Fish Communities of Coastal Wetlands: Corroboration of a Vegetative Index of Biotic Integrity

A Final Report to The Ohio Lake Erie Commission,
Lake Erie Protection Fund

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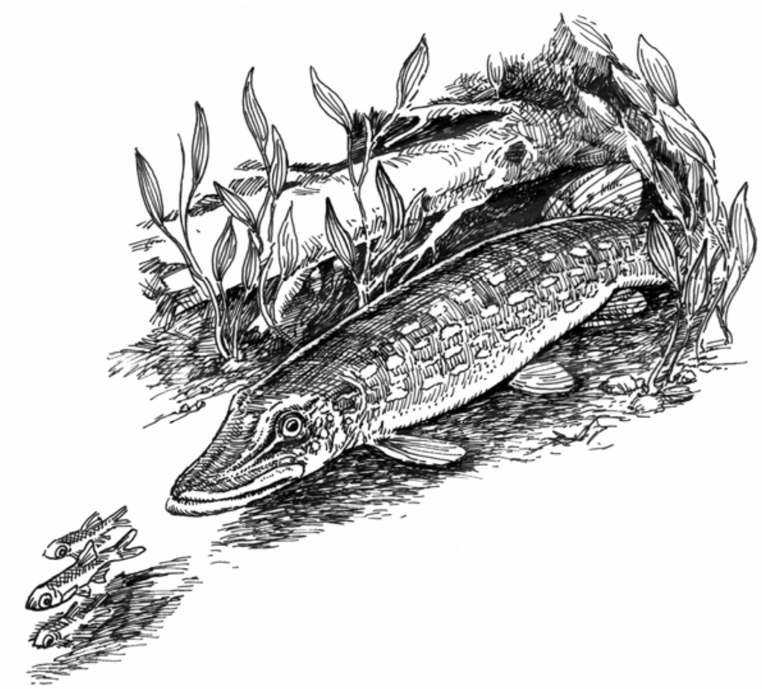

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ABSTRACT

Seiche-dominated coastal Lake Erie wetlands are an important habitat that is fast disappearing. We must find ways to evaluate these wetlands so as to make recommendations for their maintenance and rehabilitation. Indices of Biotic Integrity (IBIs) using fish assemblages have been developed specifically for Lake Erie's near shore waters, Lake Erie in general, and for Great Lakes Areas of Concern. The basis of developing an IBI is that there are sufficient species assemblage characteristics to be correlated with an independent measure of human disturbance. We collected fish once from ten coastal Lake Erie wetlands between July and September 2002 using a boat-mounted electrofisher. Electrofishing runs were from 254 to 1000 m long with most being ca. 500 m. Sampled wetlands ranged in size from 3 to 8,000 ha and yielded a total of 1,181 individual fish representing 35 species. Species richness ranged from 2 to 20 species and catch per unit effort (CPUE) ranged from 0.002 to 0.530 fish per meter (excluding gizzard shad, *Dorosoma cepedianm*). Fish were grouped by trophic and feeding guilds, and potential metrics (taxa-based assemblage characteristics which correlate with an independent measure of human disturbance) were evaluated against two measures of human disturbance, the Landscape Development Intensity Index and Ohio Rapid Assessment Method for wetlands (ORAM) v. 5.0. The ORAM was predictive for 11 of the 22 potential metrics such as numbers of sunfish species and percent tolerant individuals. Using this information, a baseline of data for these systems was established and a potential IBI for these seiche-dominated systems was constructed.

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CHAPTER 1

INTRODUCTION

1.1 Introduction and Literature Review

Lake Erie is the shallowest of the Great Lakes, the western basin having an average depth of 7.4 m and a maximum depth of 18.9 m (Bookout et al. 1989, Herdendorf 1992). Ohio's northwest shore was historically a marshy area with low barrier beaches and numerous estuarine river mouths (Herdendorf 1992). This area was once known as the Great Black Swamp and was one of the last areas in Ohio to be settled for agriculture because of its wet conditions (Trautman 1981, Mitsch and Gosselink 2000). The majority of the remaining coastal marshes along Lake Erie's shore are diked and managed, often to enhance wildlife habitat, by seasonal manipulation of water levels (e.g. Ottawa Shooting Club and Winnous Point Shooting Club). Similarly, other coastal wetlands have also been diked, drained, and used for agriculture. Consequently, many of Lake Erie's coastal wetlands have been hydrologically isolated from the lake. Natural coastal wetlands within the Great Lakes are connected to a larger water body and are influenced by cyclic, sometimes radical, water level changes from the weather-driven seiches (periodic oscillations, with irregular amplitudes of lake water level) and storm events. Now Lake Erie is at long-term average water levels (S. Mackey, U. S. Geological Survey, personal communication) and offers an opportunity to establish a baseline of fish assemblage data for these seiche-dominated wetlands. These data can be used to track the changes correlated with water level changes and human development near these wetlands.

Wetlands provide valuable habitat for many species. They are used as nursery areas as well as a source of food and habitat for adult fishes (Johnson 1989, Jude and Pappas 1992, Wilcox and Meeker 1992). Fish are often associated with macrophytes as a source of food as well as cover for both prey and predators. Some fishes, such as the northern pike depend on the previous year's standing dead macrophytes for successful spawning (all scientific names are given in Table 1) (Trautman 1981, Scott and Crossman 1998).

The Clean Water Act of 1972 mandated that ecological integrity be determined and maintained in the Nation's Waters. Ecological integrity is defined as the overlapping influence of three elements: physical, chemical, and biological integrity (Barbour et al. 2000). Biomonitoring is used as a way to integrate the physical, chemical and biological aspects by assessing an organism *in situ*. Barbour et al. (2000) suggest that one goal of biomonitoring programs should be to assess the "biotic integrity" of a system. "Reference condition" is associated with biological integrity by the idea of what may be expected if the system in question has had no human disturbance and includes the species assemblages expected in this pristine condition. Reference conditions must be derived through expectations of current conditions and the selection of "best available" or "least impacted" sites to be used in place of "reference" sites.

Biomonitoring is not a new idea, but for many projects, budgetary constraints can limit the tools available, and these tools must either be cost efficient or limited in scope.

The assessment of biotic integrity in a fairly rapid and representative manner has become a priority in recent years. Indices of Biotic Integrity (IBIs), originally developed by Karr (1981), have become a dominant method of assessment for aquatic systems using a variety of biological and ecological aspects of the species assemblages in question. Similar multimetric indices have been developed for lotic systems using fishes (Karr 1981, Minns et al. 1994, Thoma 1999), invertebrates (OEPA 1988, Applegate 2002), and for wetlands, using macrophytes (Mack 2001a, Husat 2003).

