawners. This metric is a ratio of the number of simple lithophilic spawners to the total number of fish collected. Simple lithophilic spawners require clean gravel or cobble for spawning and do not construct nests or provide parental care. They are especially sensitive to sedimentation and siltation of these substrates. Appendix F provides a list of simple lithophilic spawners.

VI. QUALITATIVE MACROINVERTEBRATE SAMPLING PROCEDURE AND DATA ANALYSIS

A. Macroinvertebrate Sampling Procedures

1. The sampling effort or time expended at each station should be sufficient to ensure that taxa present are sampled in proportion to their occurrence in the stream reach chosen. Approximately 15 to 30 minutes of sampling time by 2 trained biologists per survey station should generally ensure adequate sampling of all habitat types and macroinvertebrate taxa in a stream reach. Larger rivers may require more sampling time and small streams with uniform habitat may need less time.

2. Macroinvertebrate samples should be taken from all available habitats using a dip net with a maximum mesh size of 1 millimeter (mm) or by hand picking. When necessary, substrates should be scrubbed with a small hand brush to dislodge organisms. Samples should be taken from both high velocity and low velocity areas within the selected sampling reach. It is generally accepted that the optimum habitat for macroinvertebrates includes gravel, cobble, and boulder substrates necessary to support the periphyton-based benthic community. Additional organisms may be hand-picked, scrubbed, or netted from other habitats such as fixed submerged boulders, vegetation, logs, pilings, or other structures. The sampling team should coordinate their effort to identify all available habitats with consideration given to the proportional occurrence of these habitats. Substrates such as sand and silt should be sampled if present; however, they may be sampled with reduced effort.

3. The samples should be thoroughly rinsed in the sampling net or by using a screen with a 1 mm mesh size. Samples are placed in a bucket to form a composite sample. Large organic or inorganic debris should be vigorously shaken by hand in the composite bucket to dislodge attached organisms. This cleaned debris is carefully (i.e., avoid the loss of organisms) removed from the bucket.

4. The composite sample is subsampled to obtain approximately 300±60 organisms for identification and enumeration. The composite sample is stirred in a nonuniform direction with care taken to dislodge organisms (e.g., snails) from the sides of the bucket to ensure that all organisms are sufficiently mixed throughout the bucket. A subsample is immediately extracted using a small net with a mesh size of 1 mm while the material in the composite is still suspended. An additional subsample from the bottom of the composite bucket may be necessary if heavy material that is not evenly distributed is present.

   The subsample should be placed in a light colored plastic or enamel pan and all organisms present identified, enumerated, and recorded. Additional subsamples may be extracted from the composite as needed until approximately 300±60 organisms are counted. To avoid sampling bias, all organisms captured in a subsample must be counted; therefore, it may be prudent to limit each subsample to 1 small sweep of the composite sample with the small net so that the target number of organisms is not exceeded.

The remaining composite sample should be placed in the pan and searched for 3-5 minutes for large or rare taxa that were not included in the subsample(s). Taxa observed during sampling that were not represented in the sample should also be recorded (e.g., Gerridae, adult Gyrinidae, Decapoda, Porifera, Bryozoa). These additional taxa should be recorded by marking 1 individual on the data sheet. Mussels (Unionidae) should only be observed in the field, not included in the composite macroinvertebrate sample, and then be recorded as a 1 on the field sheet. Any mussels collected or disturbed during sampling should be placed on its side in the area where it was collected or placed in a low flow area.

B. Data to be Recorded

1. Organisms should be identified to the taxonomic level indicated in Appendix H. Appendix H also contains a list of the primary keys to be used to identify the macroinvertebrates. Alternate keys may be used, but verification of identification should be through those keys listed in Appendix H. Organisms that cannot be identified in the field should be returned to the laboratory for identification.

2. When sampling has been completed at a site, the sampling area should be identified on a detailed drawing of the site together with necessary comments. Latitude and longitude coordinates should be obtained using appropriate methods and quality control (EGLE, 2023a).

C. Data Analysis Techniques

Following sample analyses, a stream class will be assigned based on the site characteristics listed in Table 1. Once the stream class is known, a macroinvertebrate index score will be calculated for each station based on the average of all individual metric scores for a given stream class (Holden et al., 2024). Metric descriptions and expected trends with increased disturbance can be found in Table 2 and Appendix I. Each index score for an individual station is then compared to its stream class threshold to determine if macroinvertebrate community expectations are being met. Thresholds were developed using stream class-specific reference sites with minimal human disturbance (Holden et al., 2024).

Table 1. Stream classes and descriptions of characteristics.

North [c]

Stream Width (feet)	<40% Catchment Water or Wetland Land Cover [a]	40% Catchment Water or Wetland Land Cover [a]
<13	VeryNarrow	VeryNarrow
13-21.27	Narrow	Narrow
>21.27-68.367	MidSizeDry	WideOrMidSizeWet
>68.367	WideOrMidSizeWet	WideOrMidSizeWet

South [d]

Longitude	At or East of -83.72	West of -83.72	West of -83.72
% streamline slope in catchment [b]	-	< % 0.2976	> % 0.2976
Stream Class	East	WestFlat	WestSteep

a. % of catchment area classified as wetland or water land cover (National Land Cover Database, 2011, (United States Geological Survey [USGS], 2014))

b. % stream slope measured as the slope of flowline based on smoothed elevations (Source: National Hydrography Dataset Plus)

c. Ecoregions: 50 - Northern Lakes and Forests, 51 - North Central Hardwood Forests (Omernik and Bryce, 2010)
d. Ecoregions: 55 - Eastern Corn Belt Plains, 56 - Southern Michigan/Northern Indiana Drift Plains, 57 - Huron/Erie Lake Plains (Omernik and Bryce, 2010)

Table 2. Metric descriptions and expected trends with increasing disturbance. Taxa traits are listed in Appendix I.

Metric Code	Metric Category	Metric Description	Expected trend with increasing disturbance
pi_CruMol	Composition	% Crustacea and Mollusca individuals of all individuals	Increasing
pi_Crus	Composition	% Crustacea individuals of all individuals	Increasing
pi_EPT	Composition	% EPT individuals of all individuals	Decreasing
pi_EPTnoBH	Composition	% EPT excluding Baetidae and Hydropsychidae of all individuals	Decreasing
pi_IsoSnlLch	Composition	% Isopod, Snail, and Leech individuals of all individuals	Increasing
pi_nonIns	Composition	% Non-Insect individuals of all individuals	Increasing
pi_Pleco	Composition	% Plecoptera individuals of all individuals	Decreasing
pi_ffg_cllct	Functional Feeding Group	% Collector individuals of all individuals	Increasing
pi_ffg_pred	Functional Feeding Group	% Predator individuals of all individuals	Decreasing
pi_ffg_scrap	Functional Feeding Group	% Scraper individuals of all individuals	Increasing
pi_ffg_shred	Functional Feeding Group	% Shredder individuals of all individuals	Increasing
nt_hab_clngr	Habit	Number of Clinger Taxa	Decreasing
pi_hab_clmbr	Habit	% Climber individuals of all individuals	Increasing
pi_hab_clngr	Habit	% Clinger individuals of all individuals	Decreasing
pi_hab_sprwl	Habit	% Sprawler individuals of all individuals	Increasing
nt_CruMol	Richness	Number of Crustacea or Mollusca taxa in the sample	Increasing
nt_EPT	Richness	Number of EPT taxa in the sample	Decreasing
nt_nonIns	Richness	Number of non-insect taxa in the sample	Increasing
nt_Trich	Richness	Number of Trichoptera taxa in the sample	Decreasing
pt_nonIns	Richness	Percent of non-insect taxa in the sample	Increasing
nt_tv_toler	Tolerance	Number of Tolerant Taxa	Increasing
pi_tv_intol	Tolerance	% Intolerant individuals of all individuals	Decreasing
pi_tv_toler	Tolerance	% Tolerant individuals of all individuals	Increasing
pt_tv_intol	Tolerance	Intolerant taxa as a percentage of all taxa	Decreasing
pt_tv_toler	Tolerance	Tolerant taxa as a percentage of all taxa	Increasing

VII. HABITAT ASSESSMENT

Habitat evaluations are made on instream habitat first, followed by channel morphology, bank structural features, and riparian vegetation. The habitat assessment process involves rating the sum total of the 10 metrics as *Excellent, Good, Marginal,* or *Poor* based on the criteria included on the Habitat Assessment Field Data Sheets. The point ranges for both Riffle/Run and Glide/Pool streams are listed below with each station's overall rating based on its potential to support biological communities. The range of scores used to classify each metric, as well as the range of scores representing the sum total for the habitat assessment, is described in the following rating tables:

Metric (Riffle/Run) **Substrate and Instream Cover**	Scoring Range/Rating Excellent	Scoring Range/Rating Good	Scoring Range/Rating Marginal	Scoring Range/Rating Poor
1. Epifaunal Substrate/Available Cover	16 - 20	11 - 15	6 - 10	0 - 5
2. Embeddedness	16 - 20	11 - 15	6 - 10	0 - 5
3. Velocity/Depth Regime	16 - 20	11 - 15	6 - 10	0 - 5

Metric (Riffle/Run) **Channel Morphology**	Scoring Range/Rating Excellent	Scoring Range/Rating Good	Scoring Range/Rating Marginal	Scoring Range/Rating Poor
4. Sediment Deposition	16 - 20	11 - 15	6 - 10	0 - 5
5a. Flow Status – Maintained Flow Volume	9 - 10	6 - 8	3 - 5	0 - 2
5b. Flow Status – Flashiness	9 - 10	6 - 8	3 - 5	0 - 2
6. Channel Alteration	16 - 20	11 - 15	6 - 10	0 - 5
7. Frequency of Riffles (or Bends)	16 - 20	11 - 15	6 - 10	0 - 5

Metric (Riffle/Run) **Riparian and Bank Structure (Left and Right Bank Independently)**	Scoring Range/Rating Excellent	Scoring Range/Rating Good	Scoring Range/Rating Marginal	Scoring Range/Rating Poor
8. Bank Stability	9 - 10	6 - 8	3 - 5	0 - 2
9. Vegetative Protection	9 – 10	6 – 8	3 – 5	0 – 2
10. Riparian Vegetation Zone Width	9 - 10	6 - 8	3 - 5	0 - 2

Metric (Glide/Pool) **Substrate and Instream Cover**	Scoring Range/Rating Excellent	Scoring Range/Rating Good	Scoring Range/Rating Marginal	Scoring Range/Rating Poor
1. Epifaunal Substrate/Available	16 - 20	11 - 15	6 - 10	0 - 5
2. Pool Substrate Characterization	16 - 20	11 - 15	6 - 10	0 - 5
3. Pool Variability	16 - 20	11 - 15	6 - 10	0 - 5

Metric (Glide/Pool) **Channel Morphology**	Scoring Range/Rating Excellent	Scoring Range/Rating Good	Scoring Range/Rating Marginal	Scoring Range/Rating Poor
4. Sediment Deposition	16 - 20	11 - 15	6 - 10	0 - 5
5a. Flow Status – Maintained Flow Volume	9 - 10	6 - 8	3 - 5	0 - 2
5b. Flow Status – Flashiness	9 - 10	6 - 8	3 - 5	0 - 2
6. Channel Alteration	16 - 20	11 - 15	6 - 10	0 - 5
7. Channel Sinuosity	16 - 20	11 - 15	6 - 10	0 - 5

Metric (Glide/Pool) Riparian and Bank Structure (Left and Right Bank Independently)	Scoring Range/Rating Excellent	Scoring Range/Rating Good	Scoring Range/Rating Marginal	Scoring Range/Rating Poor
8. Bank Stability	9 - 10	6 - 8	3 - 5	0 - 2
9. Vegetative Protection	9 - 10	6 - 8	3 - 5	0 - 2
10. Riparian Vegetation Zone Width	9 - 10	6 - 8	3 - 5	0 - 2

Metric (Glide/Pool) Habitat Characterization	**Total Point Score (metrics 1-10)**
1. Excellent	>154
2. Good	105 – 154
3. Marginal	56 – 104
4. Poor	<56

Five of the habitat metrics discriminate between *Riffle/Run* and *Glide/Pool streams*. Metrics 2, 3, and 7 are paired into separate *Riffle/Run* and *Glide/Pool* metrics (i.e., 2a and 2b). Metrics 1 and 4 each contain criteria for both *Riffle/Run* and *Glide/Pool* systems. In addition, flow status (Metric 5) is broken down into 5a and 5b and is intended to measure both the ability of a stream to maintain sufficient base flows, as well as the flow response to runoff events (flashiness).

