Chapter 4

Invertebrate Community Indicators

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Introduction

Great Lakes coastal wetlands are subject to multiple anthropogenic disturbances. They are categorized into geomorphologic classes reflecting their location in the landscape and exposure to waves, storm surges and lake level changes (Albert and Minc 2001). The anthropogenic disturbances to Great Lakes coastal wetlands are superimposed on natural stress resulting from a highly variable hydrologic regime (Burton et al. 1999, 2002; Keough et al. 1999).

Fringing wetlands were the focus of the invertebrate studies reported here. They make up more than one-quarter of the $2.17x10^5$ hectares of Great Lakes coastal wetlands. They include protected and open embayment wetlands which form along bays and coves leeward of islands or peninsulas. They occur along all five Great Lakes, and are especially common on the southern and northern shores of lakes Michigan and Huron and in the St. Mary's river-island complex. The location of the shoreline with respect to long-shore currents and wind fetch determines the type of wetland found along the shoreline (Burton et al. 2002). The greater the effective fetch (e.g., Burton et al. 2004), the more the wetland is exposed to waves and storm surges until a threshold is reached where wetlands no longer persist. The separation of variation due to anthropogenic disturbance from variation due to natural stressors related to water level changes and to biogeographic and ecoregional differences (Brazner et al. 2007) is central to predicting community composition and in turn, developing indices of biotic integrity (IBI) for these systems.

The development of indicators of ecosystem health for the Great Lakes was recognized as a major need at the State of the Lakes Ecosystem Conference (SOLEC) in 1998 in Buffalo, N. Y., and progress in developing indicators was the emphasis of SOLEC following that time. Among the indicators listed as high priority needs at SOLEC 1998 were indices of biotic integrity (IBIs) for coastal wetlands based on fish, plants and invertebrates.

Several initiatives have been undertaken to develop IBIs for specific aquatic guilds of invertebrates in wetlands of single Great Lakes, but their applicability to the entire basin has not been tested. Krieger (1992), Thoma et al. (1999), and de Szalay et al. (2004) evaluated various sampling methods for assessing zoobenthos at Lake Erie drowned rivermouths. These studies were somewhat limited because few, if any, undegraded reference wetlands remain in Lake Erie (de Szalay et al. 2004). Wilcox et al. (2002) attempted to develop wetland IBIs for the upper Great Lakes using fish, macrophytes, and invertebrates entering activity traps. While they found attributes that showed promise, they concluded that natural water level changes were likely to alter communities and invalidate metrics. Burton et al. (1999) developed a preliminary macroinvertebrate-based bioassessment procedure for coastal wetlands of Lake Huron. This system could be used across wide ranges of lake levels since it included invertebrate metrics for as many as four deep- and shallow-water plant zones, using a scoring system based on the number of inundated zones present. That procedure has since been tested and modified (Uzarski et al. 2004). The methods presented in Uzarski et al. (2004) are recommended herein.

While Great Lakes-wide studies of aquatic macrophytes indicate that similar geomorphic wetland types support very different plant assemblages in geographically distinct ecoregions (Minc 1997, Minc and Albert 1998, Chow-Fraser and Albert 1998, Albert and Minc 2001), several plant zones are common to many of these systems. In preliminary invertebrate-based IBI development studies, Burton et al. (1999) used dip nets to collect invertebrates from four plant zones that characteristically develop in inundated shorelines of fringing lacustrine wetlands during high water years. The invertebrate metrics from each of those zones were used in the IBI of Uzarski et al. (2004), where it was argued that developing separate metrics for each wetland plant zone across a water level gradient from wet meadow to the zone of deep-water emergents could compensate for absence of higher elevation zones (e.g., wet meadow) during low lake level years by placing more emphasis on metrics from zones that remained inundated. With the exception of Lake Ontario, which is regulated, lake levels fell sharply between 1998 and 2002, permitting Uzarski et al. (2004) to test this assumption, and the IBI performed well. Based on this verification, we recommend the collection procedures and metrics described by Uzarski et al. (2004) as the primary means of assessing macroinvertebrate community health in Great Lakes coastal wetlands.

Other sampling methods and metrics have been proposed and/or implemented that pertain to other classes of wetlands or areas that have may have lost their vegetative cover. Although still in development or under refinement, these approaches can be considered where the recommended Uzarski et al. (2004) IBI procedure is unsuitable (see limitations (below).

Materials and Methods

Macroinvertebrates sampling

Macroinvertebrate samples should be collected with standard 0.5-mm mesh, D-frame dip nets from late July through August. July-August is the interval during which emergent plant communities generally achieve maximum annual biomass and are mature, in flower and hence easier to identify than earlier in the season. Late instars of most aquatic insects are present in Great Lakes coastal wetlands from early July until mid-August.

Three replicate dip net samples should be collected in each plant zone that is inundated to provide a measure of variance associated with sampling. Each replicate should be collected from a random/haphazardly chosen location ideally at least 20 meters from any other station. Each dip net replicate collection should be a composite of sweeps taken at the surface, mid-depth and just above the sediments while brushing vegetation with the base of the net to incorporate all microhabitat at a given replicate location.

