APPENDIX E

FISHERIES

IBI Methodology

A METHODOLOGY FOR ASSESSING THE BIOLOGICAL INTEGRITY OF FISH COMMUNITIES OF THE CREDIT RIVER WATERSHED

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Introduction

The Index of Biotic Integrity (IBI) is the best known approach for compiling fish community data and interpreting it as an index of stream health. The IBI includes a range of geographically derived multimetric indices based on biological measures that can diagnose chemical, physical and biological impacts including cumulative effects at a watershed scale. It is used as a tool for making comparisons and for predictive or monitoring purposes in the "Adaptive Management" of water resources promoted by Credit Valley Conservation. Most research of the IBI is based on Assessing the Sustainability and Biological Integrity of Water Resources Using Fish Communities, a compilation of over 25 papers edited by Simon, Thomas P. (1999).

"The Index of Biotic Integrity incorporates fish assemblage attributes (called metrics) that reflect predominant anthropogenic effects on streams (Karr et al., 1986). Each IBI metric describes a particular taxonomic, trophic, reproductive, or tolerance feature of the assemblage (e.g. number of darter species, proportion of individuals as top carnivores, proportion of lithophilous spawners, proportion as members of tolerant species). An IBI score represents comparisons between metric values at a sample site and those expected under conditions least affected by anthropogenic disturbance. These expectations serve as a predetermined criteria that are used as standards of comparison for scoring individual IBI metrics; hereafter referred to as "metric criteria." If an observed metric value closely matches its criterion value, then the metric is assigned an arbitrary numeric score. If observed value differs moderately from its criterion, then the metric is assigned a lower score. If the observed value differs greatly from its criterion (a condition reflecting high anthropogenic disturbance), then the metric is assigned the lowest score (tyically 1). The IBI score for a site is simply the sum of these metric scores; a high score represents fish-assemblage attributes similar to those of a least disturbed assemblage, i.e., high biotic integrity." (Smogar and Angermeier 1999)

Metrics usually selected to measure fish community attributes include:

- Number of species and/or native species
- Number of trout and/or age classes
- Number of darter and sculpin species
- Number of sucker, sunfish species
- Number of minnow species
- Number of intolerant and/or tolerant species
- Number of sensitive species
- Number of benthic specialists and/or water column species
- Percent or number of simple lithophils

- Percent omnivores, insectivores, carnivores
- Percent large individuals by size
- Percent specialist and/or generalists species
- Percent diseased fish
- Total number of fish

Species relative abundance data that is commonly used in IBI makes it a “rapid bioassessment” tool. Biomass (weight) rather than numbers of fish (that range in size) is generally accepted as better measuring biological productivity and has been utilized in at least one referenced paper (Gammon 1976). In utilizing more quantitative biomass measurements for each species, a more accurate and statistically valid method of bioassessment is expected.

It is suggested that IBIs be regionally developed and tested for relatively homogeneous regions. However, in the Credit watershed, with three distinctly different physiographic regions including cold, cool and warmwater fish assemblages, would be better assessed with a more flexible approach (i.e. one index watershed wide).

Concerns with the traditional IBI is that its does not account for patterns of increasing species diversity with stream size, and actually employs number of species as a dominant metric. Healthy and pristine coldwater streams typically have only a few species. Species diversity will simply be assessed as number of species and need not be important in the proposed biomass index. What is considered important is the number or biomass of the most ecologically important species. It is anticpated that these “indicator” species will also increase with the total number of species downstream. Biomass is also expected to be dominated by “indicator” trout species in coldwater streams. The proposed method will also underestimate the biomass of tolerant/generalized species that typically increase overall species diversity and fish biomass in cold headwater streams.