The site assessment approach for determining the *Riffle/Run* and *Glide/Pool* status of a stream is based on visual observation of the following characteristics:

Riffle/run streams characteristically:

- Demonstrate a regular (repeating) riffle/run sequence.
- Have substrates primarily composed of coarse sediment particles (i.e., coarse sand/gravel or larger particle sizes in high velocity reaches of the stream).
- Tend to have moderate to high gradient landscapes.

Glide/pool streams characteristically:

- Demonstrate primarily a glide/pool sequence.
- Have substrates that are primarily composed of fine sediment (fine sand and smaller). Coarse (gravel or larger) sediment particles may be present in firm bottom deep pools or along margins of some stream reaches; however, this occurrence is very infrequent.

- Have low to moderate gradient landscapes. Undisturbed portions of the floodplain may tend toward wetland characteristics.

There will be situations where riffle/run streams tend towards glide/pool or where glide/pool streams tend toward riffle/run. If the stream type is unclear, visually survey an expanded length of stream channel, noting the dominant substrate and flow characteristics. If the stream type remains unclear, complete both *Riffle/Run* and *Glide/Pool* habitat field forms. (Note: Riffle/Run channels that tend towards glide/pool or glide/pool channels that approach riffle/run conditions generally score nearly identically.) If there is reasonable agreement between the two forms, record an average of the two scores.

There will be occasions when the existing conditions do not fit one or more of the metrics given. In such cases, score each metric as close as possible and note the condition(s) that deviates from the expected, along with any needed explanation for your final score.

A. Procedure for Performing Habitat Assessment

The habitat assessment should be performed on a sufficient length of stream that reflects the typical habitat conditions associated with the biological sampling results. At a minimum, this reach should be no less than the section of stream used for biological sampling. Some parameters require an observation of a broader section of the watershed than the biological sampling reach alone and may require traversing the stream corridor to the extent deemed necessary to assess the habitat feature. As a general rule-of-thumb, use two lengths of the biological sampling reach to assess these parameters. If there is a team of 2 or more biologists, come to a consensus for each metric.

Metric 1 EPIFAUNAL SUBSTRATE/AVAILABLE COVER *Riffle/Run* and *Glide/Pool* Streams

This metric includes the relative quantity and variety of natural structures in the stream, such as cobble (riffles), large rocks, fallen trees, logs and branches, and undercut banks, available as refugia, feeding, or sites for spawning and nursery functions of aquatic macrofauna. A wide variety and/or abundance of submerged structures in the stream provide macroinvertebrates and fish with a large number of niches, thus increasing habitat diversity. As variety and abundance of cover decreases, habitat structure becomes monotonous, diversity decreases, and the potential for recovery following disturbance decreases. Riffles and runs are critical for maintaining a variety and abundance of insects in most riffle/run streams and serving as spawning and feeding refugia for certain fish. The extent and quality of the riffle is an important factor in the support of a healthy biological condition in riffle/run streams. Riffles and runs offer a diversity of habitat through variety of particle size and, in many small high-gradient streams, will provide the most stable habitat. Snags and submerged logs are among the most productive habitat structure for macroinvertebrate colonization and fish refugia in glide/pool streams. However, "new fall" will not yet be suitable for colonization.

Assess both *Riffle/Run* and *Glide/Pool* streams by estimating the amount of stream channel in the sample reach that contains substrates that are free from sedimentation or siltation impacts and favorable for epifaunal colonization. Materials that are easily moved or displaced (silts, sand, and fine gravels) or unstable vegetation, such as bank grass or small stemmed brush tops, are not considered as stable. Some of the larger varieties of vascular aquatic macrophytes may be considered as a stable substrate; however, woody debris that is free-floating in back eddies or temporarily trapped along stream margins should not be considered as a stable substrate.

Habitat Parameter	Condition Category			
	Excellent	**Good**	**Marginal**	**Poor**
1. Epifaunal Substrate/ Available Cover (***Riffle/Run*** **and** ***Glide/Pool***)	Greater than 70% (50% for glide/pool streams) of substrate are free from sedimentation/ siltation and favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/ snags that are <u>not</u> new fall and <u>not</u> transient).	40-70% (30-50% for glide/pool streams) mix of stable habitat; free from sedimentation/ siltation and well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of new fall, but not yet prepared for colonization (may rate at high end of scale).	20-40% (10-30% for glide/pool streams) mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed, removed, or covered by sediment/silt.	Less than 20% (10% for glide/pool streams) stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Metric 2a EMBEDDEDNESS *Riffle/Run Streams*

This metric refers to the extent to which rocks (gravel, cobble, and boulders) and snags are covered or sunken into the silt, sand, or mud of the stream bottom. Generally, as rocks become embedded, the surface area available to macroinvertebrates and fish (shelter, spawning, and egg incubation) is decreased. Embeddedness is a result of large-scale sediment movement and deposition and is a parameter evaluated in the riffles and runs of high-gradient streams. The rating of this parameter may be variable depending on where the observations are taken. To avoid confusion with sediment deposition (another habitat parameter), observations of embeddedness should be taken in the upstream and central portions of riffles and cobble substrate areas. Grasp and remove several cobbles at the sediment/water interface and estimate an average depth that is into the sediment.

Habitat Parameter	Condition Category			
	Excellent	**Good**	**Marginal**	**Poor**
2.a Embeddedness ***(Riffle/Run Stream)***	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Metric 2b POOL SUBSTRATE CHARACTERIZATION *Glide/Pool Streams*

This metric evaluates the type and condition of bottom substrates found in pools. Firmer sediment types (e.g., gravel and sand) and rooted aquatic plants support a wider variety of organisms than a pool substrate dominated by mud or bedrock and no plants. In addition, a stream that has a uniform substrate in its pools will support far fewer types of organisms than a stream that has a variety of substrate types. *Glide/Pool* systems should be assessed by visual observations and, where possible, prodding with a net handle or wading staff, or simply wading slowly and carefully through the pool area itself.

Habitat Parameter	Condition Category			
	Excellent	**Good**	**Marginal**	**Poor**
2b. Pool Substrate Characterization **(Glide/Pool)**	Mixture of substrate materials, with gravel and firm sand prevalent; root mats and submerged vegetation common.	Mixture of soft sand, mud, or clay; mud may be dominant; some root mats and submerged vegetation present.	All mud or clay or sand bottom; little or no root mat; no submerged vegetation.	Hard-pan clay or bedrock; no root mat or submerged vegetation.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Metric 3a VELOCITY/DEPTH COMBINATIONS *Riffle/Run Streams*

Patterns of velocity and depth are included for riffle/run streams under this parameter as an important feature of habitat diversity. The best streams in most riffle/run regions will have all 4 patterns present: (1) slow-deep, (2) slow-shallow, (3) fast-deep, and (4) fast-shallow. The general guidelines are 1.5 feet depth to separate shallow from deep, and 1.0 foot per second (f/s) to separate fast from slow. The occurrence of these 4 patterns relates to the stream's ability to provide and maintain a stable aquatic environment and is expected to vary with stream size and watershed characteristics.

Both depth and velocity are relative to stream size. A deep pool in a stream that is 3 feet wide may be no more than 10-12 inches deep, yet 4-6 feet deep in a river that is 80 feet or more wide. In a similar fashion, a flow velocity of 0.7 f/s may be considered to be fast in very small streams yet slow in larger systems.

Habitat Parameter	Condition Category			
	Excellent	Good	Marginal	Poor
3a. Velocity/ Depth Regimes **(Riffle/Run)**	All 4 velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (slow is <1.0 f/s, deep is >1.5 feet.)	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/depth regime (usually slow-deep).
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Metric 3b POOL VARIABILITY *Glide/Pool Streams*

This metric rates the overall mixture of pool types found in streams, according to size and depth. The 4 basic types of pools are large-shallow, large-deep, small-shallow, and small-deep. A stream with many pool types will support a wide variety of aquatic species. Rivers with low sinuosity (few bends) and monotonous pool characteristics do not have sufficient quantities and types of habitat to support a diverse aquatic community. General guidelines are any pool dimension (i.e., length, width, and depth) greater than half the cross-section of the stream for separating large from small and 3 feet depth separating shallow and deep. However, the size (width) of the stream channel will have a direct consequence on the relative relationship between pool sizes (see description of expected variation in stream velocity/depth assessment above).

Habitat Parameter	Condition Category			
	Excellent	Good	Marginal	Poor
3b. Pool Variability **(Glide Pool)**	Even mix of large-shallow, large-deep, small-shallow, small-deep pools present.	Majority of pools large-deep; very few shallow.	Shallow pools much more prevalent than deep pools.	Majority of pools small-shallow or pools absent.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Metric 4 SEDIMENT DEPOSITION *Riffle/Run and Glide/Pool Streams*

This metric estimates the amount of sediment that has accumulated in pools and the changes that have occurred to the stream bottom as a result of deposition. Deposition occurs from large-scale movement of sediment. Sediment deposition may cause the formation of islands, point bars (areas of increased deposition usually at the beginning of a meander that increases in size as the channel is diverted toward the outer bank) or shoals, or result in the filling of runs and pools. Usually deposition is evident in areas that are obstructed by natural or man-made debris and areas where the stream flow decreases, such as bends. High levels of sediment deposition are symptoms of an unstable and continually changing environment that becomes unsuitable for many organisms.

Habitat Parameter	Condition Category			
	Excellent	Good	Marginal	Poor
4. Sediment Deposition **(Riffle/Run and Glide /Pool Streams)**	Little or no enlargement of islands or point bars and less than 5% (<20% for low-gradient streams) of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand, or fine sediment; 5-30% (20-50% for glide/pool) of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand, or fine sediment on old and new bars; 30-50% (50-80% for glide/pool) of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% (80% for glide/pool) of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Metric 5 CHANNEL FLOW STATUS *Riffle/Run and Glide/Pool Streams*

The degree to which stream flow is maintained in the channel (5a) and the speed and magnitude of flow response to rain events (flashiness) (5b) collectively describes the channel flow status of the stream. The flow status will change as the channel enlarges (e.g., aggrading streambeds with actively widening channels), as a result of dams and other obstructions, diversions for irrigation, drought, increases in the amount of impervious surfaces in the watershed, or enhanced drainage to support agricultural land use. Channel flow can be especially useful for interpreting biological conditions under abnormal or lowered flow conditions, with indications of significant flow instability relatively easy to see in a stream at or near base flow conditions.

The amount of suitable substrates for aquatic organisms becomes limited when stream flow is not maintained at adequate levels. In both riffle/run and glide/pool streams, bottom substrates can become exposed, reducing good habitat areas for fish and macroinvertebrate communities. Estimating insufficient flows due to water loss can be done by looking for exposed river substrate materials along the lateral portions of the wetted channel, dried algae or fine sediment deposits on rocks, or LWD above and adjacent to the waterline.

An increased response to precipitation events is called flashiness and is often correlated with a decrease in stream habitat. Flashy streams are most often impaired by excessive erosive energy that destabilizes and impairs habitat that is otherwise suitable for colonization by aquatic organisms. In stable streams, LWD, where available, can be found throughout the wetted portion of the channel, often perpendicular to the direction of flow. Streambank vegetation typically exists at or near the water/streambank interface. In flashy systems, woody debris is generally flushed from the thalweg toward the stream banks or is removed from the active channel entirely. Streambank vegetation is removed above normal flow levels by frequent high-water events.

An estimation of stream flashiness is made by observing the vegetation density at the water/streambank interface, and, where applicable, the position of LWD and LWD jams in the stream channel. However, the difference between scoured banks and areas where streambank soils may naturally produce a poorly vegetated zone along the water/streambank interface must be recognized. Some soil types near the water's edge are continually saturated and may normally be void of vegetation. In addition, some dense clay soils may take a relatively long time to revegetate following a disturbance, resulting in a false appearance of scouring from frequent high flows. Conversations with people living near the stream can be used to corroborate observations regarding stream flashiness or the ability of the stream to maintain sufficient base flow levels.