Net contents should be emptied into white pans that are approximately 25 cm wide, 30 cm long and 5 cm deep (size of the pan can vary). Drawing a grid of 5x5 cm squares on the inside bottom of the pan helps collectors systematically examine the contents. One hundred fifty macroinvertebrates should be collected using forceps and/or a pipette, working systematically from one end of the pan to the other, attempting to pick all specimens from each grid before moving on to the next. Specimens should be immediately placed into labeled (date, site, plant zone, rep number) 30-mL or larger vials containing 70% ethanol. Special efforts should be made to ensure that smaller, cryptic and/or sessile organisms (those resting on or attached to vegetation or debris) are not overlooked. Multiple sweep net collections may be necessary to achieve the 150-specimen count.

For the majority of cases, obtaining 150 organisms per replicate is a relatively easy task. However, in some cases invertebrates are extremely scarce. Therefore, it is suggested to limit picking-time for each replicate; the following is a means of semi-quantification or catch per unit effort. Individual replicates should be picked for one-half-person-hour (i.e. two people for 15 minutes). Organisms should then be tallied; if 150 organisms have not been obtained, then picking should continue to the next multiple of 50. Therefore, each replicate sample should contain 50, 100, or 150 organisms. The number of organisms remaining in each of the picked grids of the pan should nearly always be exhausted to the point where finding just a few more organisms will require a substantial effort. If this occurs for the entire pan before the target number of specimens is reached, then timing should stop while dip nets are used to refill the pan.

In the laboratory, specimens should be identified to lowest operational taxonomic unit -- usually genus or species for most insects, crustaceans and gastropods – and then tallied. Identifications should be made with the aid of a dissecting microscope capable of at least 40x magnification. Difficult-to-identify insect taxa such as *Chironomidae* should be identified to tribe or family, and some other invertebrate groups including *Oligochaeta, Hirudinea, Turbellaria, Hydracarina* and *Sphaeriidae* should be identified to family level or, where this is not possible, to order. Taxonomic keys such as those of Thorp and Covich (1991), or Merritt and Cummins (1996) should be used for identification.

Accuracy should be confirmed by sending voucher specimens to expert taxonomists. Sample vials may occasionally contain small parasitic invertebrates that have been released from their host upon submersion in ethanol. Such organisms never occur by themselves in nature, and consequently they have not been considered in the creation of invertebrate IBIs. Therefore, they should not be included in taxonomic lists used for richness counts or metric calculations for the sample.

Deviations from Protocol

The sampling protocols of Burton et al. (1999) and Uzarski et al. (2004) were developed for sampling macroinvertebrates, and field crews were instructed to only pick macroinvertebrates. However, microinvertebrates (typically <1 mm long) such as *Copepoda* and *Cladocera* were commonly included in picked samples (D. Uzarski, personal communication). These microinvertebrates were identified to order level and included in the databases from which the IBIs of Burton et al. (1999) and Uzarski et al. (2004) were derived. Inclusion of such specimens by the original sampling crews suggests that this might also occur when others use the IBI, but it is not recommended. Nevertheless, to ensure that the IBI was robust to this common error, Uzarski et al. (2004) used those data in calculations of metrics such as percent Crustacea+Mollusca and the total richness and diversity metrics. Inclusion of the microinvertebrates had little effect on the IBI (D. Uzarski, unpublished data).

Limitations and Applicability of the IBI

Sensitivity to Interannual Fluctuation in Water Levels

Wilcox et al. (2002) argued that the IBI approach would not work for coastal wetlands because natural water level fluctuations of the Great Lakes would likely alter communities and invalidate metrics. However, by sampling only defined and inundated vegetation zones, this protocol removes enough variation associated with water level fluctuation to maintain metric consistency from year to year. During development, the IBI of Uzarski et al. (2004) was tested during times of above average annual lake levels and during times nearing record lows.

Although other collection methods may yield additional taxa and individuals, the purpose of the Consortium field methodology and data analysis is to give an indication of invertebrate community condition – not a full taxonomic inventory. Thus, consideration of the benefit using more exhaustive sampling protocols should be based on the potential diagnostic value of alternative or additional collecting methods.

Plant Zone Applicability

This IBI was developed specifically for only three plant zones commonly found in fringing Great Lakes coastal wetlands. It performed well in lakes Huron and Michigan for the Scirpus (Schoenoplectus) and wet meadow plant zones (Uzarski et al. 2004). However, Uzarski et al. (2004) recommended that the Typha IBI not be used without further modification. The Typha IBI has since been adapted for use in Lake Ontario (see below).

Many wetland types, such as drowned river mouth wetlands and dune and swale complexes, can contain very different plant and animal communities. Therefore, the Burton et al. (1999) and Uzarski et al. (2004) IBI scores will not apply. However, these data should still be collected using the standard protocol above so that IBIs specific to these systems can be developed (see below).

Modifications made for Lake Ontario

Coastal wetland macroinvertebrates have been sampled as part of the Durham Region Coastal Wetland Monitoring Project (DRCWMP) for five years, using methodology consistent with Uzarski et al. (2004) except for the vegetation zones sampled.