To evaluate the species assemblages in seiche-dominated coastal wetlands, the potential metrics must represent the responsiveness to biological and ecological aspects of the species in question. Past IBIs have considered species composition, trophic guild composition and community health metrics that will change in a predictable manner under anthropogenic stressors. Metrics take taxa-based assemblage characteristics and correlate them to an independent measure of human disturbance. These metrics are then plotted against an independent measure of human disturbance to predict the overall well being of the wetland in question where well being is defined as most like a system with least disturbance. Potential metrics are chosen from literature review, general knowledge of the assemblage of interest as well as a review of historical distribution data. It may be expected that if one independent measure of human disturbance (e.g., the Ohio Rapid Assessment Method for wetlands) shows predictable responses in one species assemblage (e.g., macrophytes), it may also be predictive for another assemblage (e.g., fish) and therefore the site in general.

In habitats where single-measure assessment methods (e.g., water quality analysis) have not been successful in predicting the well being of a system, IBIs have been found to be successful because of the integration of habitat and environmental changes within the habitat which is possible by studying of biota found in these systems (Karr 1981, Minns et al. 1994, Mack 2001a). The multimetric, assemblage-based criteria, approach to evaluating wetlands allows information to be integrated into a comprehensive analysis of the habitat and the species assemblages more so than a single-dimension measure such as species richness, chemical analysis, etc. Multimetric indices should include a range of aspects about the assemblage being studied, such as assemblage structure, guilds, and individual health (Barbour et al. 2000) to potentially be responsive to all possible anthropogenic stressors.

Karr (1981) and Hocutt (1981) suggest using fish assemblages as the most viable measure of biological integrity to assess human-related impacts on freshwater ecosystems. They list many advantages of using fishes as indicators: fishes are often used as bioassay organisms, though, rarely used in a comprehensive monitoring, until recently; the life history information of many species is known; fishes are relatively easy to identify in the field; and results can be easily communicated to the general public. The advantages are further supported when we consider that many fish species are relatively long-lived, and the effects of anthropogenic stressors can be cumulatively represented.

Jude and Pappas (1992) and Brown (2000) observe that fish assemblage associations are clearly related to the physical characteristics of the site, such as macrophytes, degree of connection to the lake, and land use. Thoma's (1999) study of Lake Erie "lacustuaries" (a "lacustuary" is combination the words "lacustrine" and "estuary" to mean an area of transition in a river which flows into a freshwater lake and is that portion of the river which is affected by changes in the water level of the lake) produced an IBI for Lake Erie lacustuarine wetlands. One of the most critical issues of applying these seiche-dominated wetland data to Thoma's IBI is that Thoma (1999), like Karr (1981), uses river mile as the independent axis and as a measure of human disturbance. We cannot apply river mile as an independent measure or as a measure of human disturbance to systems with little or no lotic influence; a different independent measure of human disturbance is necessary for seiche-dominated Lake Erie embayments.

Both Karr (1981) and Hocutt (1981) address the main disadvantage with the use of fishes as their ability to move away from sources of stress or into preferred areas, though Karr (1981) points out that these are disadvantages associated with any major taxa, with the exception of macrophytes. The absence of specific, in particular, sensitive, taxa is an indication of degradation of the sites. Fausch et al. (1990) suggest a few other disadvantages, such as identifying the primary reason for the observed response of the fishes which may or may not be anthropogenic degradation.

Seiche-dominated coastal Lake Erie wetlands are an important fish habitat (Johnson 1989, Krupa 2003, Johnson and Braig unpublished data) that is fast disappearing. We must find ways to evaluate these wetlands so as to make recommendations for their maintenance and rehabilitation. The basis of this research is the idea that sufficient fish assemblage characteristics will be correlated with an independent measure of human disturbance to allow the creation of a fish-based IBI.

CHAPTER 2

METHODS

2.1 Study Area

Seiche-dominated coastal wetlands along the southwest Lake Erie shore (USA) were identified based on U.S. Geographical Survey topographical maps (1:24 000) and site reconnaissance trips. Ten sites were selected based on accessibility for our sampling equipment and connection to Lake Erie (Figure 1). Connectivity of these sites ranged from broadly connected (Potters Pond) to seasonally/seiche connected (Bay View North and Beulah Beach) (Table 2).

2.2 Fish Sampling

A modification of the methods employed by the OEPA (Thoma 1999) was used for collection of fish samples. Electrofishing samples were collected from July to September 2002, beginning approximately 0.5 hr after sunset with a crew of 3-4 people. Starting points were selected randomly and two samples were taken at two of the ten sites; Metzger Marsh, because of the diversity and size of the wetland, and Crane Creek because of the small number of fish caught in the first sample. At least one 500-m run was attempted for each site. When more than one sample was collected at a site, the second was located approximately 1 km from the first site. Fish from the first sample were not marked. There were also some sites for which a full 500-m collection was not feasible because of the seiche, size, or depth of the wetland (exact distances are listed in Table 2).

Fish were sampled from a jon boat using a 5500 W generator and Coffelt variable-voltage pulsator, which provided electric current by varying voltage (ca. 250-300 V) to maintain 5-6 A of pulsed DC power at 60 pulses per second. Wisconsin rings suspended from a boom on the bow of the boat served as the anodes and the boat served as the cathode. Two individuals collected all fish that surfaced at the bow with 2.4-meter long-handled fiberglass-pole dipnets. A third person operated the outboard motor, pulsator controls, Garmen e-Trex GPS unit and the spotlight. If a fourth individual was present, they assisted with the emptying of the dipnets and identification of any hazards that the driver was not able to see.

Captured fish were held in a livewell until the conclusion of each pass. All fish were identified to species, measured to the nearest millimeter, and returned to the water. Weights to nearest gram were taken for some sport and wetland obligate fish (Table 1). Any species under question for identification were euthanized using Tricaine and preserved in 10% buffered formilin for later identification. Before each fish was returned to the water, it was inspected for deformities, eroded fins, lesions, and tumors (DELT). These observations were recorded and used in the development and calculation of metrics. To be able to compare results between wetlands, we converted fish numbers into a measure of catch per unit effort (CPUE=fish per meter). Gizzard shad were removed from all calculations of potential metrics because of their tendency to be caught in such large numbers that they overwhelm any possible trends observed (Thoma 1999).

2.3 Water Quality Analysis

Water quality was taken at all sites using a YSI 6820-C-M sonde with an external 12-V, deep-cycle battery. The sonde was deployed for approximately 24 hours prior to the fish sample session. The sonde recorded temperature (°C), dissolved oxygen (mg/L), conductivity (µS/cm), pH, and turbidity (NTU) every 30 min while deployed. These data were used to account for potential outliers in fish catches resulting from unusual events in the wetland such as oxygen crashes (Eugene C. Braig IV, The Ohio State University, personal communication).

