7 A Plant Index of Biotic Integrity for Drowned River Mouth Coastal Wetlands of Lake Michigan

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7.1 INTRODUCTION

Monitoring and assessment programs are being formulated to provide information on the structure and function of biological indicators for Great Lakes coastal wetlands. This has required the development of new indicators and assessment tools (Simon 2000). Development of macrophyte indicators for coastal wetlands of the Great Lakes has required a paradigm shift from previous research programs. This shift has challenged the concept that all wetlands are unique (Chow-Fraser and Albert 1998) and substituted recognition that wetlands can be clustered into three basic hydrogeomorphic classes (Keough et al., 1999).

Wetland biological assemblages have evolved in harsh, changing environments, where water fluctuations, seiche, and turbidity changes have caused significant cycles in wetland patterns (Wilcox ,1995). Likewise, land use changes around the Great Lakes have experienced shoreline development, toxic impacts, and constructed industrial and impervious structures (i.e., confined disposal facilities [CDFs]) in areas that were once large expanses of wetlands (Stewart et al., 2003). Wilhelm et al. (2003) evaluated the condition of these CDFs around the Great Lakes in order to determine recovery trajectories. Thus, fragmentation and edge effects have become significant concerns. Finally, since so few wetlands remain, it is imperative that a variety of wetland sizes, wetland conditions, and drainage areas be included in any calibration to provide an ecological dose-response curve to test candidate metrics (Karr and Chu, 1999).

The development of biological indicators for primary producers in the Great Lakes has only recently begun (Stewart et al., 1999). Wetland indicators using plant assemblages have been developed for use in Wisconsin (Nichols et al., 2000), Ohio (Mack, 2001), Minnesota (Gerness, 19xx), and the northern plains (DeKeyser et al, 2003), but no indicators have been developed for coastal wetlands. Plant indices of biotic integrity (PIBIs) using plant assemblages have been established for riverine and palustrine wetlands in southern Lake Michigan (Simon et al., 2001) and inland lacustrine wetlands in the Lake Michigan drainage (Rothrock et al., in review). As plant assemblage indicators are developed for drowned river mouth coastal wetlands of the Great Lakes, current indicators may need modification from each of these systems and require a separate calibration.

The purpose of this study was to determine whether the riverine, palustrine, or lacustrine wetland indices could be used as they are currently developed (Simon et al., 2001; Rothrock et al., in review) or adapted for coastal wetlands of the Great Lakes. We developed our pilot project in Lake Michigan for several reasons: 1) Lake Michigan is entirely within the United States and enabled sampling on both shorelines, 2) the orientation of Lake Michigan provides a snapshot of the full extent of latitudinal differences within the entire Great Lakes, 3) previous reference calibrations, tolerance, and metrics have been developed in Lake Michigan, thus, testing of these indices required sampling in Lake Michigan to enable similar comparisons. Finally, we provide a new calibration for wetland plant assemblages in Lake Michigan using a random probability design and use an ecological dose response paradigm.

7.2 MATERIALS AND METHODS

7.2.1 STUDY SITES AND STUDY DESIGN

Fifteen Lake Michigan drowned river mouth wetlands were randomly chosen as study sites using a tessellated, stratified design incorporating ecoregions and wetland size (Fig. 7.1). The sites encompassed the five EPA Level III Ecoregions that surround Lake Michigan (Northern Lakes and Forests, North Central Hardwood Forests, Southeastern Wisconsin Till Plains, Central Corn Belt Plains, and Southern Michigan/ Northern Indiana Drift Plains[Omernik 1987]). These wetlands covered a broad range of quality including several severely degraded by industrial activity and several deemed least-impacted by human activity. Stream channel width and wetland size also varied greatly across the suite of wetlands and within each Ecoregion. Overall, channel widths ranged from 3 to 65 m.

7.2.2 SAMPLING STRATEGY AND COLLECTION METHODS

Qualitative plant sampling techniques were used to evaluate plant assemblages. Sampling was done by surveying a distance of up to 35 times the channel width along the shore in all vegetative zones. The sampling intent was to perform a representative qualitative survey, not an exhaustive census, and was targeted at biological diversity and relative abundance estimates (Simon et al., 2001). All species of wetland obligate and facultative plants were identified and an abundance rating (1-Observed, 2-Rare, 3-Rare/Common, 4-Common, 5-Very Common, 6- Abundant) assigned to each species. Abundance categories represented the number of individuals of a plant species at a site; “observed" was assigned when only one individual of a species is found; "rare" was assigned when a plant species was found two to four times at a site; "rare/common" was assigned when the plant species was found more than four instances, but was never a common component of the community at a site; "common" species were those that were easily located at a site; "very common" species were slightly dominant at a site, and comprised up to about 25% of the community at a site; and "abundant" species were those that dominated a site, and comprised from 25% to almost 100% of the plant community. Identifications were done in the field and unknowns were identified using appropriate floristic manuals.