Habitat Parameter	**Condition Category**			
	Excellent	**Good**	**Marginal**	**Poor**
5a. Channel Flow Status – Maintained Flow Volume **(Riffle/Run and Glide/Pool Streams)**	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE	10 9	8 7 6	5 4 3	2 1 0

Habitat Parameter	**Condition Category**			
	Excellent	**Good**	**Marginal**	**Poor**
5b. Channel Flow Status - Flashiness **(Riffle/Run and Glide/Pool Streams)**	Vegetation along the stream banks is complete nearly to the water's edge. Little or no evidence of frequent changes in discharge and/or frequent high, water events that scour streambank vegetation. LWD (if present) stable and extending laterally across the stream channel.	Some evidence of bank scour approximately 4-8 inches above the water's surface. LWD (if present) mostly stable and extending partially into the active stream channel	Bank scour evident 9-18 inches above the water's surface. LWD (if present) tend to lay more against the streambank rather than extending into the active channel.	Bank scour severe (>20 inches) along the stream channel. LWD is generally absent from the active channel and/or may exist as woody debris jams along the streambank above the active channel.
SCORE	10 9	8 7 6	5 4 3	2 1 0

Metric 6 CHANNEL ALTERATION *Riffle/Run and Glide/Pool Streams*

This metric is a measure of large-scale changes in the shape of the stream channel. Many streams in urban and agricultural areas have been straightened, deepened, or diverted into concrete channels, often for flood control or irrigation purposes. Such streams have far fewer natural habitats for fish, macroinvertebrates, and plants than naturally meandering streams. Channel alteration is present when artificial embankments, rip-rap, and other forms of artificial bank stabilization or structures are present; when the stream is very straight for significant distances; and when dams and bridges are present. Scouring is often associated with channel alteration, as is a reduction in flow velocity during base flow conditions.

Minimal channel alterations may include short channel sections that have been modified to facilitate road/stream crossings. Estimate and record the length of river/stream/drain that has been recently channelized (within the last 5-10 years) and/or has evidence of actively, or somewhat actively, maintained stream banks.

Habitat Parameter	Condition Category			
	Excellent	**Good**	**Marginal**	**Poor**
6. Channel Alteration **(Riffle/Run and Glide/Pool Streams)**	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging (greater than past 20 years) may be present, but recent channelization is not present.	Channelization is continuous but not recent (>5 years); embankments without mature trees and dominated by grasses and shrubs.	Stream reach has been recently channelized (<5 years) or banks shored with gabion, rock, cement, or bare earth. Instream habitat greatly altered or removed entirely. Bank vegetation moderately dense to absent
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Metric 7a FREQUENCY OF RIFFLES (OR BENDS) *Riffle/Run Streams*

This metric measures the sequence of riffles and thus the heterogeneity occurring in a stream. Riffles are a source of high-quality habitat and diverse fauna; therefore, an increased frequency of occurrence greatly enhances the diversity of the stream community.

Measuring the sequencing pattern of the stream is necessary to rate this metric. Estimate the frequency of riffles (or bends) by simply measuring the distance between each occurrence. For riffle/run streams where distinct riffles are uncommon, a run/bend ratio can be used as a measure of meandering or sinuosity (see Metric 7b). To gain an appreciation of this metric in some streams, a longer segment or reach than that designated for sampling should be incorporated into the evaluation. In some situations (i.e., larger rivers), this metric may be rated from viewing topographical maps.

Habitat Parameter	Condition Category			
	Excellent	**Good**	**Marginal**	**Poor**
7a. Frequency of Riffles (or bends) **(Riffle/Run Stream)**	Occurrence of riffles relatively frequent; ratio of distance between riffles divided by width of the stream <7:1 (generally 5 to 7); variety of habitat is key. In streams where riffles are continuous, placement of boulders or	Occurrence of riffles infrequent; distance between riffles divided by the width of the stream is between 7 and 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by the width of the stream is	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is a ratio of >25.

Habitat Parameter	Condition Category			
	Excellent	Good	Marginal	Poor
	other large, natural obstruction is important.		between 15 and 25.	
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Metric 7b CHANNEL SINUOSITY *Glide/Pool Streams*

This metric evaluates the meandering or sinuosity of the stream. A high degree of sinuosity provides for diverse habitat and fauna. The absorption of flow energy by bends protects the stream from excessive erosion and flooding and provides refugia for macroinvertebrates and fish during runoff events.

Measuring the sequencing pattern of the stream is necessary to rate this metric. Channel sinuosity can be estimated by dividing a channel length that includes 2 stream bends by the straight line distance between these 2 points. In some situations (i.e., large rivers) this metric may be rated from viewing topographical maps. To gain an appreciation of this metric in glide/pool streams, a longer segment or reach than that designated for sampling may be incorporated into the evaluation.

Habitat Parameter	Condition Category			
	Excellent	Good	Marginal	Poor
7b. Channel +Sinuosity (Glide/Pool Stream)	The bends in the stream increase the stream length 3 to 4 times longer than if it was in a straight line. (Note: channel braiding is considered normal in coastal plains and other low-lying areas. This parameter is not easily rated in these areas.)	The bends in the stream increase the stream length 2 to 3 times longer than if it was in a straight line.	The bends in the stream increase the stream length 1 to 2 times longer than if it was in a straight line. (Note: lack of sinuosity may be due to channelization)	Channel straight; waterway has been channelized for a long distance.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Metric 8 BANK STABILITY (condition of banks) *Riffle/Run and Glide/Pool* Streams

This metric measures whether the stream banks are eroded (or have the potential for erosion). Steep banks are more likely to collapse and suffer from erosion than gently sloping banks and are, therefore, considered to be unstable. Signs of erosion include crumbling, unvegetated banks, exposed tree roots, and exposed soil. Eroded banks indicate a problem of soil movement into the stream and suggest a scarcity of streambank cover and organic input to the stream. Each bank is evaluated separately and the cumulative score (right and left) is used for this parameter.

Habitat Parameter	Condition Category			
	Excellent	**Good**	**Marginal**	**Poor**
8. Bank Stability (score each bank) **Note: determine left or right side by facing downstream** **(Riffle/Run and Glide/Pool Streams)**	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE ___ (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank10 9	8 7 6	5 4 3	2 1 0

Metric 9 BANK VEGETATIVE PROTECTION *Riffle/Run and Glide/Pool Streams*

This metric evaluates the degree of vegetative protection afforded to the streambank and the near-stream portion of the riparian zone. The root systems of plants growing on stream banks help hold soil in place, thereby reducing the amount of erosion that is likely to occur. This metric supplies information on the ability of the bank to resist erosion, as well as some additional information on the uptake of nutrients by the plants, the control of instream scouring, and stream shading. Banks that have full, natural plant growth are better for fish and macroinvertebrates than are banks without vegetative protection or those shored up with concrete or rip-rap. Wetland stream banks (e.g., marsh or swamp) will be dramatically different than the typical climax forest community but are equally protective to the physical and biological community. In contrast, dense monocultures of exotic plant species (i.e., purple loosestrife) do not offer the same degree of protection as a diverse community of native vegetation and should be scored accordingly. In areas of high grazing pressure from livestock or where residential and urban development activities disrupt the riparian zone, the growth of a natural plant community is impeded and can extend to the bank vegetative protection zone.

For this metric, consider the bank condition between the aquatic/terrestrial interface to a point immediately past the streambank/riparian zone interface. Each bank is evaluated separately and the cumulative score (right and left) is used for this parameter.

Habitat Parameter	Condition Category			
	Excellent	**Good**	**Marginal**	**Poor**
9. Vegetative Protection (score each bank) **Note: determine left or right side**	More than 90% of the streambank surfaces and immediate riparian zones covered by vegetation, including trees, understory shrubs, or nonwoody macrophytes;	70-90% of the streambank surfaces covered by vegetation, but 1 class of plants is not well-represented; disruption evident	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank

Habitat Parameter	Condition Category			
	Excellent	**Good**	**Marginal**	**Poor**
by facing downstream. **(Riffle/Run and Glide/Pool Streams)**	vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE ___ (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0

Metric 10 RIPARIAN VEGETATIVE ZONE WIDTH *Riffle/Run and Glide/Pool Streams*

This metric measures the width of natural vegetation from the edge of the streambank out through the riparian zone. The riparian zone prevents a wide range of pollutants from entering a stream from runoff and provides erosion control. In addition, a diverse riparian zone plays an active role in water quality by providing a continuous source of materials and shade that act to stabilize both the physical and biological aspects of the stream environment. A relatively undisturbed riparian zone that has an adequate width will support a robust stream system. Narrow riparian zones occur when roads, parking lots, fields, lawns, bare soil, rocks, or buildings are near the streambank. Residential developments, urban centers, golf courses, and agricultural land uses are the common causes of anthropogenic degradation of the riparian zone. Conversely, the presence of "old field" (i.e., a previously developed field not currently in use), paths, and walkways in an otherwise undisturbed riparian zone may be judged to be inconsequential to altering the riparian zone and may be given relatively high scores.

The ability of the riparian zone to protect aquatic environs is based on the collective function of a diverse plant community, water storage capabilities, and to a certain extent, stream width. Therefore, consider the diversity of vegetation, as well as the width of the riparian zone. Grass filter strips, lawns, or lush stream banks are not considered to be part of the riparian zone because they do not offer a significant resource to the physical or biological community. Old field land use, depending on the point of transition between agriculture and a climax riparian community, will offer some, to most, of the potential resource to the stream. A fully functional riparian zone contains diverse vegetation, including trees, understory shrubs, and nonwoody macrophytes. Small streams (approximately 10 feet wide or less) accompanied by diverse riparian widths of less than 150 feet may be considered as excellent. Wetland riparian zones (e.g., marsh or swamp) will be dramatically different than the typical climax forest community but are equally protective to the physical and biological community.

Habitat Parameter	Condition Category			
	Excellent	**Good**	**Marginal**	**Poor**
10. Riparian Vegetative Zone Width (score each bank riparian zone) **(Riffle/Run and Glide/Pool Streams)**	Width of riparian zone >150 feet; dominated by vegetation, including trees, understory shrubs, or nonwoody macrophytes or wetlands; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally. Human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 75-150 feet; human activities have impacted zone only minimally.	Width of riparian zone 10-75 feet; human activities have impacted the composition of the vegetation a great deal.	Width of riparian zone <0 feet: little or no riparian vegetation due to human activities.
SCORE____(LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0

VIII. OVERALL APPLICATION AND INTEGRATION

A. Relationship of Habitat Quality and Biological Condition

The optimum biological community stability and biological diversity of a site for both fish and macroinvertebrates may be determined by the quality of the habitat at that site. Excellent habitat will allow for high quality biological communities. Community responses to minor alteration in habitat are often subtle. As habitat quality continues to decline, recognizable and measurable biological changes (impairments) occur. These changes, in the absence of confounding water quality effects, are generally in direct proportion to the degree of habitat change. When habitat becomes severely degraded, changes in the biological communities become harder to recognize and measure. The biological communities existing under these degraded habitat conditions are represented by opportunistic species, which are more tolerant of such habitat perturbations and often insensitive to further habitat degradation. This may result in a poor habitat characterization corresponding to either a moderately or severely impacted biological community depending on the specific site and situation.

In areas of good or excellent habitat, biological communities will reflect degraded conditions when adverse water quality effects exist. As habitat degrades further in the continued presence of water quality problems, such as chemical toxicants or nutrient enrichment, the biological communities may show less dramatic changes as each community becomes dominated by tolerant and opportunistic species.

IX. QUALITY ASSURANCE/QUALITY CONTROL

As with any scientific study, quality must be assured and tested before the results can be accepted. Quality assurance is accomplished through use of professional and trained biologists, establishment of thorough field training, defined collection guidelines, and comprehensive field documentation and data analysis. Quality control is accomplished by post-sampling site and data checks prior to final upload to the survey database (e.g. identify transcription and data entry errors in macroinvertebrate and fish community data and habitat and location data).