2.4 Disturbance Scale

The Landscape Development Intensity (LDI) Index developed by Brown and Vivas (2003) was used as a measure of human disturbance. Husat (2003) found that this disturbance scale was appropriate for use in seiche-dominated coastal Lake Erie wetlands in predicting macrophytes response. Latitude and longitude data were run through the National Oceanic and Atmospheric Association's (NOAA) Coastal Change Analysis Program (C-CAP) Great Lakes 2000-Era Land Cover Metadata. Using this program, land-use was determined within a 1-km radius of a single point in the sample area (Daniel T. Button, U. S. Geological Survey, personal communication). The land-use area information was then converted to a percentage, area of influence, of the total area. This area of influence was then assigned an averaged LDI coefficient, based on the amount of non-renewable energy (e.g., gas and oil) used per unit area of land to maintain current use (e.g., high-intensity development), following Brown and Vivas (2003) and Husat (2003). The overall ranking was then calculated using the following equation:

$$LDI_{total} = \Sigma\ [(\%LU_i)(LDI_i)]$$

where:

LDI_{total} = LDI ranking for landscape unit (the area under consideration)
$\%LU_i$ = percent of the total area of influence in land use i
LDI_i = landscape development intensity coefficient for land use i
i = type of land use (e.g.: open water, agriculture, high/low density development).

The Ohio Rapid Assessment Method for Wetlands (ORAM) v. 5.0 (Mack 2001b) is a method of rapid evaluation of wetland habitat quality. This index has been successfully used as a measure of human disturbance in other IBI studies (Mack 2001a, Husat 2003) and was found an appropriate measure of anthropogenic disturbance for the wetlands studied by Husat (2003) (4 sites shared with this study). These ORAM scores were also calculated for our study sites. The ORAM score is determined through a combination of direct observation and site history with the use of the ORAM scoring sheets. Each site is evaluated by scoring individual metrics such as: wetland area, surrounding land use, hydrology and connectivity, past and current alterations to the site, as well as vegetation coverage, substrate composition, and type of habitat. Scores can range from a low of 0 (extremely degraded) to a high of 100 (pristine). Differences may occur between years or if more than one person evaluates the sites; therefore, the scores are likely to be similar, but not identical to scores collected earlier or later for a specific site.

2.5 Metric Development, Selection and Scoring

Following Johnson (1989), Brazner et al. (unpublished data) and Thoma (1999), fish species were classified into various guilds. Potential metrics for fish assemblages were based on previous IBIs developed by Karr (1981), OEPA (1988), Minns et al. (1994), and Thoma (1999) (Table 2). Based on these past IBIs, 22 potential metrics were identified. Successful metrics were selected based upon responsiveness across a gradient of anthropogenic disturbance. All data were analyzed for normality and Person's correlation using Minitab v. 13.0 for Windows (Minitab, Inc. 2000). After determination of normality, the metric data were plotted against the ORAM v. 5.0 and the 95^{th} percentile was determined and used as the upper reference limit (after Mack 2001a). The rest of the data were mathematically quadrisectioned using the 75^{th}, 50^{th}, and 25^{th} percentiles. Sites that fell above the 95^{th} percentile were termed "reference," and received a score of 10. For positive metrics, the sites that fell above the fourth quartile received a score of 10, sites within the third quartile received a score of 7, sites within the second quartile received a score of 3 and sites in the lower quartile received a score of 1. Unlike past IBIs, a metric which scored a "true 0" will receive a score of 0. For negative metrics, the quadrisection was preformed in the same way and scores were reversed: sites above fourth quartile received a score of 1, sites with in the third quartile received a score of 3, sites within the second quartile received a score of 7, while sites within the first quartile received a score of 10, with no "true 0" scored.

Species	Family	Native	Weighed
Longnose gar *Lepisosteus osseus* (Linneaus)[Tc,P]	Lepisosteidae	Yes	Yes
Bowfin *Amia calva* Linneaus[T,Tc,P]	Amiidae	Yes	Yes
Gizzard shad *Dorosoma cepedianum* (Lesueur)[T,Pl,L]	Clupeidae	No	Yes
Goldfish *Carassius auratus* (Linneaus)[T,O,P]	Cyprinidae	No	No
Common carp *Cyprinus carpio* Linneaus[T,O]	Cyprinidae	No	No
Spotfin shiner *Cyprinella spiloptera* (Cope)[T,In,P]	Cyprinidae	Yes	No
Golden shiner *Notemigonus crysoleucas* (Mitchill)[T,In,P]	Cyprinidae	Yes	No
Emerald shiner *Notropis atherinoides* Rafinesque[Pl]	Cyprinidae	Yes	No
Spottail shiner *Notropis hudsonius (*Clintori)[Pl,L]	Cyprinidae	Yes	No
Sand shiner *Notropis stramineus* (Cope)[In]	Cyprinidae	Yes	No
Bluntnose minnow *Pimephales notatus* (Rafinesque)[T,O]	Cyprinidae	Yes	No
Quillback *Carpiodes cyprinus* (Lasueur)[In,L]	Catastomidae	Yes	No
White sucker *Catostomus commersoni* (Lacepede)[T,O]	Catastomidae	Yes	No
Bigmouth buffalo *Ictiobus cyprinellus* (Valenciennes)[T,In]	Catastomidae	Yes	No
Spotted sucker *Minytrema melanops* (Rafinesque)[I,In]	Catastomidae	Yes	No
Golden redhorse *Moxostoma erythrurum* (Rafinesque)[I,In,R]	Catastomidae	Yes	No
Black bullhead *Ameiurus melas* (Rafinesque)[T,O,P]	Ictaluridae	Yes	≥ 200 mm
Yellow bullhead *Ameiurus natalis* (Lasueur)[O,P]	Ictaluridae	Yes	≥ 200 mm
Brown bullhead *Ameiurus nebulosus* (Lasueur)[O,P]	Ictaluridae	Yes	≥ 200 mm
Channel catfish *Ictalurus punctatus* (Rafinesque)[T,Tc,R]	Ictaluridae	Yes	≥ 200 mm
Northern pike *Esox lucius* Linneaus[Tc,P]	Esocidae	Yes	Yes
Brook silverside *Labidesthes sicculus* (Cope)[I,In,P]	Atherinidae	Yes	No
White perch *Morone americana* (Gmelin)[Tc,L]	Moronidae	No	No
White bass *Morone chrysops* (Rafinesque)[Tc,L]	Moronidae	Yes	No
Rock bass *Ambloplites rupestris* (Rafinesque)[I,Tc]	Centrarchidae	Yes	≥ 80 mm
Orangspotted sunfish *Lepomis humilis* (Girard)[T,In]	Centrarchidae	No	≥ 80 mm
Pumpkinseed *Lepomis gibbosus* (Linneaus)[In,P]	Centrarchidae	Yes	≥ 80 mm
Bluegill *Lepomis macrochirus* (Rafinesque)[In,P]	Centrarchidae	Yes	≥ 80 mm
Smallmouth bass *Micropterus dolomieu* (Lacepede)[I,Tc]	Centrarchidae	Yes	≥ 200 mm
Largemouth bass *Micropterus salmoidies* (Lacepede)[Tc,P]	Centrarchidae	Yes	≥ 200 mm
White crappie *Pomoxis annularis* Rafinesque[T,Tc]	Centrarchidae	Yes	≥ 100 mm
Black crappie *Pomoxis nigromaculatus* (Lesueur)[Tc,P]	Centrarchidae	Yes	≥ 100 mm
Yellow perch *Perca flavescens* (Mitchill)[In,L]	Percidae	Yes	≥ 100 mm
Freshwater drum *Aplodinotus grunniens* Rafinesque[I,O,L]	Scianidae	Yes	No
Round goby *Neogobius melanostomous* (Pallas)[T,M,B]	Gobiidae	No	No

Table 1. Species, family and native status of the 35 fish species collected from ten coastal marshes along western Lake Erie, July to September 2002. T=turbidity tolerant, I=turbidity intolerant, In=insectivore, Tc=top carnivore, O=omnivore, Pl=planktivore, M=molluscivor, P=phytophillic, L=lake, R=river and B=benthic. Classification data taken from Johnson (1989), Brazner et al. (unpublished data) and Thoma (1999).