Sweep net data collected from Typha zones in Lake Ontario did not yield suitable metrics for Burton et al. (1999) and Uzarski et al. (2004). However, the Typha zone is the only vegetation zone consistently found within Lake Ontario coastal wetlands. Inner and outer Scirpus zones are not common, and meadow marsh (when present) is seldom inundated in July and August. In support of the Consortium process, the DRCWMP developed a separate Lake Ontario-based Typha community aquatic macroinvertebrate IBI (Environment Canada and the Central Lake Ontario Conservation Authority (EC and CLOCA) 2004a, EC and CLOCA 2004b).

A modified IBI was developed using data collected from a suite of Durham Region and other Lake Ontario sites that represented a range in disturbances and hydrogeomorphic types. Data were collected according to Uzarski et al. (2004) and assessed for suitability to report on Lake Ontario Typha zones using metrics identified in Burton et al. (1999). Environment Canada has successfully applied the DRCWMP IBI to report on the condition of coastal wetlands across Lake Ontario and to contribute to the Remedial Action Plan for the Bay of Quinte Area of Concern (EC-Canadian Wildlife Service 2007).

This IBI developed by EC and CLOCA (2004) is recommended for assessment of Lake Ontario coastal wetlands. However, because it is lake-specific, additional work will be required to compare and calibrate the results of this IBI to allow them to be interpreted in a Great Lakes basin-wide context.

Alternative Methods and Associated Research Needs

The Great Lakes cover a huge area, traversing a broad latitudinal gradient. Consequently, geological and biogeographic variation has major influences on the physical structure and ecological character of the wetlands (see Landscape chapter). These differences are reflected strongly in the composition of aquatic invertebrate communities. A detailed analysis of the sources of variation affecting aquatic invertebrate indicators (Brazner et al. 2007a) found that zoobenthic community composition strongly reflects local vegetation conditions, which varies among lakes and ecoregions. Anthropogenic stress accounted for only 20% or less of the variation in 10 invertebrate metrics assessed across five wetland hydrogeomorphic types, five Great Lakes, and six ecoregions (Brazner et al. 2007a,b). Although meaningful stress-response trends could be determined, the strength and direction of responses varied complexly by wetland type within each lake (Brazner et al. 2007a). Similar results have been reported by others (Brady et al. 2006, Kostuk and Chow Fraser 2006). This makes it unlikely that a single invertebrate IBI will be developed that can be used for all wetlands in the Great Lakes. The IBI of Uzarski et al. (2004), which are calibrated to dominant emergent vegetation types, are currently the most broadly applicable across the Great Lakes. However, even this IBI needs modification to account for regional differences (e.g., Lake Ontario Typha wetlands - see below).

Table 4-1. Summary of the status of invertebrate assessment metrics developed or in development for Great Lakes coastal wetlands by some key research groups. (Definitions provided on next page.)

	RESEARCH GROUP				
	Consortium	REMAP	GLEI	Chow Fraser	OH EPA
Wetland Type					
Fringing wetlands	All (vegetation)		*S,M,H,E,O*	*H,O*	E
Drowned river mouth		M,C,E	*S,M,H,E,O*	*H,O,E*	E
Barrier protected			*S,M,H,E,O*	*H,O*	E
Unvegetated/High energy			*S,M,H,E,O*		
Sampling Type					
D-net	X	X	X		*x*
Activity trap		X		X	X
Core sampling			X		
Grab sampling			X		
Artificial substrate	*x*				*x*
Light trap	*x*				*x*
Wetland condition criterion					
Best professional judgment	X		x		X
Scores of other IBIs		X (fish, plant)		X water qual.)	
Land cover (Ag/urban)	X	X	X		
Water chemistry	X	X	X	X	X
Multiple GIS-based stresses			X		
Sites stratified along gradient(s)	X		X	X	X
Sites randomly selected		X			
IBI cross-validated	Yes	No	*Yes*	No	No
Covariates					
Date			X		
Lake	X	X	X	X	
Ecoregion			X	X	
Wetland type	X	X	X	X	X
Vegetation type	X		X		
Adjacent vegetation/Land use			X	X	
Substrate texture			X		
Substrate org. content			X		
Water depth			X		
pH, DO, Conductivity			X	X	
Turbidity			X	X	
Nutrient concentration (P,N)				X	
Chl *a*				X	
Weather conditions			X		

Research Group designations:
Consortium - Great Lakes Coastal Wetlands Consortium - Burton & Uzarski (2003); de Szalay et al. (2004), Uzarski et al. (2004), EC & COCA (2003);
REMAP – Regional Environmental Monitoring and Assessment Program - Simon & Stewart (2006)
GLEI – Great Lakes Environmental Indicators Project - Brady et al. (2006), Brazner et al. (2007a,b), Ciborowski et al. (2007)
Chow Fraser - Kostuk & Chow Fraser (2006)
OH EPA - Ohio EPA (1998),Mack (2003), Ohio EPA (2007)

Letters listed for each wetland type summarize the Great Lake for which a proposed (italic face) or existing (normal face) metric pertains. Superior (S), Michigan (M), Huron (H), St. Clair (C), Erie (E), Ontario (O).