A. Training

All personnel conducting surveys are trained in a consistent manner (by experienced biologists) to ensure that the surveys are conducted properly and in a standardized fashion. Two investigators for each site will be professional biologists trained and skilled in field aquatic sampling methods and organism identification.

B. Standard Procedures

The standard procedures described in this document are followed in the surveys. Field experience and taxonomic expertise requirements must be met by staff involved in surveys. Any deviations from the procedures should be documented as to the reason for deviation.

C. Documentation

The paper or digital field sheets are filled out as completely and accurately as possible to provide a record in support of the survey and analysis conclusions.

Field and laboratory data sheets and final reports are filed in the GLWARMS raw data files and report files, respectively.

X. RESPONSIBILITIES

Responsibility	**Action**
GLWARMS Staff	Site selection, conduct monitoring per the procedure or oversee grantee monitoring per the procedure, calculate habitat and biological community scores and determine condition and Water Quality Standard attainment for each site within a watershed, data storage and summary for use in rotating basin water quality monitoring reports.

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LINKS TO ADDITIONAL INFORMATION

APPENDICES

Appendix A: Michigan Fish Classified as Intolerant
Appendix B: Michigan Fish Classified as Omnivores
Appendix C: Michigan Fish Classified as Insectivores
Appendix D: Michigan Fish Classified as Piscivores
Appendix E: Michigan Fish Classified as Tolerant
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Appendix G: Fish Measured to Inch Group
Appendix H: Phylogenetic Order for Macroinvertebrates
Appendix I: Macroinvertebrate Taxa Trait Information

APPROVING AUTHORITY

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HISTORY

Using the table below, record the historical changes made to the policy and procedures. Actions include: original, revised and reviewed (i.e., the policy and procedure did not require changes).

Policy No.	**Action**	**Date**	**Title**
GLEAS Procedure 51	Original	April 24, 1990	Qualitative Biological Habitat Survey Protocols for Wadeable Streams and Rivers
GLEAS Procedure 51	Revised	June 16, 1991	Qualitative Biological Habitat Survey Protocols for Wadeable Streams and Rivers
GLEAS Procedure 51	Revised	January 24, 1997	Qualitative Biological Habitat Survey Protocols for Wadeable Streams and Rivers

GLEAS Procedure 51	Revised	May 28, 2002	Qualitative Biological Habitat Survey Protocols for Wadeable Streams and Rivers
WB-SWAS-051	Revised	December 23, 2008	SWAS Procedure 51 - Qualitative Biological Habitat Survey Protocols for Wadeable Streams and Rivers
WRD-SWAS-051	Revised	May 27, 2014	SWAS Procedure 51 - Qualitative Biological Habitat Survey Protocols for Wadeable Streams and Rivers
WRD-SWAS-051	Revised	XX XX, 2024	SWAS Procedure 51 - Qualitative Biological Habitat Survey Protocols for Wadeable Streams and Rivers

CONTACT/UPDATE RESPONSIBILITY

Any questions or concerns regarding this policy and procedure should be directed to EGLE, Water Resources Division.

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An EGLE policy and procedure cannot establish regulatory requirements for parties outside of EGLE. This document provides direction to EGLE staff regarding the implementation of rules and laws administered by EGLE. It is merely explanatory, does not affect the rights of or procedures and practices available to the public, and does not have the force and effect of law. EGLE staff shall follow the directions contained in this document.

Appendix A

Michigan Fish Classified as Intolerant

Petromyzontidae (lampreys)

Common Name	Scientific Name
Sea lampey (ammocoete)	Petromyzon marinus
Silver lamprey (ammocoete)	Ichthyomyzon unicuspis
Silver lamprey (adult)	Ichthyomyzon unicuspis
Northern brook lamprey (ammocoete)	Ichthyomyzon fossor
Northern brook lamprey (adult)	Ichthyomyzon fossor
Chestnut lamprey (ammocoete)	Ichthyomyzon castaneus
Chestnut lamprey (adult)	Ichthyomyzon castaneus
American brook lamprey (ammocoete)	Lampetra appendix
American brook lamprey (adult)	Lampetra appendix

Acipenseridae (sturgeons)

Common Name	Scientific Name
Lake Sturgeon	Acipenser fulvescens

Polydontidae (paddlefish)

Common Name	Scientific Name
Paddlefish **(extinct in Michigan)**	Polyodon spathula

Hiodontidae (Mooneyes)

Common Name	Scientific Name
Mooneye	Hiodon tergisus

Salmonidae (trouts)

Common Name	Scientific Name
Rainbow trout	Oncorhynchus mykiss
Brown trout	Salmo trutta
Brook trout	Salvelinus fontinalis
Coho salmon	Oncorhynchus kisutch
Chinook salmon	Oncorhynchus tshawytscha
Pink salmon	Oncorhynchus gorbuscha
Lake herring	Coregonus artedi
Lake whitefish	Coregonus cupeaformis
Bloater	Coregonus hoyi
Deepwater cisco	Coregonus johannae
Kiyi	Coregonus kiyi
Blackfin cisco	Coregonus nigripinnis
Shortnose cisco	Coregonus reighardi
Shortjaw cisco	Coregonus zenithicus
Pygmy whitefish	Prosopium coulte
Round whitefish	Prosopium cylindraceum
Atlantic salmon	Salmo salar
Lake trout	Salvelinus namaycush
Artic grayling **(extinct in Michigan)**	Thymallus arcticus

Appendix A

Esocidae (pikes)

Common Name	Scientific Name
Muskellunge	Esox masquinongy

Cyprinidae (minnows and carps)

Common Name	Scientific Name
Bigeye chub	Notropis amblops
River chub	Nocomis micropogon
Pugnose shiner	Notropis anogenus
Bigeye shiner	Notropis boops
Ironcolor shiner	Notropis chalybaeus
Weed shiner	Notropis texanus
Blackchin shiner	Notropis heterodon
Blacknose shiner	Notropis heterolepis
Spottail shiner	Notropis hudsonius
Silver shiner	Notropis photogenis
Rosyface shiner	Notropis rubellus
Southern redbelly dace	Phoxinus erthrogaster
Longnose dace	Rhinichthys cataractae
Redside dace	Clinostomus elongatus
Pearl dace	Margariscus margarita
Silver chub	Macrhybopsis storeriana
Pugnose minnow	Opsopoedus emiliae

Cottidae (sculpins)

Common Name	Scientific Name
Mottled sculpin	Cottus bairdii
Slimy sculpin	Cottus cognatus
Spoonhead sculpin	Cottus ricei
Deepwater sculpin	Myoxocephalus thompsoni

Catostomidae (suckers)

Common Name	Scientific Name
Longnose sucker	Catostomus catostomus
Creek chubsucker	Erimyzon oblongus
Northern hog sucker	Hypentelium nigricans
Black buffalo	Ictiobus niger
Spotted sucker	Minytrema melanops
Silver redhorse	Moxostoma anisurum
River redhorse	Moxostoma carinatum
Black redhorse	Moxostoma duquesnei
Shorthead redhorse	Moxostoma macrolepidotum
Greater redhorse	Moxostoma valenciennesi

Ictaluridae (Bullhead, Catfish)

Common Name	Scientific Name
Stonecat	Noturus flavus

Appendix A

Cyprinodontidae (topminnows)

Common Name	**Scientific Name**
Banded killifish	Fundulus diaphanus

Gasterosteidae (sticklebacks)

Common Name	**Scientific Name**
Ninespine stickleback	Pungitius pungitius

Centrarchidae (sunfish)

Common Name	**Scientific Name**
Rock bass	Ambloplites rupestris
Smallmouth bass	Micropterus dolomieui

Percidae (perch)

Common Name	**Scientific Name**
Eastern sand darter	Ammocrypta pellucida
Rainbow darter	Etheostoma caeruleum
Iowa darter	Etheostoma exile
Least darter	Etheostoma microperca
Orangethroat darter	Etheostoma spectabile
Banded darter	Etheostoma zonale
Channel darter	Percina copelandi

Appendix B

Michigan Fish Classified as Omnivores

Cyprinidae

Common Name	Scientific Name
Goldfish	Carassius auratus
Common Carp	Cyprinus carpio
Golden Shiner	Notemigonus crysoleucas
Fathead minnow	Pimephales promelas
Bluntnose minnow	Pimephales notatus
Creek chub	Semotilus atromaculatus
Blacknose dace	Rhinichthys atratulus
European rudd	Scardinius erthropthalmus

Catastomidae

Common Name	Scientific Name
White sucker	Catostomus commersoni
Quillback	Carpoides cyprinus

Umbridae

Common Name	Scientific Name
Central mudminnow	Umbra limi

Ictaluridae

Common Name	Scientific Name
Black Bullhead	Ameiurus melas
Brown bullhead	Ameiurus nebulosus
Yellow bullhead	Ameiurus natalis

Appendix C

Michigan Fish Classified as Insectivores

Acipenseridae (sturgeons)

Common Name	Scientific Name
Lake Sturgeon	Acipenser fulvescens

Hiodontidae (Mooneyes)

Common Name	Scientific Name
Mooneye	Hiodon tergisus

Salmonidae (trouts)

Common Name	Scientific Name
Lake whitefish	Coregonus cupeaformis
Pygmy whitefish	Prosopium coulteri
Round whitefish	Prosopium cylindraceum
Artic grayling **(extinct in Michigan)**	Thymallus arcticus

Cyprinidae (minnows and carps)

Common Name	Scientific Name
Lake chub	Couesius plumbeus
Bigeye chub	Notropis amblops
Hornyhead chub	Nocomis biguttatus
River chub	Nocomis micropogon
Emerald shiner	Notropis atherinoides
Bigeye shiner	Notropis boops
Ironcolor shiner	Notropis chalybaeus
Common shiner	Luxilus cornutus
Striped shiner	Luxilus chrysocephalus
Central bigmouth shiner	Notropis dorsalis
Blackchin shiner	Notropis heterodon
Blacknose shiner	Notropis heterolepis
Spottail shiner	Notropis hudsonius
Silver shiner	Notropis photogenis
Rosyface shiner	Notropis rubellus
Spotfin shiner	Cyprinella spilopterus
Sand shiner	Notropis stramineus
Redfin shiner	Lythrurus umbratilis
Mimic shiner	Notropis volucellus
Suckermouth minnow	Phenacobius mirabilis
Silverjaw minnow	Notropis buccatus
Finescale dace	Phoxinus neogaeus
Longnose dace	Rhinichthys cataractae
Redside dace	Clinostomus elongatus
Pearl dace	Margariscus margarita
Silver chub	Macrhybopsis storeriana
Pugnose minnow	Opsopoedus emiliae

Appendix C

Cottidae (sculpins)

Common Name	Scientific Name
Mottled sculpin	Cottus bairdii
Slimy sculpin	Cottus cognatus
Spoonhead sculpin	Cottus ricei
Deepwater sculpin	Myoxocephalus thompsoni

Catostomidae (suckers)

Common Name	Scientific Name
Longnose sucker	Catostomus catostomus
Creek chubsucker	Erimyzon oblongus
Lake chubsucker	Erimyzon sucetta
Norther hog sucker	Hypentelium nigricans
Bigmouth buffalo	Ictiobus cyprinellus
Black buffalo	Ictiobus niger
Spotted sucker	Minytrema melanops
Silver redhorse	Moxostoma anisurum
River redhorse	Moxostoma carinatum
Black redhorse	Moxostoma duquesnei
Golden redhorse	Moxostoma erythrurum
Shorthead redhorse	Moxostoma macrolepidotum
Greater redhorse	Moxostoma valenciennesi

Ictaluridae (Bullhead, Catfish)

Common Name	Scientific Name
Stonecat	Noturus flavus
Margined madtom	Noturus insignis
Tadpole madtom	Noturus gyrinus
Brindled madtom	Noturus miurus
Northern madtom	Noturus stigmosus

Aphredoderidae (pirate perch)

Common Name	Scientific Name
Pirate perch	Aphredoderus sayanus

Atherinidae (silversides)

Common Name	Scientific Name
Brook silversides	Labidesthes sicculus

Cyprinodontidae (topminnows)