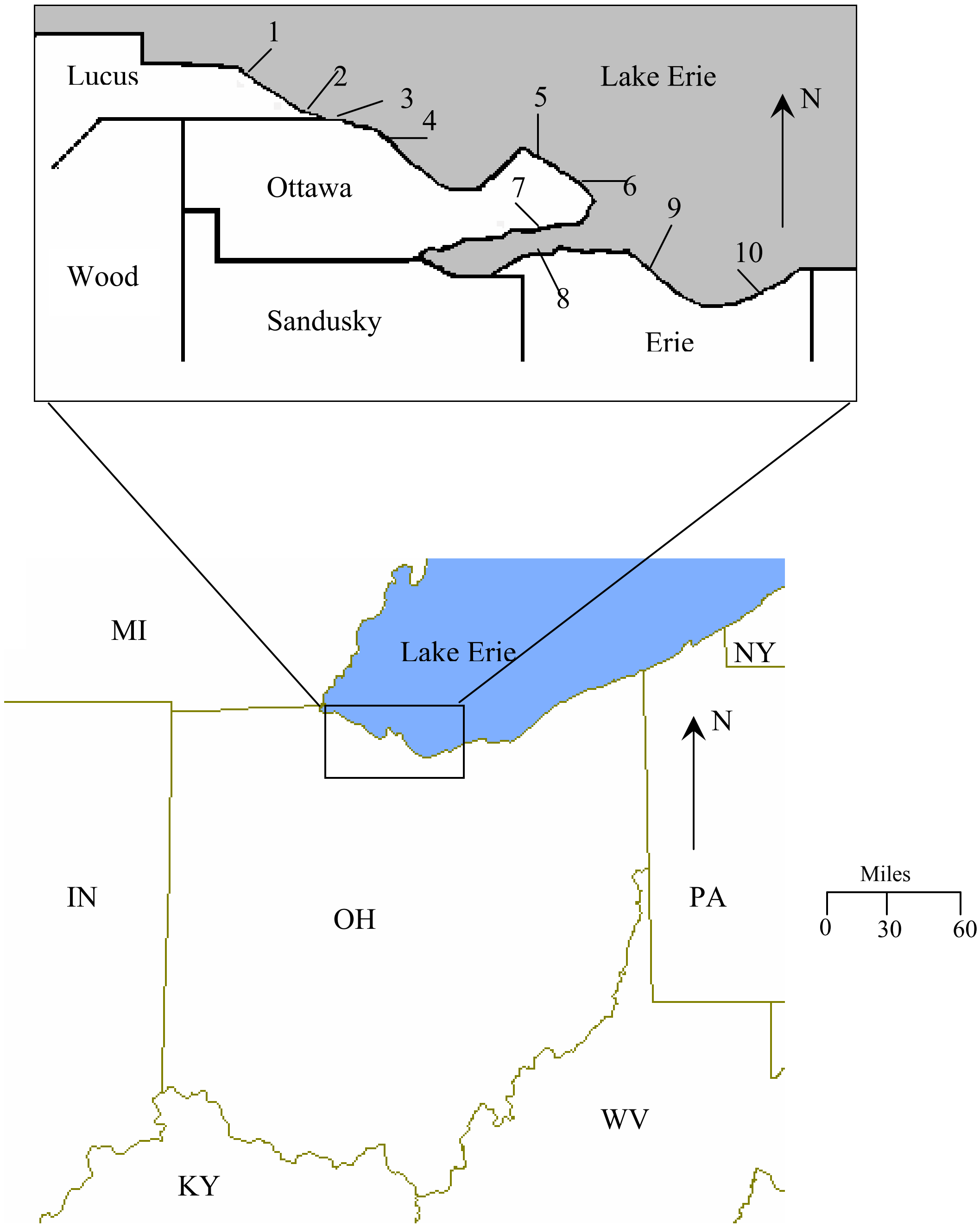


Figure 1. Location of wetlands in the western basin of Lake Erie sampled for fish assemblages, July to September 2002; 1) Potter's Pond; 2) Metzger Marsh; 3) Crane Creek; 4) Turtle Creek; 5) West Harbor; 6) East Harbor; 7) Meadow Brook; 8) Bay View North; 9) Plumb Brook; 10) Beulah Beach.

Sites	County	Township	USGS Quad	ha	Latitude	Longitude	Distance sampled (m)	Date sampled
Potters Pond	Lucas	Jerusalem	Reno Beach	16	41°40′46″	83°18′33″	550	4 Sept 2002
Metzger Marsh	Lucas	Jerusalem	Metzger Marsh	367	41°38′23″	83°13′01″	1000	6 Aug 2002
Crane Creek	Ottawa	Jerusalem	Reno Beach	323	41°37′50″	83°11′60″	1000	7 Aug 2002
Turtle Creek	Ottawa	Jerusalem	Oak Harbor	105	41°36′14″	83°09′09″	502	10 Sept 2002
West Harbor	Ottawa	Catawba Island	Gypsum	165	41°33′52″	82°49′03″	254	14 Aug 2002
East Harbor	Ottawa	Catawba Island	Gypsum	365	41°33′09″	82°48′17″	500	13 Aug 2002
Meadow Brook	Ottawa	Danbury	Gypsum	10	41°30′31″	82°48′24″	295	3 Sept 2002
Bay View	Sandusky	Margaretta	Castalia	105	41°27′59″	82°48′06″	388	15 Aug 2002
Plum Brook	Erie	Huron	Sandusky	8011	41°25′36″	82°38′26″	500	21 Aug 2002
Beulah Beach	Erie	Vermilion	Vermilion West	2	41°23′34″	82°26′23″	315	11 Sept 2002

Table 2. List of all seiche-dominated wetland sites sampled, including county, township, USGS quad map, area, latitude, longitude, distance sampled and date sampled for fish assemblage collection, July to September 2002.