Sampling types assessed by each research group are indicated by a letter X. Samples considered that were assessed and not recommended are indicated with a small italic *x;* those for which an IBI has been proposed or is in development are indicated with a large X.

Condition Criterion represents the means by which the degree of anthropogenic disturbance exists at a sampled site and was assessed during IBI development by each group. Use of a criterion is indicated for a group with a large X. Criteria evaluated and deemed unsuitable are indicated with a small italic *x.*
Sites Stratified: Site selection was based on predefining disturbance gradients and selecting wetlands to reflect the different degrees and classes of disturbance.
Sites Randomly Selected: Site selection was random or stratified-random, but selection was based on criteria other than predefined disturbance gradients.
IBI Cross-validated: Were the sites assessed for IBI effectiveness different from those used to develop the IBI?

Covariates represent variables measured for a sample site that can help determine the specific metric to be used among several alternative formulations developed by a research group.

Lake-specific invertebrate IBIs have been proposed for particular wetland classes by several consortia and individual workers (Table 4-1). Their metrics may be suitable for monitoring once they have been adequately evaluated across quantitatively determined stressor gradients and cross-validated with independent data. Other invertebrate IBIs currently in development (Kostuk and Chow Fraser 2006, Ciborowski et al. 2007) may ultimately apply within ecoregions that cross individual Great Lakes boundaries. Because aquatic invertebrates are small and relatively immobile, communities also vary greatly along relatively fine-grained environmental gradients. Therefore, complementary physical and chemical environmental data should be collected at the same time as the invertebrate samples to help categorize the type of invertebrate reference community that should be expected at the sampling area. The IBIs proposed by different workers can use different classification variables to guide selection of the most appropriate IBI metric. Table 4-1 summarizes the covariates deemed important by each of several groups proposing invertebrate metrics for Great Lakes coastal wetlands, as well as the associated invertebrate collection methods on which the metrics are based.

IBIs Proposed for Drowned River Mouth Wetlands from REMAP Assessments

In 1998, a coastal wetland regional monitoring and assessment program (REMAP) was designed to establish reference conditions and undertake an inventory and classification of Laurentian Great Lakes coastal wetlands (Simon and Stewart 2006). Wetlands in Lake Michigan were sampled during pilot studies in 1999, and other lakes were sampled in 2000 using a stratified-randomly selected subset of all inventoried wetlands (Moffett et al. 2006). Macroinvertebrate comparative sampling involved using both activity trap (Wilcox et al. 1999) and sweep net sampling (Burton et al. 1999) protocols (Stewart and Simon 2006). Pairs of activity traps were placed in each dominant habitat type for 24 hours. Up to 20 D-net sweep samples werre collected within the 500-m sampling zones of the same major habitat types as identified by Burton et al. (1999) and preserved for sorting and identification in the laboratory.

Although wetlands selected on the basis of stratified-random sampling provide an unbiased indication of average condition, such sampling is unlikely to include wetlands that reflect the full range or diversity of anthropogenic stress (ranging from undisturbed to heavily degraded). Consequently, attempts to derive IBIs from such a dataset can best be regarded as provisional and to require validation before their reliability and effectiveness can be assessed. Nevertheless, an activity trap-based IBI has been proposed for macroinvertebrates collected in activity traps (Stewart et al. 2006a). Macroinvertebrate IBIs have been proposed based on D-net sampling in drowned river mouths of lakes Michigan (Stewart et al. 2006b), St. Clair (Stewart et al. 2006c), and Erie (Stewart et al. 2006d). Variations in ecological conditions among wetlands in these studies was based on best professional judgment and on patterns suggested by simultaneously derived IBIs for fishes and aquatic plants.

Activity Trap Sampling and Comparisons with Dip net ("D-net) Sampling:

Activity traps, which consist of a jar or cylinder into which one or two inverted funnels are nested, have been evaluated and used by several investigators (Murkin et al. (1983), Wilcox et al. (1999; 2002), de Szalay et al. (2004), Kurtash and Chow Fraser (2004), Stewart and Simon (2006), Ohio EPA (2007)). Because the traps tend to collect different relative abundances of aquatic invertebrates than sweep nets or other samplers, metrics developed for sweep samples are probably not amenable to use with trap-caught data. Cross-validation of the reliability of sweep net vs. activity trap data when used with a complementary IBI is a significant research need.

De Szalay et al. (2004) compared the catches of 24-hour activity trap samples with samples collected by live-picking up to 150 sweep-netted aquatic invertebrates in the field or with equivalent samples that were preserved and sorted and enumerated in the laboratory. They found that activity traps collected only about half the total number of taxa as the sweep net procedures.

In contrast, Ohio EPA (2007) found that banks of 10 activity traps collected as many or more taxa than sweep net samples. In inland Ohio wetlands, funnel traps consistently collected an average of 10 more macroinvertebrate taxa than qualitative sampling using dip nets (Mack 2003). Mack (2003) also reported that qualitative dipnet sampling of all available habitats in a wetland collected somewhat more Mollusca and Chironomidae taxa than did funnel traps. Consequently, Ohio EPA (2007) developed a density-based invertebrate community index (DICI) on those data. Stewart and Simon (2006) found that subsamples of 300 invertebrates collected from composite D-net sweep samples were richer than subsamples of 300 invertebrates taken from composite activity trap samples.