It is, therefore, generally assumed higher fish productivity is a positive attribute (as reflected in DFO policy) and will decrease with habitat degradation. Since biomass productivity may be expected to increase in a downstream direction and with warmer water habitats it will have to be further tested and accounted for, during interpretation of results. This pattern, however, may be offset by the proportional loss of shoreline and riparian influences along widening river reaches downstream. Such cover has also been demonstrated to correlate with fish productivity. These habitats can be replaced with more productive wetland habitats and log debris deposits provided low gradient areas increase downstream. This does not seem to occur enough in the lower Credit that maintains a relatively moderate gradient and defined valley.

Habitat degradation of the lower river may also explain why preliminary analysis indicates no increase in biomass with stream size, yet the natural increase in species diversity is very apparent. The additional species are likely “minnows” that may have less effect on total biomass.

It can be noted that the application of this index is for monitoring changes over time such that spatial patterns in diversity and productivity with stream size may not be all that great of a concern. Where possible, however, it is useful to be able to hypothesize, statistically test and transfer predictions and cause and effect relationships from spatial to temporal patterns.

All in all it must be emphasized that the objective was to develop a simple, defensible index to combine the most basic ecological attributes of biomass productivity and the diversity of “indicator” species to assess the overall health of a site in space or time. The application of typical IBI metrics in scoring a fish community remains central to the index proposed for the Credit watershed. Selected metrics are described in terms of negative (-) and positive (+) values that are then tallied, following in Table 1.

Species Diversity

Number of species is reported as a separate index that should be interpreted with the expectation of greater diversities in stable warmwater habitats. However, native species are of particular value (+) for comparisons with “pristine” conditions. Rare or uncommon native species are of greatest concern (++) because losses may include genetic resources unique to watershed. “Preferred or managed” species that occupy a particular niche and are now self-sustaining such as brown trout might be considered as a positive (+), but populations (Pacific salmon) known still to be artificially hatched and stocked should be of no value. Even species known only to occasionally visit the lower Credit from their deep habitats in Lake Ontario may be discounted. Species native to Southern Ontario but not known to be endemic to parts of the Credit watershed originally may be considered as a negative (-) value including northern pike, sunfish and bass that escape from impoundments or manmade ponds. This would include stocked trout, particularly where brown and rainbow are found above the natural barrier of the Niagara escarpment. Exotic pest species such as sea lamprey and carp can negatively (-) impact ecosystems.

Trophic Level

What a fish eats best determines where it is in the “food chain” and how sensitive it could be to other biological changes. Top predators are especially valuable (++) as they require larger territories or food supplies and are most sensitive to other processes such as the “bioaccumulation” of toxins. Some smaller fish may not consume other fish but still aggressively feed on insects. These insectivores (+) are closely related to the health of their food supplies, bugs, which are also sampled as biological indicators. Omnivorous fish (-) that can feed on a variety of plant and animal matter and even decomposing, detritus are often able to flourish as food sources become limited for other species. Herbivores have also been associated with excess nutrient inputs. Fish anatomy including mouth position and teeth, length ratio of digestive tracts, feeding behaviour and analysis of stomach contents are used to classify species into feeding guilds. The unique filter feeding strategies of larval lampreys or other specialized species may be assigned more of a neutral value.

Simple Lithophilic Spawners

These species are known to be dependent on gravels to conceal and incubate eggs relatively free of sediment. Excess sediments literally cause oxygen suffocation and is associated with other water quality and habitat impacts. Most species depend solely on a clean stream environment (+) and never care for the nest or young as do sunfish and bass (-) that can fan sediment away. Species such as trout actually prepare more specific nests and bury the eggs. Siltation can still be a problem for these species that are given a neutral value because of this extra precaution.

Tolerance Ratings

Generally species are chosen as key indicator species when they disappear from “polluted” waters. Brook trout are considered as the best indicator species of the Credit (++) but other trout, sculpins and darters are more widespread (+). Smallmouth and stonecats are also good indicator species in warmer reaches along with some of the many minnow species (+). A number of species that are apparently limited in their distribution but appear to be tolerant of some pollution, such as pike, sunfish, rock bass are not rated. Even longnose dace survive in urban streams provided there are high velocity riffles.