Original IBI Metrics (Karr 1981)	Lake Erie Metrics (OEPA 1988)	Lacustuary Metrics (Thoma 1999)	Great Lakes Areas of Concern (Minns et al. 1994)	Seiche-Dominated Metrics Proposed for This Study
		Species Num ics		
# Species	# Species	# Species	# Natives	# Species
Species richness and composition of sunfish (except green sunfish)	# Sunfish species	# Sunfish species	# Centrarchidae species	# Sunfish species
Species richness and composition of darters	# Phytophillic species	# Cyprinid species	# Cyprinid species	# Native cyprinid species
Species richness and composition of Suckers	# Benthic species	# Benthic species		# Native Species
Proportion of green sunfish				

Behavior/Tropic Guild Metrics				
	% Lake associated individuals	% Phytophillic individuals	% Specialist biomass	% Phytophillic individuals
Proportion top carnivores	% Top carnivores	% Top carnivores	% Piscivore biomass	% Non-native individuals
Presence of intolerant species	# Intolerant species	# Intolerant species	# Intolerant species	% Lake associated individuals
Proportion omnivore individuals	% Omnivore individuals	% Omnivore individuals	% Generalists biomass	
Proportion insectivorous cyprinids	% Nonindigenous individuals	% Nonindigenous individuals	% Nonindigenous individuals	
	% Tolerant individuals	% Tolerant individuals		% Tolerant individuals
Community Health Metrics				
Proportion DELT*	% DELT*	% DELT*		
# Individuals	Relative numbers	Relative numbers	# Native individuals	# Native individuals
Proportion of hybrid individuals			# Nonindigenous species	# Individuals
			Biomass of native species	$e^{H'}$ (Hill's first diversity indicator)
			% Nonindigenous biomass	

*Deformities, eroded fins, lesions, or tumors (DELT)

Table 3. Three categories of metrics used in four previous studies, Karr 1981, OEPA 1988, Minns et al. 1994, and Thoma 1999, as compared to those found appropriated for the current study, sites sampled July to September 2002.

CHAPTER 3

RESULTS

3.1 Fish Sampled

We sampled 10 wetlands ranging in size from 3 to 8,011 ha (Table 2) and from these wetlands we collected a total of 1,181 individual fish representing 35 species including gizzard shad (Table 4). Species richness ranged from a high of 20 in Metzger Marsh to a low of 2 in Crane Creek. Excluding gizzard shad, we found that East Harbor had the highest CPUE of 0.530 fish per meter and Crane Creek had the lowest CPUE of 0.002 fish per meter (Table 5). The five most numerous species found in all wetlands (excluding gizzard shad) are as follows: common carp: found in six sites, pumpkinseed and bluegill sunfish: in five sites each, goldfish and largemouth bass: in four sites each (Table 6). East Harbor was the only site that did not have gizzard shad as one of the most numerous species. Following Thoma (1999), gizzard shad were excluded from all calculations because they can overwhelm the sample and mask results.

3.2 Development of Fish Index of Biotic Integrity for Seiche-Dominated Wetlands

With no prior IBI developed for seiche-dominated Lake Erie coastal wetlands, we were able to test a variety of potential metrics that would be responsive to anthropogenic stresses and to investigate the predictive power of two measures of human disturbance. These fish assemblage data were then used to illustrate a potential IBI for seiche-dominated wetlands. No independent data were available to confirm the IBI.

1-km Landscape Development Intensity (LDI) Index

This index was not found to be significantly correlated with any of the proposed metrics of fish assemblages in coastal Lake Erie seiche-dominated wetlands. Using Pearson's correlation of fish assemblage characteristics verses LDI index scores, all *p*-values for this measure of human disturbance were 0.214 or greater. The LDI was predictive for Husat's coastal vegetation IBI (V-IBI-C) (2003) in similar systems.

Ohio Rapid Assessment Method (ORAM) v. 5.0

The ORAM scores were calculated for each wetland (Table4) and using Pearson's correlation, this measure of human disturbance was found to be correlated with 11 metrics at α=0.100 level. The metric *Number of species* was deemed too important and was retained even though p=0.105. ORAM as a measure of human disturbance was also found to be correlated for Husat's V-IBI-C study (2003).

3.3 Metrics

The selection of metrics was based on the strong response of the eleven hypothesized metrics to increasing human disturbance, and these metrics form a basis for the creation of an IBI (r^2 values and *p*-values are reported excluding gizzard shad) as measured by ORAM v. 5.0. To illustrate, we will apply these data as an IBI.

Species Composition and Richness

Number of Species

This metric has been used in most fish IBIs since Karr in 1981. Karr (1981) states that this is an obvious choice for a metric, and is the reason for retaining this metric even with the slightly elevated *p*-value. Karr (1981) does caution that this metric must be used in conjunction with the knowledge of the number of species a particular system is able to support under natural conditions. The number of species present reflects the ability of that assemblage to adapt to human disturbances. There is an increase in the number of species present with the increase ORAM v. 5.0 score (Figure 2a: r^2=0.295, p=0.105). Though not proven significant here, it may be expected that seiche-dominated wetlands connected to a larger body of water would have similar fish assemblages, depending on wetland size and connection to the larger water body and that this metric will decline with increasing human disturbance.

Number of Sunfish Species

This metric has been used by Karr (1981), OEPA (1988), Fore et al. (1994), Minns et al. (1994), and Thoma (1999). This metric is made with the inclusion of green sunfish (*Lepomis cyanellus* Rafinesque), if present, and following the modification made by Thoma (1999) the inclusion of the genera *Pomoxis* and *Micropterus*. This metric responded positively in response to increasing ORAM v. 5.0 score (Figure 2b: r^2=0.442, p=0.036).

Number of Native Cyprinid Species

Minns et al. (1994) and Thoma (1999) have used the number of cyprinid species as a metric in their IBIs. This metric has been modified to specifically exclude goldfish and carp, two species that can also dominate a site similar to gizzard shad. This metric to increases with increasing ORAM v. 5.0 score(Figure 2c: r^2=0.515, p=0.020). It has been observed that the number of non-native species tends to increase as degradation increases, which may allow for the perpetuation of the degradation.

Number of Native Species

This metric was used by both Minns et al. (1994) and Drake and Pereira (2002). They found that native species richness is a strong overall indicator of ecosystem health. This metric responded in a similar manner as the number of species; the number of native species increased as the ORAM v. 5.0 score increased (Figure 2d: r^2=0.305, p=0.098). Native species are adapted to the historical environs of coastal wetlands. With an increase in anthropogenic affects, the native species may not be able to adapt as well as some non-native species and fewer natives may be expected in highly degraded systems.

Behavior/Trophic-Guild Metrics

Percent Phytophillic Individuals

Thoma (1999) was the first to use *Percent Phytophillic Individuals* as a guild trait. The OEPA (1988) used the number of phytophillic species in their IBI for Lake Erie. We used the *Percent Phytophillic Individuals* because this metric fit the model better. This metric is expected to be sensitive to human disturbance relative to anthropogenic reduction of macrophytes in a wetland. The percent of phytophillic individuals was positively correlated with ORAM v. 5.0 score (Figure 2e: r^2=0.546, p=0.015).