De Szalay et al. (2004) found that mean taxa richness of live-picked samples was not significantly different than richness of laboratory-processed samples, although there was a trend for more taxa to be found in lab-processed samples. Lab-processed samples contained 5-15 times as many specimens and required 3 times as long to process as did field-picked samples. These assessments were limited in that no composition-specific comparisons were made. Nor were certain taxa identified below nominal levels (Oligochaeta, Chironomidae, Hydracarina). The major drawback associated with laboratory sorting is the investment of time

Grab and core sampling:

Grab and core samples (including stove-pipe samples) have the desirable property of quantitatively collecting benthic invertebrates from a fixed area. Furthermore, some of these samplers can be deployed from a boat to sample at depths greater than can be reached by wading. Grabs and cores become less effective than sweep netting in vegetated areas because coarse debris impedes the closing mechanism and the ability of the sampler to penetrate the substrate. Thoma (Ohio EPA 1998) developed a nearshore benthic IBI for organisms found in Ponar grab samples collected from Ohio drowned rivermouths. A multivariate zoobenthic index based on Ponar grabs is also being developed by GLEI researchers (Ciborowski et al. in prep).

Artificial substrates:

Benoit et al. (1997) and Thoma (Ohio EPA 1998) assessed artificial substrates to assess zoobenthic colonization in coastal wetlands. Thoma studied colonization of Hester-Dendy multiplate samplers tied to concrete blocks in drowned river mouths (which he termed 'lacustuaries') for 6-week periods. Lewis et al. (2001) also used Hester-Dendy samplers to evaluate the feasibility of invertebrate IBI development for New England lakes. Although the technique was suitable for development of 12 proposed metrics by Lewis et al. (2001), Mack (2003) concluded that "Hester-Dendy artificial substrate samplers were ineffective for sampling most wetland macroinvertebrates, except oligochaetes, Chironomidae, and Mollusca".

Benoit et al. (1997) constructed artificial substrates from ceramic tile, to which they glued commercially made "aquarium" plants designed to mimic Myriophyllum. They concluded that tiles left in place for 8 days collected a representative suite of macroinvertebrates whose density became stable over this time. Leonhardt (2003) found that such tiles were as effective as D-net sampling in assessing the macroinvertebrate communities of constructed wetlands but required only a fraction of the processing time. To our knowledge, these types of samplers have not been used in Great Lakes coastal wetlands.

Discussion

Reliability of the Invertebrate IBI in a Basinwide Context: Summary of Invertebrate Site Scores Plotted Along the GLEI "Sum-Rel" Gradient

An overall assessment of human land-use disturbance in the watersheds associated with coastal wetland sites sampled by all Consortium groups across the Great Lakes basin was calculated as a sum of the relativized measures of several different classes of disturbance, "Sum-Rel" (Figure 4-1). The Sum-Rel scores were derived from data provided by the Great Lakes Environmental Indicators (GLEI) project Danz et al. 2005) using a method outlined by Host et al. (2005). The method is outlined in detail in the Landscape chapter of this document. The boundaries of each second-order or higher watershed in the Great Lakes was delineated using a GIS approach (Hollenhorst et al. 2007). The relative amount of each of three classes of human disturbance was then determined for each watershed, scaled from 0.0 (least disturbed watershed in the Great Lakes basin) to 1.0 (most disturbed watershed). The Sum-Rel score for a wetland site was the sum of the 3 relative disturbance scores pertaining to the watershed in which that site occurred. The Sum-Rel scores were based on integrated landcover, road density and population density information from 1990s digital land cover data sets (Hollenhorst et al. 2007).

The Sum-Rel scores of wetlands sampled by Consortium researchers ranged from a low of 0.0880 to a high of 2.667. Only the wetland suite sampled by the Marsh Monitoring Program (MMP) covered this full range of values. The overall range sampled by MMP researchers was considerably broader than the range observed for the sites that were sampled for invertebrates. The Sum-Rel scores at invertebrate sites ranged from a minimum value of 0.696 at a Lake Erie site (Thorofare) on Long Point to a maximum of 2.444 at a Lake Ontario fringing site (Frenchman's Bay).

It was counterintuitive to find that the wetlands with the two lowest Sum-Rel scores (i.e., the 'least disturbed' locations) were located in Lake Erie and were not Lake Superior sites, given our general knowledge of landscape conditions and relative human disturbance in these regions. However, the two low scoring sites on Lake Erie were both associated with small, undeveloped and protected watersheds on Long Point, Ontario. So, despite the relatively coarse nature of the summary that was done for "Sum-Rel" calculations, the scores do seem to reflect relative disturbance levels accurately. The values observed for the Long Point, Lake Erie sites demonstrate some of the limitations of landscape analysis in that small watersheds with associated wetlands immersed in a "sea" of highly polluted/disturbed waters (L. Erie proper) may reflect disturbed biology even though the watersheds are relatively intact (e.g. Uzarski et al. 2005). Bhagat (2005) observed a similar phenomenon in her attempts to develop fish IBIs for Great Lakes coastal margins sampled as part of the GLEI project. She found that fish IBI and community composition better reflected the condition of entire "segment sheds" than the condition of the landscape immediately surrounding the sampling site. Obviously, the accuracy of an IBI score will depend on a number of factors (wetland type, level and type of disturbance etc), but the plant and animal communities at these kinds of sites seem unlikely to overcome the broad-scale stress of a highly disturbed system in which they lie, even if the bordering uplands are in good condition.