Other species such as carp and bulhead catfish (--) are known to even flourish where no other fish can. Naturally stressed environments of intermittent streams as well as highly altered streams are often dominated by blacknose dace, creek chub, brook stickleback and bluntnose minnows that are also considered tolerant (-).These species are usually tolerant of low flows and oxygen, turbidity and high temperature fluctuations. Tolerance ratings are meant to be more reflective of water quality rather than of physical habitats discussed next.

Habitat Specialists / Generalists

Many authors have described species according to their physiological abilities to specifically adapt to restricted niches or to survive in a variety of different conditions. Generalists or "opportunists" are nonselective in their habits (-) and range over more than a single trophic level. Creek chub and blacknose dace are often most cited in the literature as an adaptive generalist to degraded habitats or as a colonizing species into new or temporary habitats. In contrast some species are very unique in their anatomy and behaviour that they have evolved for the exploitation of specific habitats (+) such as cold groundwater areas for brook trout or high velocity rock riffles of the longnose dace. These species also tend to produce fewer offspring and sexually mature later (e.g. 3yrs for redside dace) than generalists species that may even spawn more than once a year (e.g. fathead minnow) Any changes to such specific requirements are usually reflected in the simplest form of presence/absence data. A few species were not classified as a generalist nor specialist.

Table 1. IBI Metric Scores for Fishes of the Credit Watershed.

Species	Index of Biotic Integrity Total Metrics Score	Rare/Uncommon Native ++ Native/Endemic or fully Naturalized + Stocked 0 Exotic/Pest/ Lentic escapees -	Omnivore/ Detrivore – Filter/Herbe-vore 0 Insectivore+ Carnivore++	Simple Litho-Philic Spawner + Other silt tolerant breeders-	Intolerant Species + Tolerant Species -	Specilaist + (benthic, mid-water, coldwater, bogs and late maturing) Generalist Species –
American brook lamprey	+3	+			+	+
Sea lamprey	+1	-			+	+
Coho salmon	+3	-	++		+	+
Chinook salmon	+3	-	++		+	+
Rainbow trout	+4		++		+	+
Atlantic salmon	+4		++		+	+
Brown trout	+5	+	++		+	+
Brook trout	+6	+	++		++	+
Northern pike	+2		++	-		+
Central mudminnow	+1	+	+	-	-	+
White sucker	+1	+	-	+	-	+
Northern hog sucker	+5	+	+	+	+	+
Goldfish	-6	-	-	-	--	-
Northern redbelly dace	+3	+			+	+
Finescale dace	+3	+			+	+
Redside dace	+7	++	+	+	++	+
Carp	-6	-	-	-	--	-
Brassy minnow	+1	+		-		+
River chub	+6	++	+	+	+	+
Golden shiner	-1	+		-	-	
Emerald shiner	0	+		-		
Common shiner	+1	+	+			-
Spottail shiner	+4	+	+		+	+
Rosyface shiner	+5	+	+	+	+	+
Spotfin shiner	0	+	-	-		+
Bluntnose minnow	-4	+	-	-	--	-
Fathead minnow	-4	+	-	-	--	-
Blacknose dace	+1	+	+	+	-	-
Longnose dace	+4	+	+	+		+
Creek chub	0	+	+		-	-
Pearl dace	+2	+	+	-		+
Brown bullhead	-3	+		-	--	-
Stonecat	+3	+	+	-	+	+
Brook stickleback	+1	+	+	-	-	+
Rock bass	+3	+	++	-		+
Pumpkinseed sunfish	0	+	+	-		-
Smallmouth bass	+4	+	++	-	+	+

Largemouth bass	+1	-	++	-		+
Black crappie	+1	-	++	-		+
Yellow perch	+1	-	++	-		+
Rainbow darter	+5	+	+	+	+	+
Iowa darter	+3	+	+	-	+	+
Fantail darter	+4	+	+	+		+
Johnny darter	+3	+	+	-		+
Mottled sculpin	+4	+	+	-	+	++
Slimy sculpin	+4	+	+	-	+	++
Hornyhead chub	+2	++	-	+		
Troutperch	+5	+	+	+	+	+
Alewife	-1	-	+	+		