In addition to the qualitative plant sampling, each site was assigned a quality rank, from 0 to 10, based upon the best professional judgment (BPJ) of two independent observers. The BPJ rankings by independent observers consistently differed by 2 or less and had a Spearman $r_2 = 0.81$ ($p < 0.0003$). These average BPJ estimates for each site provided one benchmark for the testing of metric hypotheses.

7.2.3 TESTING OF METRICS

We used cluster analysis to demonstrate whether wetland types were so exceptionally distinct as to require multiple PIBI tools for assessing Lake Michigan river mouth wetlands. Between-site similarity of the wetland plant communities was evaluated by clustering and by ordination techniques. For clustering analysis, the species X cover matrix was converted to a distance matrix and subjected to an unweighted pair-group cluster analysis.

Our previous PIBI's consisted of 11 to 12 metrics covering 4 or 5 function categories. We retested the metrics from the palustrine and riverine PIBI (Simon et al., 2001) and lacustrine PIBI (Rothrock et al., in review) as well as new metrics across four function categories. Metric hypotheses were examined graphically against estimates of habitat quality to determine if the patterns found fit expectations. Further quantitative testing was then performed by means of Spearman correlations. Correlations between potential metrics were calculated and those with $r_2 = 0.80$ and above were considered redundant. The scoring for each PIBI metric follows Karr et al. (1986). In short, each metric was scaled against river width to detect possible factor ceiling-distributions and the data were then trisected. A score of 5 was assigned to the least impacted or reference condition wetlands, 3 to the middle grouping that shows deviation from reference conditions, and 1 to the lowest quality, most impacted sites.

We used Swink and Wilhelm's (1994) coefficient of conservatism (CC) to classify plants as either sensitive or tolerant. Plants with highest scores (8—10) are sensitive while tolerant plants have low scores (0—2). Plants with high CC values are not necessarily rare in the flora nor are plants with low CC values necessarily common. In each case, plants are essentially defined on the basis of ecological behavior. Values have been formalized for plants of northeastern Illinois (Swink and Wilhelm, 1994), Michigan (Herman et al., 1996), and recently for Wisconsin (Bernthal, T.W. 2003).

7.3 RESULTS AND DISCUSSION

7.3.1 FLORA AND COMMUNITY SIMILARITY

The drowned river mouth wetland communities of Lake Michigan have a diverse flora. The 15 coastal wetland sites in this study supported about 225 species from over 60 families (Rothrock et al., chapter 10). Among the largest families are Cyperaceae (32 species), Potamogetonaceae and Poaceae (14 species), and Asteraceae (12 species). The physiognomy of these species is also broad. There were over 25 species of submergents, 8 floating-leaved species, and 160 emergent and 25 woody species. Of the species observed, 1/3 were considered sensitive (i.e., had coefficients of conservatism ranging between 8--10), while 20% were exotic species or tolerant species (i.e., had coefficients ranginf between 0--2). Only two species that we encountered are considered threatened or endangered at the state level (Michigan State University Extension 2000). Given the large number of sensitive species observed, i.e., species characteristic of intact natural communities, we do not consider these sites to have experienced sufficient history of disturbance to extirpate the rarest elements. Rather, we suggest that this paucity of endangered or threatened species indicates that these productive Lake Michigan wetland habitats historically lacked numbers of rare species (Moore et al. 1989) and that they currently remain expansive enough to support sustainable populations of indigenous species.

Cluster analyses and ordination of the 15 coastal wetland sites did not reveal any unexpected heterogeneity of wetland communities (Fig. 7.2). Neither of the ordination methods showed any compelling necessity for developing multiple PIBIs within the Lake Michigan basin. High quality wetlands located in different Ecoregions readily clustered with others, as seen with Dead River (IL) and Hog Island Creek (MI); as well as between Dunes Creek (IN) and Pigeon River (MI). The cluster formed by White River (MI), Arcadia (MI), Kenauwee River, (WI), and Little Tail Creek (WI) not only included different ecoregions but also different river channel widths and associated watershed areas that differed strongly in scale (Fig. 7.2). The narrowest channel, Little Tail Creek, measured only 3 m in width compared to 39 m for Kenauwee River. Although the two most degraded sites, i.e., Grand Calumet River and Fox River, had low species diversity, they fell within the general clustering of wetland sites.