The wetlands in Lake Superior and northern Lake Huron and Lake Michigan that that had Sum-Rel scores at the low end of the disturbance scale were most likely to have invertebrate IBI values reflecting the highest ecological integrity because of the overall health of the lakes/regions in which they occur. However, the lowest of these Lake Superior and northern lake Huron-Michigan scores (1.274; Fig. 4-1) was from a Lake Superior site in Tahquamenon Bay, which is only near the midpoint of all Consortium sites that were scored (see Fig. 4-1, bottom row of points). If most "Sum-Rel" scores accurately reflect the relative human disturbance in their watersheds, these "Sum-Rel" scores suggest that the breadth of the overall gradient sampled for the invertebrate IBI-development study was fairly limited, and the suite of samples reported by Uzarski et al. (2004) primarily reflects conditions at the more disturbed end of the human disturbance scale in the Great Lakes. The alternative and perhaps more likely explanation for the

Taquamenon site is that local pollution, including leachates from the campsite toilets and showers from the state campground at that site, may have resulted in lower invertebrate IBI scores than indicated for Sum-Rel scores based on watershed landscape analyses. This indicates that local sources of pollution should be recorded by field crews and considered when a site is an outlier in subsequent analyses.

Synopsis – Current recommendations and future work

The invertebrate IBIs proposed and tested by Uzarski et al. (2004) seem to be the best developed and most broadly applicable means of assessing invertebrate community condition currently available for Great Lakes coastal wetlands. They appear to reflect conditions and effects of anthropogenic stresses in the Scirpus (Schoenoplectus) and wet meadow zones of Great Lakes fringing wetlands. A modified version of the Typha IBI has been applied to Lake Ontario fringing wetlands. Other metrics are available for additional classes of wetlands, but require data collected by field methods that differ slightly (D-net sampling with laboratory-based sorting) or substantially (activity traps; Ponar grab; coring) from those of Uzarski et al. (2004). Furthermore, because these alternative IBIs are either still in development or the testing phase, or have not been quantitatively assessed against well-defined gradients of anthropogenic disturbance, it is premature to recommend their use. Nevertheless, the alternative methodologies could be used to collect data that can be archived until the alternative metrics have been better evaluated.

The research required to expand the value of using invertebrates to assess coastal wetland condition includes:

1. comparison of the relative diagnostic value of activity traps vs. D-net sampling methods across the full gradient of diverse anthropogenic disturbances, as exemplified by the GLEI basinwide GIS-derived stressor scores; crosswalking derived values to permit equivalencies to be determined between the methods
2. true cross-validation of IBIs to assess their predictive value with samples independent of those used to derive indices. In some cases, this could be accomplished through the exchange of existing data. In others, it would required coordinated, contemporaneous wetlands sampling by each method.
3. Analysis of existing or new data to provide IBIs algorithms that apply to each wetland hydorgeomorphic class across the five Great Lakes.