Common Name	Scientific Name
Banded killifish	Fundulus diaphanus
Starhead topminnow	Fundulus dispar
Blackstripe topminnow	Fundulus notatus

Appendix C

Gasterosteidae (sticklebacks)

Common Name	**Scientific Name**
Brook stickleback	Culaea inconstans
Threespine stickleback	Gasterosteus aculeatus
Ninespine stickleback	Pungitius pungitius

Centrarchidae (sunfish)

Common Name	**Scientific Name**
Green sunfish	Lepomis cyanellus
Pumpkinseed	Lepomis gibbosus
Orangespotted sunfish	Lepomis humilis
Bluegill	Lepomis macrochirus
Longear sunfish	Lepomis megalotis
Redear sunfish	Lepomis microlophus

Percidae (perch)

Common Name	**Scientific Name**
Eastern sand darter	Ammocrypta pellucida
Rainbow darter	Etheostoma caeruleum
Iowa darter	Etheostoma exile
Greenside darter	Etheostoma blennioides
Fantail darter	Etheostoma flabellare
Least darter	Etheostoma microperca
Johnny darter	Etheostoma nigrum
Orangethroat darter	Etheostoma spectabile
Banded darter	Etheostoma zonale
Logperch	Percina caprodes
Channel darter	Percina copelandi
Blackside darter	Percina maculata
River darter	Percina shumardi
Ruffe	Gymnocephalus cernuus

Percopsidae (Trout-perch)

Common Name	**Scientific Name**
Trout-perch	Percopsis omiscomaycus

Sciaenidae (drums)

Common Name	**Scientific Name**
Freshwater drum	Aplodinotus grunniens

Gobiidae (gobies)

Common Name	**Scientific Name**
Round goby	Neogobius melanostomus
Tubenose goby	Proterorhinus marmoratus

Poeciliidae (livebearers)

Common Name	**Scientific Name**
Western mosquitofish	Gambusia affinis

Appendix D

Michigan Fish Classified as Piscivores

Common Name	**Scientific Name**
Common Name	Scientific Name
Spotted gar	Lepisosteus oculatus
Longnose gar	Lepisosteus osseus
Bowfin	Amia calva
American eel	Anguilla rostrata
Channel catfish	Ictalurus punctatus
Flathead catfish	Pylodictis olivaris
Grass pickerel	Esox americanus vermiculatus
Northern pike	Esox lucius
Muskellunge	Esox masquinongy
Burbot	Lota lota
White perch	Morone americana
White bass	Morone chrysops
Rock bass	Ambloplites rupestris
Largemouth bass	Micropterus salmoides
Smallmouth bass	Micropterus dolomieu
Walleye	Stizostedion vitreum
Sauger	Stizostedion canadense

Appendix E

Michigan Fish Classified as Tolerant

Amiidae (bowfins)

Common Name	**Scientific Name**
Bowfin	Amia calva

Umbridae (mudminnows)

Common Name	**Scientific Name**
Central mudminnow	Umbra limi

Cyprinidae (minnows and carps)

Common Name	**Scientific Name**
Goldfish	Carassius auratus
Common Carp	Cyprinus carpio
Creek chub	Semotilus atromaculatus
Golden shiner	Notemigonus crysoleucas
Fathead minnow	Pimephales promelas
Bluntnose minnow	Pimephales notatus
Blacknose dace	Rhinichthys atratulus
European rudd	Scardinius erythropthalmus

Catostomidae (suckers)

Common Name	**Scientific Name**
White sucker	Catostomus commersoni

Ictaluridae (Bullhead, Catfish)

Common Name	**Scientific Name**
Yellow bullhead	Ameiurus natalis

Centrarchidae (sunfish)

Common Name	**Scientific Name**
Green sunfish	Lepomis cyanellus

Percidae (perch)

Common Name	**Scientific Name**
Johnny darter	Etheostoma nigrum

Sciaenidae (drums)

Common Name	**Scientific Name**
Freshwater drum	Aplodinotus grunniens

Appendix F

Michigan Fish Classified as Simple Lithophilic Spawners

Acipenseridae (sturgeons)

Common Name	**Scientific Name**
Lake sturgeon	Acipenser fulvescens

Polydontidae (paddlefish)

Common Name	**Scientific Name**
Paddlefish **(extinct in Michigan**	Polyodon spathula

Hiodontidae (mooneyes)

Common Name	**Scientific Name**
Mooneye	Hiodon tergisus

Cyprinidae (minnows and carps)

Common Name	**Scientific Name**
Lake chub	Couesius plumbeus
Bigeye shiner	Notropis boops
Common shiner	Luxilus cornutus
Striped shiner	Luxilus chrysocephalus
Silver shiner	Notropis photogenis
Rosyface shiner	Notropis rubellus
Suckermouth minnow	Phenacobius mirabilis
Southern redbelly dace	Phoxinus erthrogaster
Blacknose dace	Rhinichthys atratulus
Longnose dace	Rhinichthys cataractae
Pearl dace	Margariscus margarita

Catostomidae (suckers)

Common Name	**Scientific Name**
Longnose sucker	Catostomus catostomus
White sucker	Catostomus commersoni
Northern hog sucker	Hypentelium nigricans
Spotted sucker	Minytrema melanops
Silver redhorse	Moxostoma anisurum
River redhorse	Moxostoma carinatum
Black redhorse	Moxostoma duquesnei
Golden redhorse	Moxostoma erythrurum
Shorthead redhorse	Moxostoma macrolepidotum
Greater redhorse	valenciennesi

Appendix F

Percidae (perch)

Common Name	Scientific Name
Rainbow darter	Etheostoma caeruleum
Orangethroat darter	Etheostoma spectabile
Banded darter	Etheostoma zonale
Logperch	Percina caprodes
Channel darter	Percina copelandi
Blackside darter	Percina maculata
River darter	Percina shumardi
Sauger	Stizostedion canadense
Walleye	Stizostedion vitreum
Ruffe	Gymnocephalus cernuus

Gadidae (codfishes)

Common Name	Scientific Name
Burbot	Lota lota

The following fish are to be measured to inch group:

Percidae (Perches)

Common Name	**Scientific Name**
Yellow perch	Perca flavescens
Sauger	Stizostedion canadense
Walleye	Stizostedion vitreum

Cyprinidae (minnows)

Common Name	**Scientific Name**
Creek chub	Semotilus atromaculatus
Pearl dace	Margariscus margarita
Goldfish	Carassius auratus
Common carp	Cyprinus carpio
Common shiner	Notropis cornutus
Hornyhead chub	Nocomis biguttus
River chub	Nocomis micropogon
Golden shiner	Notemigonus crysoleucas

All members of the families:

Catostomidae (suckers)
Lepistosteidae (gars)
Amiidae (bowfin)
Anquillidae (eel)
Clupeidae (herring)
Osmeridae (smelts)
Salmonidae (salmon, trouts, whitefish)
Esocidae (pike)
Ictaluridae (bullheads, catfish)
Percichthyidae (temperate basses)
Centrarchidae (sunfishes)
Sciaenidae (drums)

Appendix H

Phylogenetic order for macroinvertebrates, level of taxonomy, and primary keys to be used for site evaluations.

Key: Pennak, 1989; Klemm, 1972

Phylum	Subphylum	Class/Subclass	Superorder/Order	Taxonomic Identification
Porifera [L/R]	-	-	-	Phylum
Platyhelminthes	-	Turbellaria	-	Class
Nematomorpha	-	-	-	Phylum
Bryozoa [L/R]	-	-	-	Phylum
Annelida	-	Hirudinea	-	Class
Annelida	-	Oligochaeta	-	Class
Arthropoda	Crustacea	Malacostraca	Amphipoda	Order
Arthropoda	Crustacea	Malacostraca	Decapoda	Order
Arthropoda	Crustacea	Malacostraca	Isopoda	Order
Arthropoda	Crustacea	Arachnoidea	Acariformes (Hydracarina)	Superorder

Key: Merritt et al., 2019

Phylum	Class	Order/Suborder	Family	Taxonomic Identification
Arthropoda	Insecta	Ephemeroptera	Ameletidae	Family
Arthropoda	Insecta	Ephemeroptera	Ametropodidae	Family
Arthropoda	Insecta	Ephemeroptera	Arthropleidae	Family
Arthropoda	Insecta	Ephemeroptera	Baetidae	Family
Arthropoda	Insecta	Ephemeroptera	Baetiscidae	Family
Arthropoda	Insecta	Ephemeroptera	Caenidae	Family
Arthropoda	Insecta	Ephemeroptera	Ephemerellidae	Family
Arthropoda	Insecta	Ephemeroptera	Ephemeridae	Family
Arthropoda	Insecta	Ephemeroptera	Heptageniidae	Family
Arthropoda	Insecta	Ephemeroptera	Isonychiidae	Family
Arthropoda	Insecta	Ephemeroptera	Leptohyphidae[NC]	Family
Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae	Family
Arthropoda	Insecta	Ephemeroptera	Metretopodidae	Family
Arthropoda	Insecta	Ephemeroptera	Neoephemeridae	Family
Arthropoda	Insecta	Ephemeroptera	Polymitarcyidae	Family
Arthropoda	Insecta	Ephemeroptera	Potamanthidae	Family
Arthropoda	Insecta	Ephemeroptera	Pseudironidae	Family
Arthropoda	Insecta	Ephemeroptera	Siphlonuridae	Family
Arthropoda	Insecta	Plecoptera	Capniidae[ID]	Family
Arthropoda	Insecta	Plecoptera	Chloroperlidae	Family
Arthropoda	Insecta	Plecoptera	Leuctridae [ID]	Family
Arthropoda	Insecta	Plecoptera	Nemouridae [ID]	Family

Appendix H

Phylum	Class	Order/Suborder	Family	Taxonomic Identification
Arthropoda	Insecta	Plecoptera	Perlidae	Family
Arthropoda	Insecta	Plecoptera	Perlodidae	Family
Arthropoda	Insecta	Plecoptera	Pteronarcyidae	Family
Arthropoda	Insecta	Plecoptera	Taeniopterygidae [ID]	Family
Arthropoda	Insecta	Odonata/Anisoptera	Aeshnidae	Family
Arthropoda	Insecta	Odonata/Anisoptera	Cordulegastridae	Family
Arthropoda	Insecta	Odonata/Anisoptera	Corduliidae [ID]	Family
Arthropoda	Insecta	Odonata/Anisoptera	Gomphidae	Family
Arthropoda	Insecta	Odonata/Anisoptera	Libellulidae [ID]	Family
Arthropoda	Insecta	Odonata/Anisoptera	Macromiidae	Family
Arthropoda	Insecta	Odonata/Zygoptera	Calopterygidae	Family
Arthropoda	Insecta	Odonata/Zygoptera	Coenagrionidae	Family
Arthropoda	Insecta	Odonata/Zygoptera	Lestidae	Family
Arthropoda	Insecta	Hemiptera	Belostomatidae	Family
Arthropoda	Insecta	Hemiptera	Corixidae	Family
Arthropoda	Insecta	Hemiptera	Gelastocoridae	Family
Arthropoda	Insecta	Hemiptera	Gerridae	Family
Arthropoda	Insecta	Hemiptera	Hydrometridae	Family
Arthropoda	Insecta	Hemiptera	Mesoveliidae	Family
Arthropoda	Insecta	Hemiptera	Naucoridae	Family
Arthropoda	Insecta	Hemiptera	Nepidae	Family
Arthropoda	Insecta	Hemiptera	Notonectidae	Family
Arthropoda	Insecta	Hemiptera	Pleidae	Family
Arthropoda	Insecta	Hemiptera	Saldidae	Family
Arthropoda	Insecta	Hemiptera	Veliidae	Family
Arthropoda	Insecta	Megaloptera	Corydalidae	Family
Arthropoda	Insecta	Megaloptera	Sialidae	Family
Arthropoda	Insecta	Neuroptera	Sisyridae	Family
Arthropoda	Insecta	Trichoptera	Apataniidae	Family
Arthropoda	Insecta	Trichoptera	Brachycentridae	Family
Arthropoda	Insecta	Trichoptera	Dipseudopsidae	Family
Arthropoda	Insecta	Trichoptera	Glossosomatidae	Family
Arthropoda	Insecta	Trichoptera	Goeridae	Family
Arthropoda	Insecta	Trichoptera	Helicopsychidae	Family
Arthropoda	Insecta	Trichoptera	Hydropsychidae	Family
Arthropoda	Insecta	Trichoptera	Hydroptilidae	Family
Arthropoda	Insecta	Trichoptera	Lepidostomatidae	Family
Arthropoda	Insecta	Trichoptera	Leptoceridae	Family
Arthropoda	Insecta	Trichoptera	Limnephilidae	Family
Arthropoda	Insecta	Trichoptera	Molannidae	Family
Arthropoda	Insecta	Trichoptera	Odontoceridae	Family
Arthropoda	Insecta	Trichoptera	Philopotamidae	Family
Arthropoda	Insecta	Trichoptera	Phryganeidae	Family