7.3.2 METRICS FOR SPECIES RICHNESS AND COMPOSITION

The number of species, a common measure of species diversity, has found wide usage in animal IBI's (Karr and Chu, 1999) and in recent PIBI efforts (Simon et al., 2001; Rothrock et al., in review). The metric hypothesis postulates that the number of plant species would increase with biotic integrity due to reductions in chemical and physical disturbances (Ehrenfeld and Schneider, 1990; Jurik et al., 1994; Findlay and Houlahan, 1997). We accepted this hypothesis because the most degraded sites had 10—33 species, while three high quality sites had between 60—79 species. Conversely, it is important to note that the two sites, Dead River and Hog Island Creek, which were given the highest ranking of site quality based upon best professional judgment, only had 44—48 species. In this study, the response of total species richness to changes in habitat quality was a non-linear, resulting in a low Spearman correlation (Table 7.2). We attribute the anomalous behavior of these two sites to unusual stream morphology. These waterways incise through rather sandy substrates resulting in relatively narrow and U-shaped channels with restricted wetland areas. Nonetheless, these sites scored high for most metrics, especially metrics that evaluate species quality. Despite the limited wetland area, the total species number observed in Dead River and Hog Island Creek was high enough to achieve a 5 (least impacted score).

Two groups of emergent graminoids, sedges (Cyperaceae) and rushes (Juncaceae) are an important component of temperate and cold temperate wetland communities (Heywood, 1978). Simon et al. (2001) found that a greater number of *Carex* species, a large and significant genus of Cyperaceae, were associated with high quality riverine wetlands. We found that same relationship to apply to drowned river mouth coastal wetlands. In addition, members of the genus *Juncus* have the potential, either alone or in combination with members of the sedge family, to act as a metric of habitat quality. We tested the metric for total sedge-rush species, expecting an increase in the number of species as quality increased. A significant relationship was demonstrated ($p = 0.03$, Table 7.2): worst sites had as few as 0—2 species compared to 15 or more in best quality sites (Fig. 7.3). As with total number of species (Fig. 7.3A), no relationship was evident between river width and the range of values for this metric (Fig. 7.3B).

PIBI's for lacustrine and palustrine sites (Simon et al., 2001; Rothrock et al., in review) used the metric "number of emergent species" in place of a one based upon graminoids alone. For coastal wetlands we found that a high correlation ($r^2 = 0.97$) existed between the number of emergent species and total number of species, rendering this potential metric redundant.

Waters of the Great Lakes have a high natural diversity of submergent species, especially those belonging to the genus *Potamogeton* (Voss, 1972; Wiegleb, 1988). Previous work (Simon et al., 2001) indicated that the number of submergent species would increase with habitat quality in riverine habitat, but too few *Potamogeton* species were present to provide a useful metric. In the lacustrine setting (Rothrock et al., in review), although both metrics were predictive of habitat quality, the total number of submergent species was tightly constrained than the number of *Potamogeton* species alone. For Lake Michigan drowned river mouth wetlands, the generalized metric, number of submergent species, provided a strong indicator of habitat quality (Table 7.2), which had a low correlation with other potential metrics(r^2 mostly << 0.5). Least impacted sites often had 9 or more submergent species, while degraded sites ranged from 0 to 3. Surprising, the severely degraded Grand Calumet River site supported 3 species, although the most abundant among these was the weedy exotic *Potamogeton crispus*.

Finally, in constructing PIBI's for palustrine, riverine, and lacustrine settings, the number or percent of floating species and perennial species were potential measures of biotic integrity. Floating species, useful in lacustrine PIBI, proved too few in number in drowned river mouth coastal wetlands. The number of perennial species showed some relationship to biotic integrity, but was highly correlated ($r^2 = 0.99$) with the total number of species.