IBI Species Biomass Factors

Total scores ranging from –6 to +7 (in one case) are then reduced to three categories and assigned an "IBI Species Biomass Factor as follows:

-6 to +1= 1 X factor (i.e. species providing simple biomass conversion function)
+2 to +3= 2 X factor (i.e. species with several or dominant ecological roles)
+4 to +7= 3 X factor (i.e. most valuable "indicator species" re: biological integrity)

These categories were chosen such that all "negatively" scoring species are equally treated as providing the most basic ecological function of converting energy and nutrients to biomass (as measured). Including scores <1 in this category and assigning scores >+3, a 3X biomass factor resulted in a reasonably even distribution of species in the Credit to each of the three categories summarized in Table 2. The distribution of larger vs. smaller and common vs. uncommon species also appears equitable. It can also be noted that definitive coldwater species (trout and sculpin) score high which may reflect the larger number of functions they may perform to counteract the natural tendancy of coldwater habitats to be less diverse and productive.

The reduction of scores to three factor classes is not as sensitive to some disagreement among biologists when assigning a whole range of negative and positive ecological values to each species.

Table 2. Summary of Fish Species by IBI Biomass Factors

IBI Factor: 3X	2X	1X
"Larger fish"		
Rainbow trout	American brook lamprey	*Sea lamprey*
Brown trout	*Coho salmon*	White sucker
Atlantic salmon	*Chinook salmon*	Pumpkinseed sunfish
Brook trout	*Northern pike*	Largemouth bass
Northern hog sucker	Creek chub	*Black crappie*
Smallmouth bass	Stonecat	*Yellow perch*
	Rock bass	Brown bullhead
		Carp
		Alewife
"Minnows"		
Redside dace	Northern redbelly dace	Common shiner
River chub	*Finescale dace*	Bluntnose minnow
Spottail shiner	Central mudminnow	*Spotfin shiner*
Rosyface shiner	*Pearl dace*	Fathead minnow
Longnose dace	*Hornyhead Chub*	Blacknose dace
Rainbow darter		*Emerald shiner*
Iowa darter		*Golden shiner*
Fantail darter		*Brassy minnow*
Johnny darter		Brook stickleback
Mottled sculpin		Goldfish
Troutperch		
Slimy sculpin		

*common and *uncommon* species for the Credit noted

1 X factor (i.e. species providing simple biomass conversion function)
2 X factor (i.e. species with several or dominant ecological roles)
3 X factor (i.e. most valuable "indicator species" re: biological integrity)

Calculation of a Station Health Index

At each sampling station on the Credit the biomass/square meter of each species is now multiplied by its corresponding IBI Species Biomass Factor. All species are then totaled to provide a Fish Health Index of Biotic Integrity for comparisons over time at each station and across the watershed. This single index combines the measures of fish biomass with weighted values related to the diversity of species found and their ecological values. One can still refer to and compare the total number of species and total fish biomass/square meter sampled at each station. Other patterns requiring further hypotheses testing and analysis can be visualized with bar graphs depicting each species biomass with each sampling season.

Descriptive Classifications

After an assessment of the range of values for the Fish Health Index of Biotic Integrity was generated across the watershed a further descriptive classification was assigned:

- >15 Excellent "Health"
- 10-15 Good
- 5-10 Fair
- 3-5 Degraded
- 0-2 Severely degraded