Appendix H

Phylum	Class	Order/Suborder	Family	Taxonomic Identification
Arthropoda	Insecta	Trichoptera	Polycentropodidae	Family
Arthropoda	Insecta	Trichoptera	Psychomyiidae	Family
Arthropoda	Insecta	Trichoptera	Rhyacophilidae	Family
Arthropoda	Insecta	Trichoptera	Sericostomatidae	Family
Arthropoda	Insecta	Trichoptera	Thremmatidae [NC] (one genus *Neophylax*)	Family
Arthropoda	Insecta	Lepidoptera	-	Order
Arthropoda	Insecta	Coleoptera*	Dryopidae	Family
Arthropoda	Insecta	Coleoptera*	Dytiscidae	Family
Arthropoda	Insecta	Coleoptera*	Elmidae	Family
Arthropoda	Insecta	Coleoptera*	Gyrinidae (A)(L)	Family
Arthropoda	Insecta	Coleoptera*	Haliplidae (A)(L)	Family
Arthropoda	Insecta	Coleoptera*	Hydrophilidae	Family
Arthropoda	Insecta	Coleoptera*	Lampyridae (L)	Family
Arthropoda	Insecta	Coleoptera*	Noteridae [ID] (A)(L)	Family
Arthropoda	Insecta	Coleoptera*	Psephenidae (L)	Family
Arthropoda	Insecta	Coleoptera*	Scirtidae (A)(L)	Family
Arthropoda	Insecta	Diptera	Athericidae	Family
Arthropoda	Insecta	Diptera	Blephariceridae	Family
Arthropoda	Insecta	Diptera	Ceratopogonidae	Family
Arthropoda	Insecta	Diptera	Chaoboridae	Family
Arthropoda	Insecta	Diptera	Chironomidae	Family
Arthropoda	Insecta	Diptera	Culicidae	Family
Arthropoda	Insecta	Diptera	Dixidae	Family
Arthropoda	Insecta	Diptera	Dolichopodidae	Family
Arthropoda	Insecta	Diptera	Empididae	Family
Arthropoda	Insecta	Diptera	Ephydridae [ID]	Family
Arthropoda	Insecta	Diptera	Muscidae	Family
Arthropoda	Insecta	Diptera	Psychodidae	Family
Arthropoda	Insecta	Diptera	Ptychopteridae	Family
Arthropoda	Insecta	Diptera	Sciomyzidae	Family
Arthropoda	Insecta	Diptera	Simuliidae	Family
Arthropoda	Insecta	Diptera	Stratiomyidae	Family
Arthropoda	Insecta	Diptera	Syrphidae [ID]	Family
Arthropoda	Insecta	Diptera	Tabanidae	Family
Arthropoda	Insecta	Diptera	Tipulidae	Family

Appendix H

Key: Burch, 1991

Phylum	Class	Family/Species	Taxonomic Identification
MOLLUSCA	Gastropoda	Ancylidae	Family
MOLLUSCA	Gastropoda	Bithyniidae	Family
MOLLUSCA	Gastropoda	Hydrobiidae	Family
MOLLUSCA	Gastropoda	Lymnaeidae	Family
MOLLUSCA	Gastropoda	Physidae	Family
MOLLUSCA	Gastropoda	Planorbidae	Family
MOLLUSCA	Gastropoda	Pleuroceridae	Family
MOLLUSCA	Gastropoda	Pomatiopsidae	Family
MOLLUSCA	Gastropoda	Valvatidae	Family
MOLLUSCA	Gastropoda	Viviparidae	Family
MOLLUSCA	Bivalvia	Cyrenidae/*Corbicula fluminea*	Species
MOLLUSCA	Bivalvia	Dreissenidae	Family
MOLLUSCA	Bivalvia	Pisidiidae [NC]	Family
MOLLUSCA	Bivalvia	Unionidae [L/R]	Family

* Note: For certain Coleoptera families labeled (L), only larvae are counted (non-aquatic adults). Families labeled (A)(L) the adults and larvae are counted separately.
NC Name Changes: Leptohyphidae=Tricorythidae; Pisidiidae = Sphaeriidae; Thremmatidae=Uenoidae
ID Recommend bringing back for ID confirmation
L/R Record as “onesie” (Large/Rare) only

Michigan Metric Response Mechanisms

The metrics in the index have comprehensible mechanisms of response to increasing environmental stress. Metrics were selected for inclusion in the index based on performance statistics (DE and Z-score), response mechanisms, and metric diversity (metrics representative of many metric categories). The recommended index consists of metrics representative of taxonomic richness, community composition, pollution tolerance, functional feeding groups, and taxa habits. Interpretable metrics provide easier interpretation of assemblage structure in relation to index scores. Taxa attributes related to the metrics are in Tables 3 and 4 below.

Number of taxa of Orders Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies) (nt_EPT)

Description: Number of distinct taxa in the insect orders EPT

EPT taxa are generally sensitive to environmental degradation such as reduced dissolved oxygen, unstable substrates, reduced food quality, and contamination due to heavy metals and other pollutants. As environmental conditions become worse, the sensitive and specialist taxa of these groups will emigrate or perish.

Metric Category: Richness *Index Application:* VeryNarrow

Trend: Expected to decrease with stress and decreases in the Michigan dataset.

References: Angradi, 1999; Barbour et al., 1999; Yuan and Norton, 2003; Hutchens et al., 2009

Number of taxa not of Class Insecta (nt_nonIns)

Description: Number of distinct taxa that are non-insects

Taxa richness generally decreases with increasing stress, as the sensitive and specialist taxa emigrate or perish when exposed to intolerable conditions such as pollution, greater sedimentation, or reduced food quality. Non-insects (primarily gastropods, bivalves, crustaceans, and worms) can be tolerant or take advantage of stresses, and therefore, indicate the presence of disturbance.

Metric Category: Richness *Index Application:* WideOrMidSizeWet

Trend: Expected to increase with stress and increases in the Michigan dataset.

References: Barbour et al., 1999; Yuan and Norton, 2003

Percent (0-100) taxa not of Class Insecta (pt_nonIns)

Description: Of all taxa, the percentage of taxa that are non-insects

Taxa richness generally decreases with increasing stress, as the sensitive and specialist taxa emigrate or perish when exposed to intolerable conditions such as pollution, greater sedimentation, or reduced food quality. Non-insects (primarily gastropods, bivalves, crustaceans, and worms) can be tolerant or take advantage of stresses, and therefore, an increase in relative abundance indicates the presence of disturbance.

Metric Category: Richness

Index Application: VeryNarrow, Narrow, MidSizeDry, WestFlat, East

Trend: Expected to increase with stress and increases in the Michigan dataset.

References: Barbour et al., 1999; Yuan and Norton, 2003

Number of taxa of Order Trichoptera (nt_Trich)

Description: Number of distinct taxa in the insect order Trichoptera (caddisflies)

Trichoptera taxa are generally sensitive to environmental degradation such as reduced dissolved oxygen, unstable substrates, reduced food quality, and contamination due to heavy metals and other pollutants. As environmental conditions become worse, the sensitive and specialist taxa of this order will emigrate or perish.

Metric Category: Richness *Index Application:* WestSteep, East

Trend: Expected to decrease with stress and decreases in the Michigan dataset.

References: Angradi, 1999; Barbour et al., 1999; Yuan and Norton, 2003; Hutchens et al., 2009

Number of taxa of Phylum Mollusca and Subphylum Crustacea (nt_CruMol)

Description: Number of distinct taxa in the phylum Mollusca (snails, bivalves) and subphylum Crustacea (amphipods, decapods, isopods)

Taxa richness generally decreases with increasing stress, as the sensitive and specialist taxa emigrate or perish when exposed to intolerable conditions such as pollution, greater sedimentation, or reduced food quality. Non-insects, such as gastropods, bivalves, and crustaceans can be tolerant or take advantage of stresses, and therefore, indicate the presence of disturbance.

Metric Category: Richness *Index Application:* MidSizeDry

Trend: Expected to increase with stress and increases in the Michigan dataset.

References: Barbour et al., 1999; Yuan and Norton, 2003

Percent (0-100) individuals of Subphylum Crustacea and Phylum Mollusca (pi_CruMol)

Description: Of all individuals, the percentage of individuals that are in the phylum Mollusca (snails, bivalves) and subphylum Crustacea (amphipods, decapods, isopods)

Taxa richness generally decreases with increasing stress, as the sensitive and specialist taxa emigrate or perish when exposed to intolerable conditions such as pollution, greater sedimentation, or reduced food quality. Non-insects, such as gastropods, bivalves, and crustaceans can be tolerant or take advantage of stresses, and therefore, an increase in relative abundance indicates the presence of disturbance.

Metric Category: Composition *Index Application:* MidSizeDry

Trend: Expected to increase with stress and increases in the Michigan dataset.

R*eferences:* Barbour et al., 1999; Yuan and Norton, 2003

Percent (0-100) individuals of Subphylum Crustacea (pi_Crus)

Description: Of all individuals, the percentage of individuals that are in the subphylum Crustacea (amphipods, decapods, isopods)

Taxa richness generally decreases with increasing stress, as the sensitive and specialist taxa emigrate or perish when exposed to intolerable conditions such as pollution, greater sedimentation, or reduced food quality. Non-insects, such as crustaceans, can be tolerant or take advantage of stresses, and therefore, an increase in relative abundance indicates the presence of disturbance.

Metric Category: Composition *Index Application:* VeryNarrow

Trend: Expected to increase with stress and increases in the Michigan dataset.

References: Barbour et al., 1999; Yuan and Norton, 2003

Percent (0-100) individuals of Orders EPT (pi_EPT)

Description: Of all individuals, the percentage of individuals that are in the insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies)

The stressor mechanisms described for EPT taxa also affect the relative abundance of EPT individuals in a stream. The sensitive and specialist individuals of the mayfly, stonefly, and caddisfly insect orders emigrate or perish with increasing stress.

Metric Category: Composition

Index Application: Narrow, WestFlat

Trend: Expected to decrease with stress and decreases in the Michigan dataset

References: Angradi 1999; Barbour et al. 1999; Yuan and Norton 2003; Hutchens et al. 2009

Percent (0-100) individuals of Orders EPT and not Families Baetidae or Hydropsychidae (pi_EPTnoBH)

Description: Of all individuals, the percentage of individuals that are in the insect orders EPT

The stressor mechanisms described for EPT taxa also affect the relative abundance of EPT individuals in a stream. The sensitive and specialist individuals of the mayfly, stonefly, and caddisfly insect orders emigrate or perish with increasing stress. Families Baetidae and Hydropsychidae, which are relatively tolerant EPT taxa were removed from this metric to concentrate on sensitive EPT taxa.

Metric Category: Composition *Index Application:* WestSteep

Trend: Expected to decrease with stress and decreases in the Michigan dataset.

References: Angradi, 1999; Barbour et al., 1999; Yuan and Norton, 2003; Hutchens et al., 2009

Percent (0-100) individuals of Order Plecoptera (pi_Pleco)

Description: Of all individuals, the percentage of individuals that are in the insect order Plecoptera (stoneflies)

Plecoptera taxa are generally sensitive to environmental degradation such as reduced dissolved oxygen, unstable substrates, reduced food quality, and contamination due to heavy metals and other pollutants. As environmental conditions become worse, the sensitive and specialist taxa of this order will emigrate or perish, and therefore, the relative abundance of Plecoptera taxa will decrease.