7.3.3 SPECIES TOLERANCE AND SENSITIVITY

Sensitive species, those species associated with less impacted natural communities, are expected to be among the first to disappear under conditions of declining biological integrity (Karr 1981; Simon et al. 2001). On the other hand, tolerant and exotic species can grow under a wide range of habitat conditions, such as high rates of sedimentation (Dittmar and Neely 1999), and would tend to increase with increasing degradation and disturbance (Karr 1981; Magee et al. 1999). The expected behavior of sensitive and tolerant/exotic species was supported by results from the 15 wetland sites. The percent sensitive species increased significantly ($p = 0.008$) with increasing habitat quality, while degraded habitat showed an even stronger relationship ($p < 0.0001$) with the percent of tolerant and exotic species (Table 7.2). Least-impacted wetlands had at least 20% sensitive species and less than 30% tolerant species (Table 7.1). In calibrating these metrics, no scaling against river width was required (Fig. 7.2).

7.3.4 GUILD STRUCTURE

Root (1967) coined the term "guild" to describe groups of functionally similar species in a community. The concept of trophic guilds has wide usage in zoological literature, including IBI’s for fish and macroinvertebrate communities (Karr 1981; Kerans and Karr 1994; Karr and Chu 1999). For PIBI’s, guild identification has relied upon a broad range of attributes, such as obligate wetland species; woody, emergent, floating-leaved, and submergent species; pioneer and weed species; and tolerant and sensitive species (Simon et al. 2001; Rothrock et al. in review). Measuring the integrity of these guilds is achieved by estimating either the number, percent of species within the guild, or the overall relative abundance of guild members.

Obligate wetland plants are species occurring in wetlands with an estimated probability of greater than 99% under natural conditions (Reed 1988). The number of species in this guild is expected to decline with changes in hydrology due to ditches or dredging (Ehrenfeld and Schneider 1991), with nutrient enrichment and pollution from septic and industrial effluents (Moore et al. 1989), and with loss of aerial extend due to wetland filling (Camargo 1997). Results from Lake Michigan coastal wetland sites supported this hypothesis (Table 7.2; Fig. 7.2) since the most degraded wetlands had fewer than 12 obligate species compared to over 30 in those considered least-impacted (Table 7.1).

Pioneer species are characteristic of early successional stages or invade bare substrates (Whittaker 1993); where, according to Grime's (1977) primary plant strategies model, competition and stress are low to moderate. Pioneer species include many annual and biennial herbs and may be part of a persistent seedbank (van der Valk 1981) that germinates following disturbance or sedimentation (Dittmar and Neely 1999). Competitive weed species, in contrast, may perform poorly under these same conditions (Jurik et al. 1994). Instead weed species are perennials or woody plants with a strong power of vegetative spread (e.g., clonal dominants such as *Typha angustifolia* and *T. latifolia*), rapid growth rates and competitive ability (e.g. *Lythrum salicaria*), and phenotypic plasticity (Hill 1977; van der Valk 1981; Bazzaz 1986). Late successional communities are expected to have a minor presence of pioneer species, while the percent pioneer species should be higher in a community experiencing physical disturbance. Similarly, the percent weed species should be higher in disturbance communities, especially when experiencing nutrient enrichment (Weiher et al. 1996). Our sites supported this trend for Lake Michigan drowned river mouth wetlands (Table 7.2; Fig. 7.3). The most impacted wetlands, such as of Grand Calumet, Fox, and Kewaunee Rivers, had over 30% of both weed and pioneer species (Table 7.1). In calibrating these guild structure metrics, none required scaling against river width (Fig. 7.3).

Emergent species provided diagnostic guild metrics for palustrine and riverine wetlands (Simon et al. 2001). In these communities, the percent emergent species was lower in reference wetlands than in degraded sites. We tested percent emergents and relative abundance of emergents as guild metrics for drowned river mouth wetlands. Both metrics proved to be non-predictive ($r^2 < 0.02$, $p = 0.96$).

In the lake PIBI, the relative abundance of woody species was a non-redundant guild-based metric (Rothrock et al. in review). We tested this same metrics for drowned river mouth coastal wetlands, as well as the relative abundance of submergents, various emergent cohorts, and sensitive and tolerant species. While the relative abundance of sensitive and tolerant species had significant responses with biological integrity, they were also correlated (Spearman $r^2 = 0.80$ or more) with other metrics. The relative abundance of woody species, which decreased under reference conditions in lacustrine wetlands, did not respond in drowned river mouth communities (Spearman $r^2 = -0.16$, $p = 0.5$). The relative abundance of native submergents showed potential as a signature of environmental quality, usually having greater than 8% representation in least impacted sites. Several degraded sites completely lacked submergent plants; however, one of our most severely degraded sites, Grand Calumet River, had a relative abundance of native submergents of 15%. The high percentage we observed was seen when comparing a modest submergent plant community against total community abundance derived from only a few, prolific weedy species. To resolve this problem, we tested an alternative metric, average cover of native submergents, and found a consistent response signature to habitat quality ($r^2 = 0.75$; $p = 0.001$).