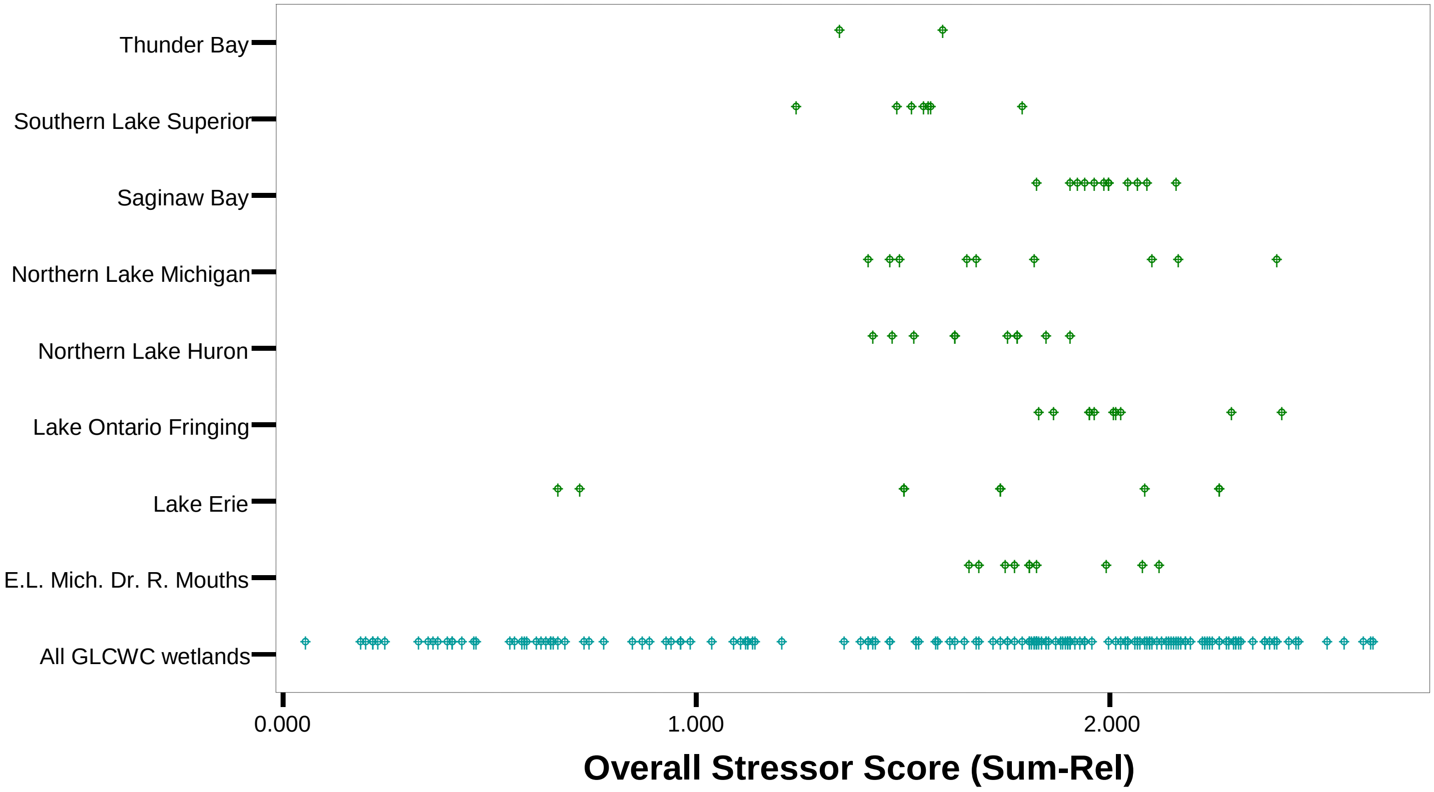

Figure 4-1. Consortium invertebrate sampling locations relative to the "Sum_Rel" overall landscape stressor scores.

Worksheet for Calculating IBI Scores

IBI use and interpretation of results

An index of biotic integrity (IBI) for fringing Great Lakes Coastal Wetlands. **All values should be based on the median of at least three replicates taken from each zone.** When all vegetation zones are present, wetlands are scored as follows: A total score of 31 to 53 (0% to 15% of possible score) = "Extremely Degraded.", or "in comparison to other Lake Huron wetlands, this wetland is amongst the most impacted"; total score of >53 to 76 (>15% to 30% of possible score) = "Degraded" or "the wetland shows obvious signs of anthropogenic disturbance"; total score of >76 to 106 (>30% to 50% of possible score) = "Moderately Degraded" or "the wetland shows many obvious signs indicative of anthropogenic disturbance;" total score of >106 to 136 (>50% to 70% of possible score) = "Moderately Impacted" or "the wetland shows few, but obvious, signs of anthropogenic disturbance;" total score of >136 to 159 (>70% to 85% of possible score) = "Mildly Impacted" or "the wetland is beginning to show signs indicative of anthropogenic disturbance"; total score of > 159 to 182 (>85% to 100% of possible score) = "Reference Conditions" or "the wetland is among the most pristine of Lake Huron." **When only a subset of vegetation zones are present, wetland category scores are adjusted as follows:** Wet Meadow Only = 9 to 14; >14 to 19; >19 to 27; >27 to 34; >34 to 39; >39 to 45; Inner Scirpus only = 11 to 19; >19 to 29; >29 to 41; >41 to 53; >53 to 62; >62 to 72; Outer Scirpus only = 11 to 18; >18 to 26; >26 to 37; >37 to 48; >48 to 56; >56 to 65; Wet Meadow and Inner Scirpus = 20 to 33; >33 to 47; >47 to 66; >66 to 84; >84 to 99; >99 to 113; Wet Meadow and Outer Scirpus = 20 to 32; >32 to 46; >46 to 64; >64 to 82; >82 to 96; >96 to 110; Inner and Outer Scirpus = 22 to 38; >38 to 55; >55 to 79; >79 to 102; >102 to 119; >119 to 137;

Table 4-2. Wet Meadow Zone: Dominated by Carex and Calamagrostis

Metric	Score 1	Score 3	Score 5
Odonata taxa richness (Genera):	0 score= 1	>0 to 3 score= 3	>3 score= 5
Relative abundance Odonata (%):	0 to <1 score= 1	>1 to 5 score= 3	>5 score= 5
Crustacea plus Mollusca taxa richness (Genera):	<2 score= 1	>2 to 6 score= 3	>6 score= 5
Total Genera richness:	<10 score= 1	>10 to 18 score= 3	>18 score= 5
Relative abundance Gastropoda (%):	0 to 1 score= 1	>1 to 25 score= 3	>25 score= 5
Relative abundance Sphaeriidae (%):	0 score= 1	>0 to 3 score= 3	>3 score= 5
Evenness:	0 to 0.4 score= 1	>0.4 to 0.7 score= 3	>0.7 score= 5
Shannon diversity index:	0 to 0.4 score= 1	>0.4 to 0.9 score= 3	>0.9 score= 5
Simpson index:	>0.3 score= 1	>0.15 to 0.3 score= 3	0 to 0.15 score= 5

Table 4-3. Inner Scirpus Zone: Often dense Scirpus mixed with Pontedaria and submergents, protected from wave action.