Percent Lake Associated Individuals

The OEPA (1988) uses this metric for their Lake Erie IBI. This metric was chosen because it would be expected that low numbers of lake-associated fishes would be present in late summer in a minimally disturbed seiche-dominated wetland because of their physiological intolerance of wetlands. This metric is inversely related to ORAM v. 5.0. As the ORAM v. 5.0 score increased, this metric decreased (Figure 2f: r^2=0.370, p=0.062).

Percent Non-native Individuals

The OEPA (1988), Minns et al. (1994), and Thoma (1999) use this metric. Thoma (1999) found that the number of non-native species increased in areas of higher disturbance, particularly in areas with high urban populations. Similar to Thoma, we found that a higher ORAM v. 5.0 score (lower human disturbance) was correlated to a decrease in numbers of non-native individuals (inversely related) (Figure 2g: r^2=0.407, p=0.047).

Percent Tolerant Individuals

This metric has been used by the OEPA (1988) and Thoma (1999) and is used for both lake and lacustuary areas as a metric similar to Karr's (1981) use of percent green sunfish. This metric was indirectly correlated to ORAM v. 5.0. As the level of human disturbance increased (lower ORAM score), this metric was found to increase (Figure 2h: r^2=0.408, p-value=0.047).

Community Health Metrics

Number of Individuals

Karr (1981), OEPA (1988), and Thoma (1999) have used this metric. According to Karr (1981) this metric, like the number of species, is an obvious choice. Both OEPA (1988) and Thoma (1999) calculated this metric without gizzard shad, and as "relative numbers." We see a positive correlation of this metric with ORAM v. 5.0 (Figure 2i: r^2=0.388, p=0.054). As the number of individuals increases with the ORAM v. 5.0 score.

Number of Native Individuals

Minns et al. (1994) used this metric. This metric is related to the *Number of Native Species* and responds similarly. As the level of human disturbance decreases (higher ORAM v. 5.0 score), the number of native individuals increases (Figure 2j: r^2=0.364, p=0.065).

Hill's First Diversity Indicator (N1=$e^{H'}$)

This metric has not been used in past IBIs, as Karr (1981) suggests that it is a compound metric, incorporating both species richness and evenness, but when used within a framework of other metrics, it is unlikely to bias the observed changes. Ludwig and Reynolds (1988) describe Hill's first diversity indicator as the number of abundant species, the effective number of species present, when each species is weighted by its abundance in the sample. This diversity indicator is a modification of Shannon's index measuring the average degree of uncertainty to predict to what species an individual chosen at random from a collection of *S* species and *N* individuals will belong. There is a bias involved with the calculation of this index where the possible number of species in an environment is likely to be greater than that in the sample, though with large enough numbers, this can be minimized. Hill's first diversity indicator is found by raising Shannon's index to the natural logarithm base *e* to find the number of abundant species. This metric was correlated to the ORAM v. 5.0 (Figure 2k: r^2=0.494, p=0.023). With a decrease in the ORAM v. 5.0 score, increased human disturbance, we see a corresponding decrease in N1, the number of abundant species.

3.4 IBI Development

After the determination of the metrics, the total scores were figured for each site (Table 7). When the sum of the metric score data is plotted against the ORAM v. 5.0 calculated values, we find that there is a relationship (Figure 3: r^2=0.423, p=0.002) between the total metric score for all sites and the ORAM score. We may then calculate the 95th, 75th, 50th, and 25th percentile for assignment of reference, excellent, good, fair and poor rankings for these sites. Two sites were ranked at the 95th percentile, Metzger Marsh and East Harbor, and were classified as reference sites. Beulah Beach was the only site that ranked >75th percentile and was classified as excellent. West Harbor and Plumb Brook were classified as good (>50th percentile). Two sites were classified as fair

(>25th percentile), Turtle Creek and Bay View North. Three sites were classified as poor (<25th percentile), Potters Pond, Crane Creek, and Meadow Brook.

3.5 Water Quality Analysis

Even though the fish assemblage does not necessarily reflect water quality data, we calculated and compared the average turbidity of the sites with the number of common carp found in 9 sites (water quality data was not available for Metzger Marsh). There were significant correlations with the average turbidity and the presence or absence of common carp (Figure 4: r^2=0.423, p=0.058).

	Potters Pond	Metzger Marsh	Crane Creek	Turtle Creek	West Harbor	East Harbor	Meadow Brook	Bay View North	Plumb Brook	Beulah Beach
Longnose gar		1								1
Bowfin				2	1					
Gizzard shad	9	6	16	23	94	3	15	105	24	44
Goldfish		4		7		7	5	5	3	55
Common carp		7	2	2	1	10	7	6	1	3
Golden shiner		5				3				
Emerald shiner									2	
Spottail shiner		1								
Spotfin shiner	1									
Sand shiner										2
Bluntnose minnow		3			22	6		1	13	
Quillback					1			1		1
White sucker									1	1
Bigmouth buffalo				2	2			2		1
Spotted sucker										1
Golden redhorse										1
Black bullhead									1	
Yellow bullhead		1			1			2		
Brown bullhead				1		6	3		28	11
Channel catfish								3	1	
Northern pike		2								
Brook silversides		3			2	24			2	
White perch	5	1		16	4		1	3		3
White bass									1	
Rock bass		12				1				1
Orangespotted sunfish		1								
Pumpkinseed		3			20	37	3		9	21
Bluegill		11			40	121	1	1	14	24
Smallmouth bass		2								
Largemouth bass		65		1	19	44		1	14	9
White crappie										1
Black crappie					1					
Yellow perch		1		1	2	4				
Freshwater drum	3	2		7	10	2	1	1	1	
Round goby		1			1					
Total number of individuals per site	18	132	18	62	221	268	36	131	115	180
Number of species per site	4	20	2	10	16	13	8	12	15	16
ORAM v. 5.0 scores	46	64	46	39	48	63.5	59	47	63	54

Table 4. Fish sampled from each wetland including numbers of individuals of each species and the total number of individuals and total number of species caught at each site as well as the ORAM v 5.0 score for each wetland. Wetlands were sampled between July and September 2002. Scientific names listed in Table 1.

	POTTERS POND	METZGER MARSH	CRANE CREEK	TURTLE CREEK	WEST HARBOR	EAST HARBOR	MEDOW-BROOK	BAYVIEW NORTH	PLUMB BROOK	BUELAH BEACH
# SPECIES	3	19	1	9	15	12	7	11	14	16
TOTAL DISTANCE (m)	393	1000	1000	502	254	500	295	388	500	315
# FISH	9	126	2	39	127	265	21	26	91	136
FISH/M (CPUE)	0.023	0.126	0.002	0.078	0.500	0.530	0.071	0.067	0.182	0.432

Table 5. Wetlands sampled with number of species caught, number of individuals caught, distances sampled in each wetland and catch per unit effort (CPUE) for each location. Samples are shown excluding gizzard shad. Wetlands were sampled between July and September 2002.