7.3.5 Vegetation Abundance

Low abundance values may be due to general diminution of vegetative cover, but typically are the result of vegetative dominance of a few weedy species (Farnsworth & Ellis 2001). Mean relative abundance may be indicative of degraded wetland habitats as seen, for example, in lacustrine and palustrine settings (Simon et al. 2001; Rothrock et al. in review). In the Lake Michigan coastal wetlands this potential metric increased with habitat quality, but correlated with total species richness ($r^2 > 0.85$, $p < 0.0001$) and was not used in the PIBI due to redundancy.

Although average abundances failed our validation test as a metric, abundance can resolve issues of species dominance or evenness across the wetland community. Abundance in reference wetlands is expected to follow a log normal curve, i.e. many species have low to moderate abundance and a few have higher abundance. The contrasting degraded sites tend to have a limited number of low abundance species and high dominance by one or a few species. We used the variance of relative abundances as a simple means of capturing dominance (Table 7.2; Fig. 7.3). The variance in degraded sites was generally high (>1.67), an indication of high dominance by a few species, while the variance of least-impacted sites was low (<1.33).

Exotic species are known for their negative impact on habitat quality (McKnight 1993). Habitat degradation creates conditions favorable for invasion and high relative abundance of exotic species (Morin et al. 1989; David 1999; Galatowitsch et al. 1999). As expected, least impacted drowned river mouth wetland sites had relative abundance of exotics less than 10%, while severely degraded sites had higher relative abundances greater than 20% (Table 7.2; Fig. 7.3). Neither dominance nor abundance of exotics required scaling with river width (Fig. 7.3).

7.3.6 PLANT INDEX OF BIOTIC INTEGRITY

The Floristic Quality Index (FQI) assesses the diversity and quality of a plant community and has found wide acceptance in the Midwestern USA. The FQI is based upon the number of species observed in a habitat and the average quality of those species as determined through application of the CC concept. We calculated the FQI's for each of the 15 drowned river mouth wetland sites and compared them to our total PIBI values (Table 7.3). Since both FQI and PIBI are attempting to specifically estimate vegetation quality and since the PIBI even relies to a limited extent upon the same criterion (namely CC values) used in the FQI, it was expected that the two indices would have a high correlation (Spearman $r_2 = 0.88$, $p< 0.0001$). PIBI scores in the good to excellent range (PIBI = 44 or more) had FQI values above 36.9 (Table 3). By contrast, poor to very poor sites (PIBI = 31 or less) had FQI values of less than 27. Further validation and calibration of the PIBI is needed through assessment of additional drowned river mouth wetland sites and to test its general applicability to other Great Lake basins.

Nonetheless, the comparison between PIBI and FQI suggests that PIBI can be a potent rapid assessment tool for wetland habitats. At the same time, given the current availability of FQI as a measure of habitat quality, what advantage is provided by a PIBI? We suggest that a PIBI provides additional information about site quality in the form of response signatures. In addition to the final PIBI value, 11 sub-scores are available that detail specific aspects of community function that either meet standards or diverge from reference conditions. For example, fair quality sites may have weedy species and exotics, compromises that could be readily observed in low sub-scores, and yet support an overall richness of species and a richness of submerged species in particular. To highlight a specific case among our study sites, the Manistee River wetland scored negatively for the dominance metric, due to significant patches of *Alnus* trees and *Phalaris arundinacea* and *Circium arvense* in portions of this large wetland. A comparable PIBI score was measured at the White River site; however, in this case, the deficient metric was a low percentage of sensitive species due to the overall lower species richness. A third fair site, Portage Creek had a dearth of submergent plants, perhaps due to channel dredging.

Although PIBI and FQI have high correlations, it is of interest to note that the two sites with the highest PIBI scores, i.e., Dead River and Hog Island Creek, did not achieve the highest FQI score. In these cases, FQI, which only evaluates species number and quality, neglected relevant measures of community structure such as the abundance of exotic and submergent species guilds.

Since the Lake Michigan sites were part of a larger study of drowned river mouth coastal wetlands we evaluated predicted quality with QHEI (qualitative habitat evaluation index) scores (Table 7.3). The correlation between QHEI and PIBI was low (r_2 = 21, p = 0.45). This shows that habitat quality as measured for invertebrate and fish assemblages does not correlated with habitat quality in plant assemblages. This shows that plants are not responding to the same environmental signs as animal assemblages.