Metric	Score 0	Score 1	Score 3	Score 5	Score 7
Odonata taxa richness (Genera):		0 score= 1	>0 to <1 score= 3	1 to 2 score= 5	>2 score= 7
Relative abundance Odonata (%):		0 score= 1	>0 to <2 score= 3	<2 to 7 score= 5	>7 score 7
Crustacea plus Mollusca taxa richness (Genera):		0 to 2 score= 1	>2 to 4 score= 3	>4 to 6 score= 5	>6 score= 7

Total Genera richness:		<10 score= 1	<10 to 14 score= 3	>14 to 18 score= 5	>18 score= 7
Relative abundance Gastropoda (%):		0 score= 1	>0 to 2 score= 3	>2 to 4 score= 5	>4 score= 7
Relative abundance Sphaeriidae (%):		0 score= 1	>0 to 0.05 score= 3	>0.05 score= 5	
Ephemeroptera plus Trichoptera Taxa richness (Genera)		0 score= 1	>0 to 3 score= 3	>3 score= 5	
Relative abundance Crustacea plus Mollusca (%):		<8 score= 1	<8 to 30 score= 3	>30 score= 5	
Relative abundance Isopoda (%):	0 score= 0	0 to 1 score= 1	>1 to 10 score= 3	>10 to 20 score= 5	>20 score= 7.
Evenness:		0 to 0.4 score= 1	>0.4 to 0.7 score= 3	>0.7 score= 5	
Shannon diversity index:		0 to 0.4 score= 1	>0.4 to 0.9 score= 3	>0.9 score= 5	
Simpson index:		>0.3 score= 1	>0.15 to 0.3 score= 3	0 to 0.15 score= 5	

Relative abundance Amphipoda (%):
If 40 to 60 _____and total score from Innner Scirpus Zone (metrics 1 through 12) is greater than 41, then subtract 5;
If 40 to 60 _____and total score from Innner Scirpus Zone (metrics 1 through 12) is less than 41, then add 5.

Table 4-4. Outer Scirpus Zone: Sometimes relatively sparse, usually monodominant stands, subject to direct wave action.

Metric	Score 1	Score 3	Score 5	Score 7
Odonata taxa richness (Genera):	0 score= 1	>0 to <1 score= 3	>1 to 2 score= 5	>2 score= 7
Relative abundance Odonata (%):	0 score= 1	>0 to <1 score= 3	>1 to 2 score= 5	>2 score= 7
Crustacea plus Mollusca taxa richness (Genera):	0 to 2 score= 1	>2 to 4 score= 3	>4 to 5 score= 5	>5 score= 7
Total Genera richness:	<8 score= 1	>8 to 13 score= 3	>13 to 17 score= 5	>17 score= 7
Relative abundance Gastropoda (%):	0 score= 1	>0 to 3 score= 3	>3 to 5 score= 5	>5 score= 7
Relative abundance Sphaeriidae (%):	0 score= 1	>0 to 0.05 score= 3	>0.05 score= 5	
Total number of families:	0 to 7 score= 1	>7 to 12 score= 3	>12 score= 5	
Relative abundance Crustacea plus Mollusca (%):	<8 score= 1	>8 to 30 score= 3	>30 score= 5	
Evenness:	0 to 0.4 score= 1	>0.4 to 0.7 score= 3	>0.7 score= 5	
Shannon diversity index:	0 to 0.4 score= 1	>0.4 to 0.9 score= 3	>0.9 score= 5	
Simpson index:	>0.3 score= 1	>0.15 to 0.3 score= 3	0 to 0.15 score= 5	

For further reference, see Appendix B (Uzarski et al. 2004) at the end of this document.

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Appendix 4-1.

Field Equipment Checklist
For invertebrate and accompanying chemical/physical (covariates) sampling

Presampling checklist:

______Conductivity meter

______DO meter/Probe/Repair kit

______Tape

______Field notebooks

______2 dip nets

______Fine-tipped forceps/eyedroppers

______Invertebrate sample vials (Ethanol-filled)
and labels+pencil (9 per site)

______Cooler and ice (depending on temp)

______ Insect repellent

______Filter apparatus

______Metal hand pump/tubing
bottles

______ Turbidimeter

______1 L water sample
bottles (at least 3 per site)

______Mechanical pencils

______Meter stick

______White enamel pans

______Alcohol (95%) in 1 L
bottles and 1 squirt bottle

______Permanent marker

______Waders or boots

______Cell phone

______Filters/forceps

______250 mL sample
(at least 3 per site)

In field:

Water samples → Surface 1 L (1 sample per station)

Invertebrate samples → 3 per station