	Potters Pond	Metzger Marsh	Crane Creek	Turtle Creek	West Harbor	East Harbor	Meadow Brook	Bay View North	Plumb Brook	Beulah Beach
Goldfish				7			5	5		55
Common carp		7	2	2		10	7	6		
Pumpkinseed					20	37	3		9	21
Bluegill		11			40	121			14	24
Largemouth bass		65			19	44			14	

Table 6. The five most common species for all wetlands sampled. Numbers are individuals caught excluding gizzard shad. Wetlands were sampled between July and September 2002.

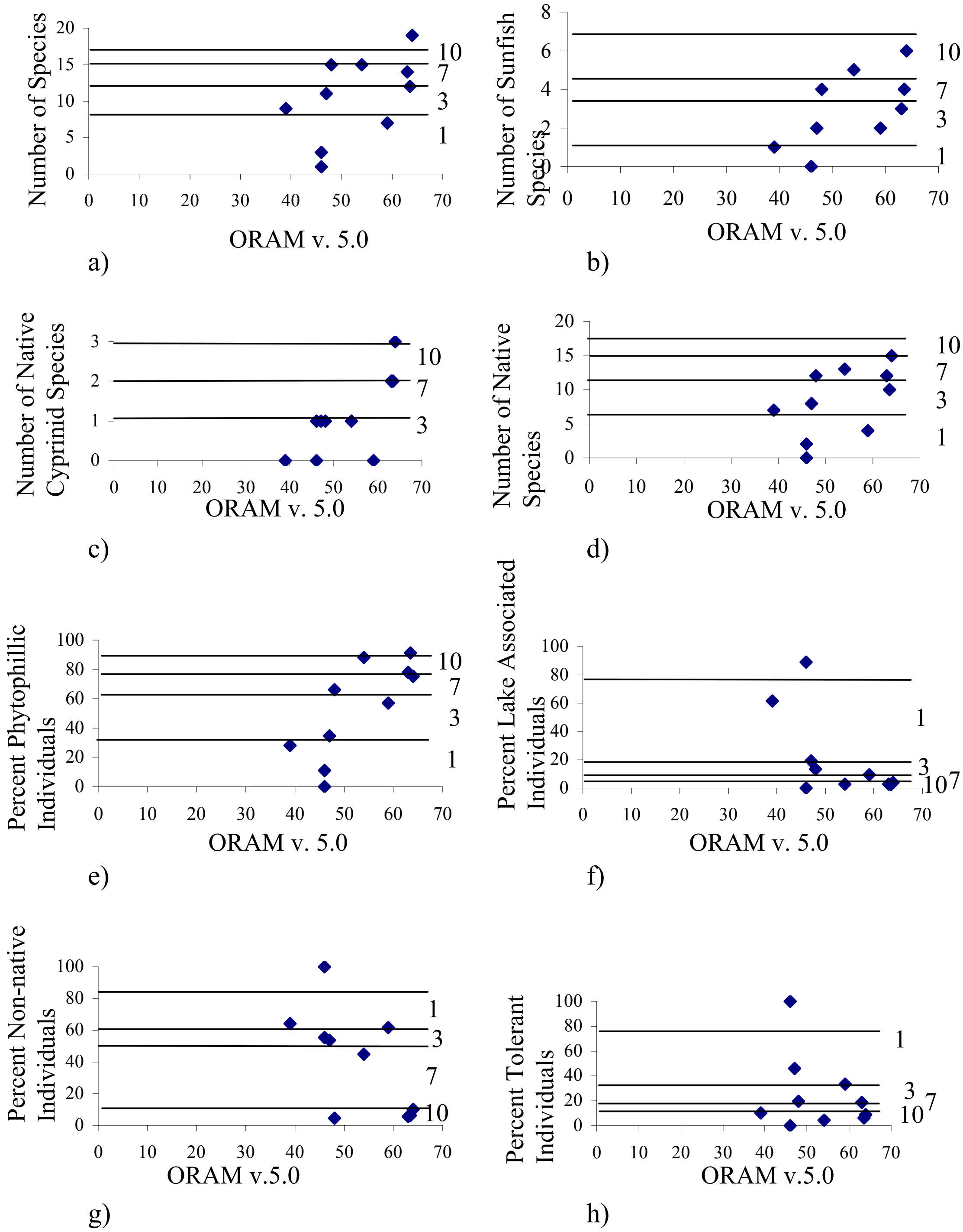
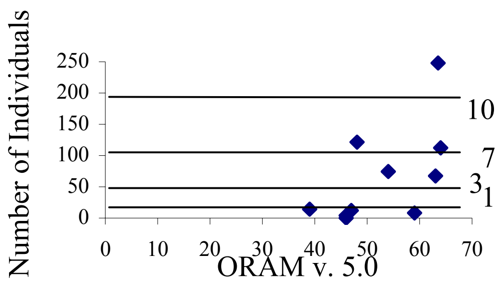
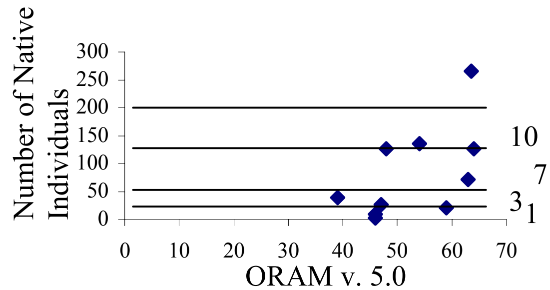


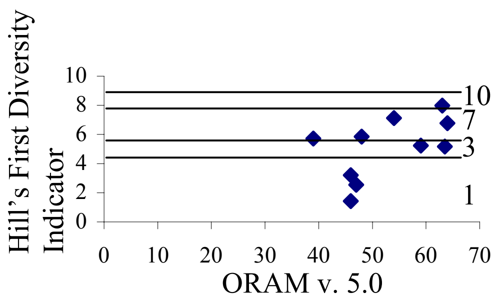
Figure 2. Scatter plots (a-k) of fish metrics correlated with ORAM v. 5.0 scores for coastal, seiche-dominated wetlands. Wetlands were sampled between July and September 2002.



i)



j)



k)

Figure 2 (cont.)

	Potters Pond	Metzger Marsh	Crane Creek	Turtle Creek	West Harbor	East Harbor	Meadow Brook	Bay View North	Plumb Brook	Beulah Beach
# Species	1	10	1	3	10	7	1	3	7	7
# Sunfish species	0	10	0	3	10	10	3	3	7	10
# Native cyprinid species	7	10	0	0	7	10	0	7	10	7
# Native Species	1	10	0	10	10	10	1	3	10	10
$e^{H'}$ (Hill's first diversity indicator)	1	10	1	7	7	7	7	1	10	10
% Phytophillic individuals	1	7	0	1	7	10	3	3	10	10
% Non-native individuals	7	10	1	3	10	10	3	7	10	10
% Tolerant individuals	10	10	1	10	7	10	3	3	7	10
% Lake associated individuals	1	10	10	3	7	10	7	3	10	10
# Native individuals	1	10	0	3	10	10	1	3	7	7
# Individual fish	1	7	1	3	10	10	1	3	7	10
Sum (from 110)	31	104	15	46	95	104	30	39	95	101
Classification	Poor	Reference	Poor	Fair	Good	Reference	Poor	Fair	Good	Excellent

Table 7. Calculated IBI scores for ten wetland sites sampled from July to September 2002, and the classifications suggested from these scores.