Fish and macroinvertebrate indices of biotic integrity have enjoyed wide usage over the part several decades. Our recent investigation of plant IBI's in the Midwestern USA Great Lake region has demonstrated the feasibility of making similar rapid, multimetric quality assessments based upon vegetation. The development of PIBI has entailed a diversity of metrics and, an overview of the metrics included in PIBI, to date, may provide a pattern for devising PIBI for additional habitat types (Table 7.4). Some metrics have been of value across a range of wetland habits. These include number of species overall and of submergent and emergent species; tolerant and sensitive species (either as number or percent of species); pioneer species; overall vegetation abundance or dominance; and abundance of exotics. A few had specific application; floating leaved species were diverse in the lacustrine setting as were woody species. Similarly, the cover of native submergent species showed relative worth well in the drowned river mouth coastal wetlands.

The individual deformity and anomaly metric used in animal IBI's to identify the lowest levels of biological integrity (Karr 1981; Karr et al. 1986), may lack a clear response signature in PIBI's. Symptoms of toxicity that might be observed during rapid assessment could include growth reduction, small leaves, necrotic, chlorotic or discolored leaves, and early leaf fall (Adamus et al. 2001). In our experience, individual plant condition, even in our most degraded sites, remained visually excellent. Among the Lake Michigan drowned river mouth sites, two were particularly degraded. The Grand Calumet site supported an abundance of a few tolerant species with no visible deterioration of individual health despite murky water quality and sediments capable of emitting hydrocarbons. Likewise, the second most degraded site on the Fox River, Wisconsin, lacked observable submergent species. With the exception of a large stand of purple loosestrife undergoing experimental treatment with *Galerucella* beetles, river margin emergent species had abundant, vigorous biomass.

In conclusion, it is clear from the comparison of PIBI metrics (Table 7.4) that a working prototype for PIBI's is emerging. Nonetheless, as with animal IBI's, validation of metrics, as well as their calibration, is necessary before applying a PIBI to a new community type. In addition, we would observe that more information is needed on the inter-annual stability of vegetation quality. The Great Lakes are known to undergo meaningful, natural changes in water level. Water level changes in Lake Michigan are sometimes measured at 1 m or more over a several year period (Environment Canada, 2003). As a result, habitat quality measures may obtain lowered values during the several years of transition and could occur in high quality as well as degraded sites. In this study the entire suite of sites were visited within the same growing season, thus avoiding this confounding factor. However, for purposes of monitoring plant community quality around Lake Michigan, reference wetlands need to be identified.

7.4 CONCLUSIONS

Indices of Biotic Integrity (IBI) have been developed for a variety of animal assemblages and aquatic habitat types. The use of macrophytes as indicators of wetland quality, especially in the form of plant IBI's, are in a formative stages of development. Fifteen drowned river mouth coastal wetlands in Lake Michigan, diverse in size, quality, and ecoregion location, were semi-quantitatively sampled. Eleven metrics, divided in 4 function categories (species richness and composition, species tolerance, guild structure, and vegetative abundance) had strong response signatures and low autocorrelation. Final PIBI scores, ranging from 17 to 53, were strongly correlated with the familiar floristic quality index (FQI) but did not show significant cluster or ordination relationships with either Ecoregions or wetland size. Specific wetland examples suggest that although the PIBI represents a rapid assessment technique, it can provide more information about vegetation quality than the FQI.

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TABLE 7.1

Calibration of plant index of biological integrity (PIBI) for submerged rivermouth wetlands of Lake Michigan. The ranges for the various IBI scores are based upon trisection of the metrics presented in figure 7.2.

		Scoring	
Attribute	1 (worst)	3	5 (best)
I. Species richness and composition			
1. total number of species	0-21	22-43	>43
2. number of sedge-rush species	0-5	6-11	>11
3. number of submergent species	0-3	4-7	>7
II. Species tolerance			
1. percent sensitive species	0-10	10-20	>20
2. percent tolerant and exotic species	>40	30-40	<30
III. Guild structure			
1. number of obligate wet species	0-16	16-30	>30
2. average cover of native submergent species	0-0.8	0.8-1.6	>1.6
3. percent pioneer species	>36	31-36	<31
4. percent weed species	>22	11-22	<11
IV. Vegetation Abundance			
1. dominance (variance)	<0.62	0.62-0.77	>0.77
2. relative abundance of exotics	>18	9-18	<9

TABLE 7.2.