Metric Category: Composition *Index Application:* WideOrMidSizeWet

Trend: Expected to decrease with stress and decreases in the Michigan dataset.

References: Angradi, 1999; Barbour et al., 1999; Yuan and Norton, 2003; Hutchens et al., 2009

Percent (0-100) individuals of Order Isopoda, Class Gastropoda, Subclass Hirudinea (pi_IsoSnILch)

Description: Of all individuals, the percentage of individuals that are in the Order Isopoda, Class Gastropoda, or Subclass Hirudinea

Taxa richness generally decreases with increasing stress, as the sensitive and specialist taxa emigrate or perish when exposed to intolerable conditions such as pollution, greater sedimentation, or reduced food quality. Non-insects, such as gastropods, leaches, and crustaceans can be tolerant or take advantage of stresses, and therefore, an increase in relative abundance indicates the presence of disturbance.

Metric Category: Composition *Index Application*: WideOrMidSizeWet, East

Trend: Expected to increase with stress and increases in the Michigan dataset.

References: Barbour et al., 1999; Yuan and Norton, 2003

Percent (0-100) individuals not of Class Insecta (pi_nonIns)

Description: Of all individuals, the percentage of individuals that are non-insects

Taxa richness generally decreases with increasing stress, as the sensitive and specialist taxa emigrate or perish when exposed to intolerable conditions such as pollution, greater sedimentation, or reduced food quality. Non-insects (primarily gastropods, bivalves, crustaceans, and worms) can be tolerant or take advantage of stresses, and therefore, an increase in relative abundance indicates the presence of disturbance.

Metric Category: Composition Index Application: WideOrMidSizeWet

Trend: Expected to increase with stress and increases in the Michigan dataset.

References: Barbour et al., 1999; Yuan and Norton, 2003

Percent (0-100) individuals of Functional Feeding Group - collector-gatherer (CG) (pi_ffg_cllct)

Description: Of all individuals, the percentage of individuals that gather food resources among the substrate

Collectors primarily wander the stream bottom scavenging for dead organisms, detritus, or other small food particles (<1 mm) that get lodged between rocks or in deep pools. Increased detritus would increase collector prevalence.

Metric Category: Functional Feeding Groups Index Application: WestFlat, WestSteep

Trend: Expected to increase with stress and increases in the Michigan dataset.

References: Merritt et al., 2008; Hutchens et al., 2009; Lan Fu et al., 2016

Percent (0-100) individuals of Functional Feeding Group - predator (PR) (pi_ffg_pred)

Description: Of all individuals, the percentage of individuals that consume other organisms using different strategies to capture prey.

Predators employ a diversity of strategies for capturing prey, including modified mouth parts and behavior. Some species of invertebrates are predators in both the larval and adult stages of their life.

Metric Category: Functional Feeding Groups Index Application: MidSizeDry

Trend: Expected to decrease with stress and decreases in the Michigan dataset.

References: Merritt et al., 2008; Hutchens et al., 2009; Lan Fu et al., 2016

Percent (0-100) individuals of Functional Feeding Group - scraper (SC) (pi_ffg_scrap)

Description: Of all individuals, the percentage of individuals that scrape food resources from substrates

Scrapers take advantage of biofilm that accumulates on rocky substrates. When the food quality is reduced or the substrate is unstable, the scrapers are not as prevalent. However, scrapers might also increase when excess nutrients and decreased canopy cover increase the availability of algal biofilm.

Metric Category: Functional Feeding Groups *Index Application:* WideOrMidSizeWet

Trend: Response is increasing with stress in the Michigan dataset.

References: Merritt et al., 2008; Hutchens et al., 2009

Percent (0-100) individuals of Functional Feeding Group - shredder (SH) (pi_ffg_shred)

Description: Of all individuals, the percentage of individuals that consume coarse plant material using tearing mouthparts

Shredders are organisms that shred, rip, cut, or chew plant material; shredders break down large particles into smaller pieces that are then either available to consume by other stream organisms or transported downstream. Shredders are more prevalent when more food is available.

Metric Category: Functional Feeding Groups *Index Application:* VeryNarrow, Narrow, MidSizeDry

Trend: Expected to decrease with stress but increases in the Michigan dataset.

References: Merritt et al., 2008; Hutchens et al., 2009; Lan Fu et al., 2016

Number of taxa of Habit Clingers (CN) (nt_hab_clngr)

Description: Number of distinct taxa that maintain position and move through stream currents by clinging to substrates

Clingers indicate a complex habitat that includes stable substrates and flowing waters. When no stable substrates are available, the clingers are not as diverse.

Metric Category: Habit *Index Application:* East

Trend: Expected to decrease with stress and decreases in the Michigan dataset.

References: Merritt et al., 2008; Hutchens et al., 2009

Percent (0-100) individuals of Habit - climbers (CB) (pi_hab_clmbr)

Description: Of all individuals, the percentage of individuals that climb vertically

Climbers are organisms that are adapted for living on vascular plants or detrital debris such as branches, roots, and submerged plants and brush. Climbers have physiological modifications for moving vertically on stems. Climbers are more prevalent when habitats contain more detritus and submerged vegetation.

Metric Category: Habit *Index Application:* Narrow

Trend: Expected to increase with stress and increases in the Michigan dataset.

References: Merritt et al., 2008; Hutchens et al., 2009

Percent (0-100) individuals of Habit - clingers (CN) (pi_hab_clngr)

Description: Of all individuals, the percentage of individuals that maintain position and move through stream currents by clinging to substrates

Clingers have physiological and behavioral adaptations for attachment to surfaces in swift moving water. Clingers indicate a complex habitat that includes stable substrates and flowing waters. When no stable substrates are available, the clingers are not as prevalent.

Metric Category: Habit *Index Application:* VeryNarrow, MidSizeDry, WestSteep

Trend: Expected to decrease with stress and decreases in the Michigan dataset.

References: Merritt et al., 2008; Hutchens et al., 2009

Percent (0-100) individuals of Habit - sprawlers (SP) (pi_hab_sprwl)

Description: Of all individuals, the percentage of individuals that inhabit surfaces

Sprawlers live on the surfaces of floating leaves and fine sediments and have physiological modifications for staying atop substrates. Sprawler prevalence is expected to increase as habitats contain more floating surfaces and fine substrates.

Metric Category: Habit *Index Application:* WestFlat

Trend: Expected to increase with stress and increases in the Michigan dataset.

References: Merritt et al., 2008; Hutchens et al., 2009

Number of taxa with tolerance value ≥ 7 - tolerant (nt_tv_toler)

Description: Number of distinct taxa that are relatively tolerant to stressors

Taxa respond differently to environmental stressors; therefore, can be arranged on a continuum from intolerant to tolerant. Intolerant taxa will emigrate or perish as environmental conditions worsen. Conversely, tolerant taxa may not respond negatively to environmental conditions and may actually increase as niches open from extirpated intolerant taxa.

Metric Category: Tolerance *Index Application:* MidSizeDry

Trend: Expected to increase with stress and increases in the Michigan dataset.

References: Hilsenhoff, 1987; Yuan, 2006; USGS, 2013

Percent (0-100) individuals with tolerance value ≤ 3 - intolerant (pi_tv_intol)

Description: Of all individuals, the percentage of individuals that are relatively intolerant or sensitive to stressors

Taxa respond differently to environmental stressors; therefore, can be arranged on a continuum from intolerant to tolerant. Intolerant taxa will emigrate or perish as environmental conditions worsen. Conversely, tolerant individuals may not respond negatively to environmental conditions and may actually increase as niches open from extirpated intolerant taxa.

Metric Category: Tolerance *Index Application*: East

Trend: Expected to decrease with stress and decreases in the Michigan dataset.

References: Hilsenhoff, 1987; Yuan, 2006; USGS, 2013

Percent (0-100) individuals with tolerance value ≥ 7 - tolerant (pi_tv_toler)

Description: Of all individuals, the percentage of individuals that are relatively tolerant to stressors

Taxa respond differently to environmental stressors; therefore, can be arranged on a continuum from intolerant to tolerant. Intolerant taxa will emigrate or perish as environmental conditions worsen. Conversely, tolerant individuals may not respond negatively to environmental conditions and may actually increase as niches open from extirpated intolerant taxa.

Metric Category: Tolerance *Index Application:* Narrow, East

Trend: Expected to increase with stress and increases in the Michigan dataset.

References: Hilsenhoff, 1987; Yuan, 2006; USGS, 2013

Percent (0-100) taxa with tolerance value ≤ 3 - intolerant (pt_tv_intol)

Description: Of all taxa, the percentage of taxa that are relatively intolerant or sensitive to stressors

Taxa respond differently to environmental stressors; therefore, can be arranged on a continuum from intolerant to tolerant. Intolerant taxa will emigrate or perish as environmental conditions worsen. Conversely, tolerant taxa may not respond negatively to environmental conditions and may actually increase as niches open from extirpated intolerant taxa.

Metric Category: Tolerance *Index Application:* VeryNarrow, WestFlat

Trend: Expected to decrease with stress and decreases in the Michigan dataset.

References: Hilsenhoff, 1987; Yuan, 2006; USGS, 2013

Percent (0-100) taxa individuals with tolerance value ≥ 7 - tolerant (pt_tv_toler)

Description: Of all taxa, the percentage of taxa that are relatively tolerant to stressors

Taxa respond differently to environmental stressors; therefore, can be arranged on a continuum from intolerant to tolerant. Intolerant taxa will emigrate or perish as environmental conditions worsen. Conversely, tolerant taxa may not respond negatively to environmental conditions and may actually increase as niches open from extirpated intolerant taxa.

Metric Category: Tolerance *Index Application:* WideOrMidSizeWet, WestFlat, WestSteep

Trend: Expected to increase with stress and increases in the Michigan dataset.

References: Hilsenhoff, 1987; Yuan, 2006; USGS, 2013

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Table 3. Attribute (trait) descriptions, codes, and statistics for the taxa in the EGLE dataset.

Macroinvertebrate Traits

Attribute	Description	Categories	Sources	Number of taxa with trait assignment (out of 154)	Percent of total
Functional feeding group (FFG)	The primary strategy or mechanism for obtaining food resources	PR = predator CG = collector-gatherer SH = shredder SC = scraper CF = collector-filterer	MDEQ, USGS traits database, by association with MDEQ designation, literature	133	86%
Tolerance values	Relative sensitivity to pollution. In this dataset, the tolerance values are oriented toward detection of organic pollution (Hilsenhoff, 1987)	Values range from 0 (most *intolerant*) to 10 (most *tolerant*). Intolerant taxa 0 to 3. Tolerant taxa 7 to 10	Meta-analysis of USGS traits database	117	76%
Habit	Distinguishes the primary mechanism a particular species utilizes for maintaining position and moving in the aquatic environment (Merritt et al., 1996)	SP = sprawler SW = swimmer CN = clinger CB = climber BU = burrower	Meta-analysis of USGS traits database	107	69%
BCG	Sensitivity to human disturbance derived through consensus of an expert panel	2 = highly sensitive and uncommon 3 = sensitive 4 = moderately tolerant or unresponsive 5 = tolerant	Average of family level averages from Indiana, Illinois, and Minnesota	107	69%