Recommended IBI Statistical Tests

- IBI vs. number of species and total biomass.
- IBI vs. invertebrate indices
- IBI vs. selected water quality parameters (DO, phosphorous, toxins, chlorides, bacteria)
- IBI coldwater vs. warmwater sites (or fish management zones as per Fisheries Management Plan)
- IBI vs. watershed area, width, depth and/or volume
- IBI vs. baseflow and flood peaks / unit watershed area
- IBI vs erosion or similar geomorphic stability index
- IBI vs. substrate size and embeddedness or % fines
- IBI vs. % watershed urban and/or other ELC land use designations
- IBI vs. instream and/or riparian cover
- IBI vs. "impacted" and "natural" stations considering impacts other than urban area (e.g. # sewage, stormwater or other point sources, water withdrawls, mining, intensive agricultural, dams, length of headwater loss or channelization)
- Individual metrics and/or species could also be tested for different physiographic regions and stream size and how much of a correlation with the IBI it alone can account for.

Preliminary Analysis of Results

Figure 1. Ranking of Stations by IBI score and with biomass density and number of species.

Table 3. Approximation of Stations as warm vs. coldwater, large vs. small size and habitat conditions as natural vs. impacted.

- Species diversity is highest in all main river stations (regardless of habitat conditions) but the IBI is not related to stream size. Likewise there does not seem to be a correlation between biomass density and stream size.
- Species diversity does not appear to be greater in warm vs. coldwater streams.
- Stations first perceived to have the most natural habitat conditions are not necessarily reflected by their IBI. Stations perceived to have "impacted" habitat conditions appear to have a lower IBI.
- Intermittent streams tend to have a lower IBI.
- There is a slight tendency for cold water stations to have a higher IBI and warmwater stations to be less healthy.
- There is a correlation between total biomass density and the derived IBI weighted species biomass densities, as expected but with sufficient variation to suggest the value of using weighted "indicator" species (rather than # of species).
- No correlation is apparent between species diversity and the IBI.
- Species diversity may have a weak correlation with increasing biomass (using more "natural" stations).
- "Impacted" sites correlate better with the IBI than species diversity.

Spatial correlations found to be significant will be further investigated for cause and effect relationships over time at various stations. The IBI based Index proposed for the Credit will consider these tests to better interpret results or to revise the index along with peer reviews and increased knowledge of individual species.

REFERENCES

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Table 3. Approximation of Stations as warm vs. coldwater, large vs. small size and habitat conditions as natural vs. impacted.

Station Name	large	small	cold	warm	natural	impacted
Mill Creek u/s Dawson Rd		X		X		*
Mullet Creek u/s Erin Centre Blvd				X		X
Caledon Creek trib d/s 15th SR		X		X		
Credit River u/s Old Derry Rd	X			X		
Escarpment trib d/s Winston Churchill Blvd		X			X	*
Rogers Creek d/s Winston Churchill		X				*
Black Creek u/s 8th L			X		X	
Credit River @ Terra Cotta Inn	X				X	
Caledon Creek trib d/s McCorm Rd		X		X		X*
MillCreek @ Amanda St		X				X*
Credit River @ Port Credit marshes	X			X		X
Silver Creek d/s Wildwood					X	
West Credit River @ Belfountain			X		X	
Levi Creek u/s Derry Rd				X		X
Huttonville Creek d/s Queen St		X				
West Credit River @ 8th L						
Credit River d/s Forks	X		X		X	
West Credit u/s 10th L			X			
Shaws Creek u/s Hwy 136						
Shaws Creek d/s Mississauga Rd					X	
Black Creek d/s 3rd L			X			
Credit River @ Glen Williams	X				X	
East Credit River trib u/s Grange SR		X	X		X	
Caledon Creek u/s Credit River confluence		X	X			
Fletchers Creek u/s 2cd L				X		X
Credit River @ Ferndale	X				X	
Credit River @ Mill St Cheltenham	X				X	
Silver Creek u/s Hwy 7 Norval						
Huttonville creek u/s Queen St		X		X		*
Lower Monora Creek u/s 1st L			X			
Credit River u/s south Hwy 10 crossing	X		X			
Shaws Creek trib d/s Town Line			X		X	

* denotes intermittency that may represent a natural constraint similar to other impacts