Spearman rank correlation coefficients and significance level between proposed plant metrics and qualitative estimates of habitat quality (best professional judgment).

Metric	Hypothesized Change with Increasing Quality	r^2	p
I. Species Richness and Composition			
1. total number species	Increase	0.33	0.23
2. number of sedge-rush species	Increase	0.56	0.03
3. number of submergent species	Increase	0.69	0.005
II. Species tolerance			
1. per cent sensitive species	Increase	0.65	0.008
2. percent of tolerant and exotic species	Decrease	-0.90	<0.0001
III. Guild Structure			
1. number of obligate species	Increase	0.55	0.03
2. average cover of native submergent species	Increase	0.75	0.001
3. percent pioneer species	Decrease	-0.61	0.02
4. percent weed species	Decrease	-0.78	0.007
IV. Vegetation Abundance			
1. dominance (variance)	Decrease	-0.81	0.0003
2. relative abundance of exotics	Decrease	-0.68	0.006

TABLE 7.3

Submerged rivermouth sites of coastal Lake Michigan: ecoregion, floristic quality index (FQI) and plant index of biotic integrity (PIBI). CCBP = central corn belt plains; NCHF = north central hardwood forests; NLF = northern lakes and forests; SMNITP = southern Michigan/ northern Indiana till plains; SWTP = southeastern Wisconsin Till Plains.

Site	Ecoregion	QHEI	FQI	PIBI
Dead River, IL	CCBP	78	37.8	53
Hog Island, MI	NLF	50	36.9	51
Pigeon River, MI	SMNITP	66	45.3	51
Dunes Creek, IN	CCBP	71	47.5	51
Days River, MI	NLF	51	41.2	49
Arcadia, MI	NCHF	43	37.3	47
Little Tail Point, WI	NCHF	55	33.8	43
Keyes Creek, WI	NCHF	72	33.1	41
Pentwater River, MI	SMNITP	54	32.9	37
Manistee River, MI	NCHF	62	35.3	37
Portage Creek, MI	NLF	57	35.5	33
White River, MI	SMNITP	65	24.4	33
Kewaunee River, WI	SWTP	72	26.8	31
Grand Calumet, IL	CCBP	48	8.5	17
Fox River. WI	SWTP	49	17.2	17

TABLE 7.4.

Comparison of metrics used in plant indices of biotic integrity: lake IBI (Rothrock et al. in review), palustrine IBI and riverine IBI (Simon et al., 2001), and drowned rivermouth IBI. Yes = used, Variation = used in modified form, No = not used, Yes* = used but not calibrated.

Metric	Lake IBI	Palustrine IBI	Riverine IBI	Rivermouth IBI
I. Species richness and composition				
Total number of species	Yes	Yes	Yes	Yes
Number of emergent species	Yes	Yes	Variation	Variation
Number of floating leaved species	Yes	No	No	No
Number of submergent species	Yes	Variation	Yes	Yes
Number of perennial species	No	Yes	Yes	No
II. Species Tolerance				
Sensitive species	Number	Number	Number	Percent
Tolerant and exotic species	Percent	Number	Number	Percent
III. Guild Structure				
Obligate species	Relative abundance	Percent	Percent	Number
Emergent species	No	Percent	Percent	No
Submergent species	No	No	No	Avg. Cover
Pioneer species	Relative abundance	Number	Number	Percent
Weed species	No	Number	Number	Percent
Woody Species	Relative abundance	No	No	No
IV. Abundance				
Mean relative abundance, mean cover, dominance	Mean cover	Mean relative abundance	Mean relative abundance	Dominance
Exotics (relative abundance)	Yes	No	No	Yes
V. Individual condition				
Percent taxa with deformities or anomalies	No	Yes*	Yes*	No