Class/Order	Taxonomic Identification	Tolerance Value	Functional Feeding Group	Habit
Annelida	Annelida	-	-	Burrower (a)
Hirudine	Hirudinea	-	Predator (b)	Sprawler (a)
Oligochaeta	Oligochaeta	-	Collector (b)	Burrower (a)
Arachnida	Arachnoidea	-	-	-
Arachnida	Hydracarina	5.5 (a)	Predator (b)	-
Crustacea	Amphipoda	6.2 (a)	Shredder (b)	-
Crustacea	Decapoda	6.4 (a)	Collector (b)	-
Crustacea	Isopoda	7.6 (a)	Shredder (b)	-
Coleoptera	Chrysomelidae	8 (a)	Shredder (c)	Clinger (a)
Coleoptera	Coleoptera	5.3 (a)	-	-
Coleoptera	Curculionidae	6 (a)	Shredder (c)	Burrower (a)
Coleoptera	Dryopidae	4.9 (a)	Scraper (b)	Climber, Clinger (a)
Coleoptera	Dytiscidae	6.2 (a)	Predator (b)	Burrower, Swimmer
Coleoptera	Elmidae	4 (a)	Collector (b)	Clinger (a)
Coleoptera	Gyrinidae	4.1 (a)	Predator (c)	Swimmer (a)
Coleoptera	Haliplidae	7.3 (a)	Shredder (c)	-
Coleoptera	Helophoridae	-	Shredder (d)	-
Coleoptera	Heteroceridae	-	-	-
Coleoptera	Hydraenidae	4.5 (a)	Scraper (b)	Clinger (a)
Coleoptera	Hydrophilidae	5.4 (a)	Predator (b)	Burrower, Swimmer
Coleoptera	Lampyridae	-	Predator (c)	-
Coleoptera	Limnichidae	-	Collector (b)	-
Coleoptera	Noteridae	7.1 (a)	Predator (c)	Climber (a)
Coleoptera	Psephenidae	3.9 (a)	Scraper, Shredder	Clinger (a)
Coleoptera	Ptilodactylidae	3.8 (a)	Shredder (c)	Clinger, Sprawler (a)
Coleoptera	Scirtidae	6 (a)	Scraper (c)	Climber (a)
Diptera	Athericidae	2 (a)	Predator (b)	Sprawler (a)
Diptera	Ceratopogonidae	6.3 (a)	Predator (b)	Burrower, Sprawler
Diptera	Chaoboridae	8.2 (a)	Predator (b)	Sprawler (a)
Diptera	Chironomidae	5.5 (a)	Collector (b)	-
Diptera	Culicidae	8.1 (a)	Filterer (b)	Swimmer (a)
Diptera	Diptera	5.4 (a)	-	-
Diptera	Dixidae	2.9 (a)	Collector (b)	Swimmer (a)
Diptera	Dolichopodidae	4.3 (a)	Predator (b)	Sprawler (a)
Diptera	Empididae	5.3 (a)	Predator (b)	Clinger, Sprawler (a)
Diptera	Ephydridae	4.5 (a)	Shredder (b)	Burrower, Sprawler (a)
Diptera	Muscidae	5.5 (a)	Predator (b)	Burrower (a)
Diptera	Psychodidae	6 (a)	Collector (b)	Burrower (a)
Diptera	Ptychopteridae	6 (a)	Collector (b)	Burrower (a)
Diptera	Sciomyzidae	6 (a)	Predator (b)	Burrower (a)
Diptera	Simuliidae	4.2 (a)	Filterer (b)	Clinger (a)
Diptera	Stratiomyidae	6.1 (a)	Collector (b)	Sprawler (a)

Class/Order	Taxonomic Identification	Tolerance Value	Functional Feeding Group	Habit
Diptera	Syrphidae	9.9 (a)	Collector (b)	Burrower (a)
Diptera	Tabanidae	6.3 (a)	Predator (b)	Sprawler (a)
Diptera	Thaumaleidae	-	Scraper (b)	-
Diptera	Tipulidae	4 (a)	Collector (b)	Burrower (a)
Ephemeroptera	Ameletidae	-	Collector (d)	-
Ephemeroptera	Ametropodidae	-	Filterer (b)	Burrower (a)
Ephemeroptera	Baetidae	4.6 (a)	Collector (b)	Clinger, Swimmer (a)
Ephemeroptera	Baetiscidae	3.3 (a)	Collector (b)	Burrower, Clinger, Sprawler (a)
Ephemeroptera	Caenidae	4.2 (a)	Collector (b)	Burrower, Sprawler (a)
Ephemeroptera	Ephemerellidae	2.2 (a)	Scraper (b)	Clinger (a)
Ephemeroptera	Ephemeridae	3 (a)	Collector (b)	Burrower (a)
Ephemeroptera	Ephemeroptera	3 (a)	-	-
Ephemeroptera	Heptageniidae	1.9 (a)	Scraper (b)	Clinger (a)
Ephemeroptera	Isonychiidae	2.8 (a)	Filterer (b)	Swimmer (a)
Ephemeroptera	Leptohyphidae	-	-	-
Ephemeroptera	Leptophlebiidae	2.3 (a)	Collector (b)	Cling, Swim (a)
Ephemeroptera	Metretopodidae	2.7 (a)	Collector (b)	Swimmer (a)
Ephemeroptera	Oligoneuriidae	3 (a)	Filterer (b)	Burrower (a)
Ephemeroptera	Polymitarcyidae	1.8 (a)	Collector (b)	Burrower (a)
Ephemeroptera	Potamanthidae	1.5 (a)	Filterer (b)	Burrower (a)
Ephemeroptera	Siphlonuridae	6.4 (a)	Collector (b)	Swimmer (a)
Ephemeroptera	Tricorythidae	-	Collector (d)	-
Hemiptera	Belostomatidae	9.9 (a)	Predator (b)	Climber, Swimmer (a)
Hemiptera	Corixidae	8.2 (a)	Collector (b)	Swimmer (a)
Hemiptera	Gelastocoridae	-	Predator (b)	Burrower, Sprawler
Hemiptera	Gerridae	5.7 (a)	Predator (b)	Skater (a)
Hemiptera	Hemiptera	7.3 (a)	-	-
Hemiptera	Mesoveliidae	-	Predator (b)	Skater (a)
Hemiptera	Naucoridae	6 (a)	Predator (b)	Climber (a)
Hemiptera	Nepidae	7.4 (a)	Predator (b)	Climber, Clinger (a)
Hemiptera	Notonectidae	8.6 (a)	Predator (b)	Swimmer (a)
Hemiptera	Pleidae	-	Predator (b)	Swimmer (a)
Hemiptera	Saldidae	-	Predator (b)	Skater (a)
Hemiptera	Veliidae	6.3 (a)	Predator (b)	Skater (a)
Lepidoptera	Lepidoptera	4.6 (a)	-	-
Lepidoptera	Noctuidae	-	Shredder (b)	-
Lepidoptera	Pyralidae	4.3 (a)	Shredder (b)	Clinger (a)
Megaloptera	Corydalidae	4.9 (a)	Predator (b)	Clinger (a)
Megaloptera	Megaloptera	5 (a)	Predator (c)	-
Megaloptera	Sialidae	5.1 (a)	Predator (b)	Burrower (a)
Neuroptera	Neuroptera	8.2 (a)	-	-

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Neuroptera	Sisyridae	8.2 (a)	Predator (b)	Climber (a)
Odonata	Aeshnidae	5.7 (a)	Predator (b)	Climber, Clinger (a)
Odonata	Anisoptera	4.7 (a)	Predator (c)	-
Odonata	Calopterygidae	6.1 (a)	Predator (b)	Climber, Clinger (a)
Odonata	Coenagrionidae	8.1 (a)	Predator (b)	Climber, Sprawler (a)
Odonata	Cordulegastridae	2.9 (a)	Predator (b)	Burrower (a)
Odonata	Corduliidae	4.4 (a)	Predator (b)	Sprawler (a)
Odonata	Gomphidae	4 (a)	Predator (b)	Burrower (a)
Odonata	Lestidae	6.9 (a)	Predator (b)	Climber (a)
Odonata	Libellulidae	9.2 (a)	Predator (b)	Climber, Sprawler (a)
Odonata	Macromiidae	3 (a)	Predator (b)	-
Odonata	Odonata	5.6 (a)	-	-
Odonata	Zygoptera	7 (a)	-	-
Plecoptera	Capniidae	1.4 (a)	Shredder (b)	Climber, Sprawler (a)
Plecoptera	Chloroperlidae	0.7 (a)	Predator (b)	Clinger (a)
Plecoptera	Leuctridae	0.6 (a)	Shredder (b)	Sprawler (a)
Plecoptera	Nemouridae	1.9 (a)	Shredder (b)	Sprawler (a)
Plecoptera	Peltoperlidae	1.7 (a)	Shredder (b)	Clinger (a)
Plecoptera	Perlidae	1.8 (a)	Predator (b)	Clinger (a)
Plecoptera	Perlodidae	1.6 (a)	Predator (b)	Clinger (a)
Plecoptera	Plecoptera	1.6 (a)	-	-
Plecoptera	Pteronarcyidae	0.4 (a)	Shredder (b)	Clinger (a)
Plecoptera	Taeniopterygidae	2.6 (a)	Shredder (b)	Sprawler (a)
Trichoptera	Brachycentridae	1 (a)	Filterer (b)	Clinger (a)
Trichoptera	Glossosomatidae	0.6 (a)	Scraper (b)	Clinger (a)
Trichoptera	Helicopsychidae	2 (a)	Scraper (b)	Burrower (a)
Trichoptera	Hydropsychidae	2.7 (a)	Filterer (b)	Clinger (a)
Trichoptera	Hydroptilidae	4 (a)	Scraper (b)	Clinger (a)
Trichoptera	Lepidostomatidae	1 (a)	Shredder (b)	Climber (a)
Trichoptera	Leptoceridae	3.6 (a)	Shredder (b)	Sprawler, Swimmer (a)
Trichoptera	Limnephilidae	2.8 (a)	Shredder (b)	Sprawler (a)
Trichoptera	Molannidae	5.2 (a)	Scraper (b)	Sprawler (a)
Trichoptera	Odontoceridae	0 (a)	Scraper (b)	Sprawler (a)
Trichoptera	Philopotamidae	1.4 (a)	Filterer (b)	Clinger (a)
Trichoptera	Phryganeidae	4.5 (a)	Shredder (b)	Climber, Clinger (a)
Trichoptera	Polycentropodidae	5.5 (a)	Predator (b)	Clinger (a)
Trichoptera	Psychomyiidae	2.5 (a)	Scraper (b)	Clinger (a)
Trichoptera	Rhyacophilidae	0.9 (a)	Predator (b)	Clinger (a)
Trichoptera	Sericostomatidae	1.9 (a)	Scraper (b)	Sprawler (a)
Trichoptera	Trichoptera	2.9 (a)	-	-
Trichoptera	Thremmatidae (*Neophylax*)	1.5 (a)	Scraper (b)	Clinger (a)

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	Pelecypoda	-	Filterer (a)	-
Unionoida	Unionidae	5 (a)	Filterer (c)	Burrower (a)
Veneroida	Corbicula	-	Filterer (b)	-
Veneroida	Dreissenidae	-	Filterer (b)	Clinger (a)
Veneroida	Pisidiidae	6.6 (a)	Filterer (c)	Burrower (a)
Veneroida	Sphaeriidae	6.6 (a)	Filterer (c)	-
Gastropoda	Gastropoda	6.3 (a)	Scraper (c)	Climber, Sprawler (a)
Mesogastropoda	Pomatiopsidae	-	Scraper (b)	-
Architaenioglossa	Viviparidae	4.3 (a)	Scraper (b)	Climber (a)
Basommatophora	Ancylidae	6.7 (a)	Scraper (b)	Climber, Clinger (a)
Basommatophora	Lymnaeidae	6.4 (a)	Scraper (b)	Climber (a)
Basommatophora	Physidae	8 (a)	Scraper (b)	Climber (a)
Basommatophora	Planorbidae	6.5 (a)	Scraper (b)	Climber (a)
Heterostropha	Valvatidae	8 (a)	Scraper (b)	-
Littorinimorpha	Bithyniidae	-	Scraper (b)	Clinger (a)
Neotaenioglossa	Hydrobiidae	6.9 (a)	Scraper (b)	Clinger (a)
Neotaenioglossa	Pleuroceridae	3.6 (a)	Scraper (b)	Climber (a)
-	Bryozoa	-	Collector (b)	-
-	Hydrozoa	-	Filterer	-
Nematoda	Nematoda	-	-	-
Nematomorpha	Nematomorpha	-	Predator (b)	-
Nemertea	Nemertea	-	Predator (e)	-
Platyhelminthes	Turbellaria	-	Collector (b)	-
Polychaeta	Polychaeta	-	-	-
Porifera	Porifera	-	Filterer (b)	-

a. Meta-analysis USGS traits database. MDEQ Procedure WRD-SWAS-022.
b. Derived by Association with other MDEQ traits.
c. Merritt et al., 2019.
d. McDermott and Roe, 1985.