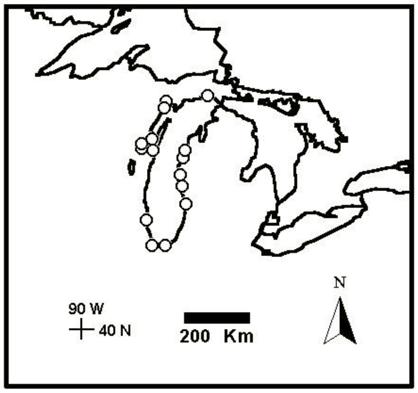
Figure Captions

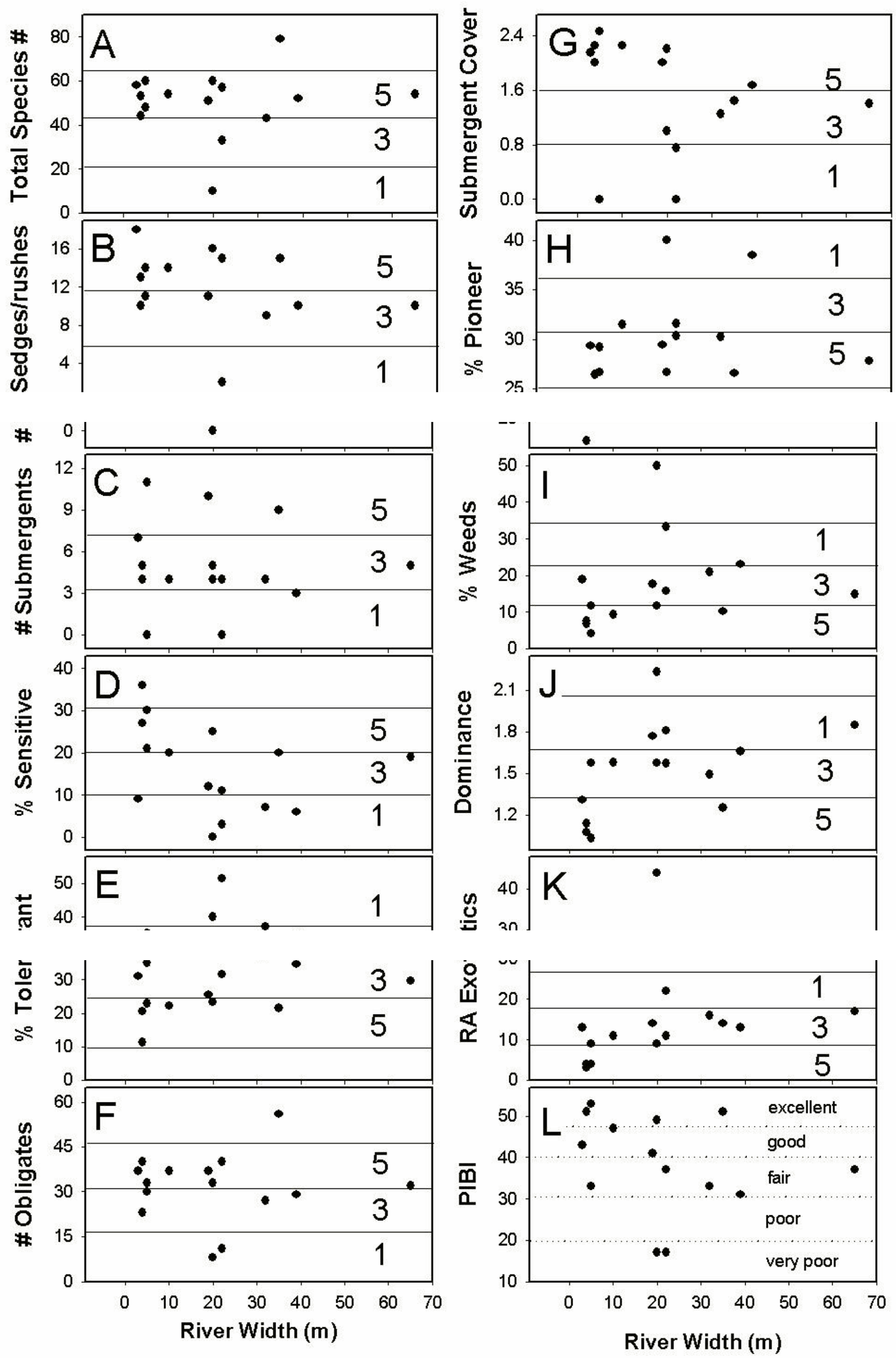
Figure 7.1. Map showing the 15 drowned river mouth coastal wetland sites sampled in Lake Michigan.

Figure 2. Cluster analysis of 15 Lake Michigan drowned river mouth coastal wetlands. Only taxa found in more than two samples were used in the analysis.

Figure 3. Metrics of drowned river mouth coastal wetland plant community used in assessment of biotic integrity.

Fig. 7.1





Total Species #
Sedges/rushes #
Submergents
% Sensitive
% Tolerant
# Obligates
Submergent Cover
% Pioneer
% Weeds
Dominance
RA Exotics
PIBI
excellent
good
fair
poor
very poor
River Width (m)