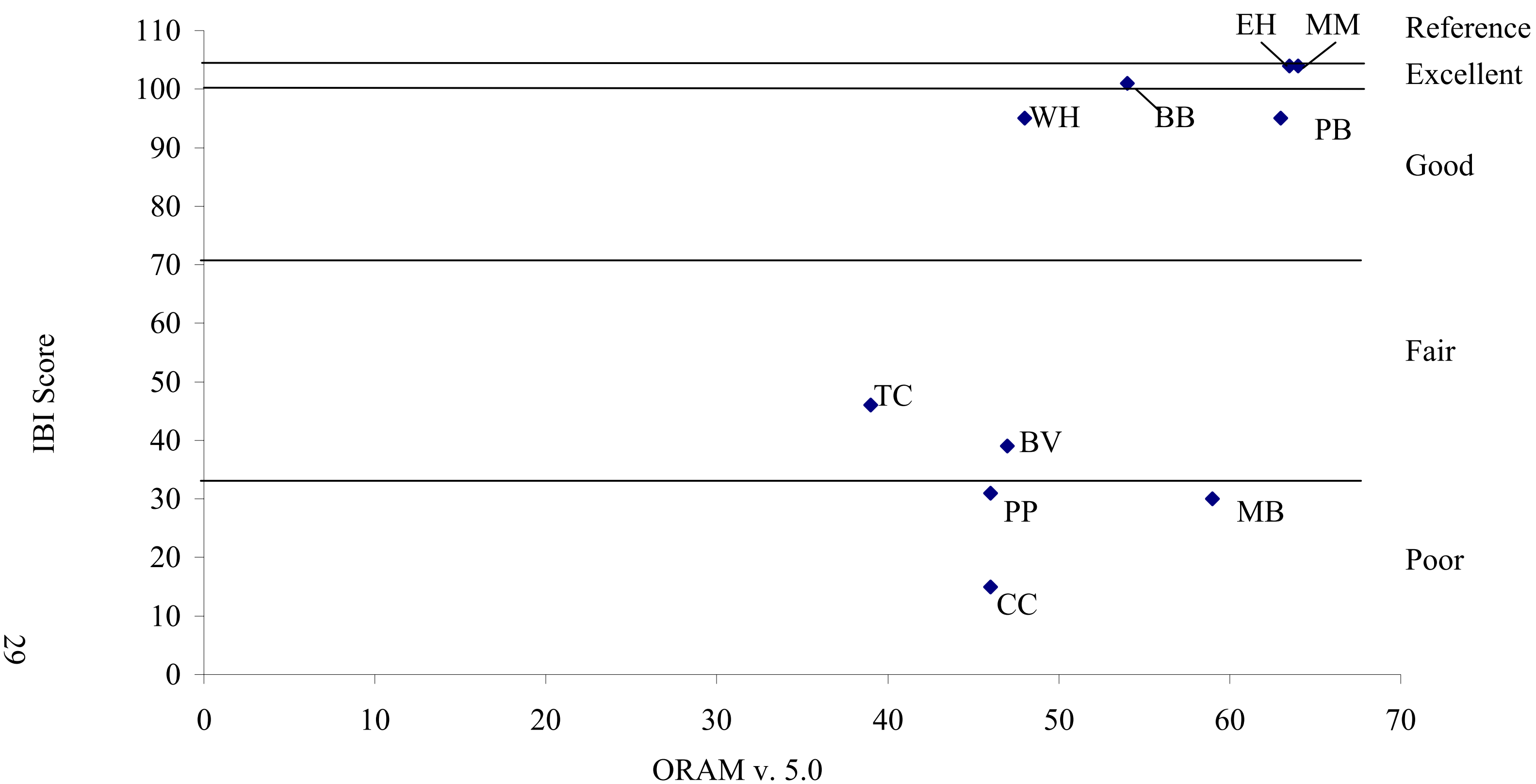


Figure 3. Calculated IBI Score plotted against ORAM v. 5.0 with suggested classification based on 95th, 75th, 50th and 25th percentile break points. Classification categories are based on previously developed IBIs. Wetlands were sampled between July and September 2002. (PP=Potters Pond, MM=Metzger Marsh, CC=Crane Creek, TC= Turtle Creek, WH=West Harbor, EH=East Harbor, MB=Meadow Brook, BV=Bay View North, PB=Plumb Brook, and BB=Beulah Beach).

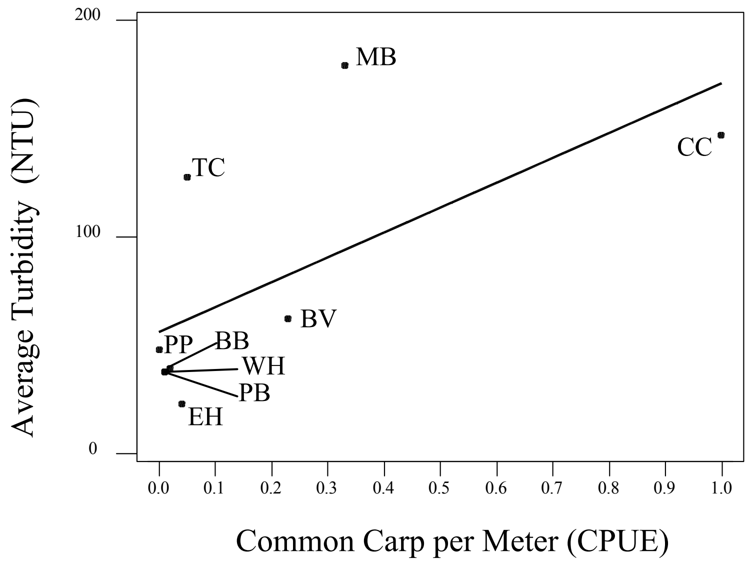


Figure 4. Average turbidity (NTU) plotted against common carp per meter (catch per unit effort) for each site sampled (r^2=0.423, p=0.058). (PP=Potters Pond, MM=Metzger Marsh, CC=Crane Creek, TC= Turtle Creek, WH=West Harbor, EH=East Harbor, MB=Meadow Brook, BV=Bay View North, PB=Plumb Brook, and BB=Beulah Beach). Data for Metzger Marsh (MM) were not available. Wetlands were sampled between July and September 2002.

CHAPTER 4

DISCUSSION

The purpose of an IBI is to allow for the rapid evaluation of a site. The hypothesis of an IBI is that if one measure of human disturbance (e.g., ORAM) is predictive of changes in one assemblage (e.g., macrophytes), than it may also be predictive for others (e.g., fish) in the same or similarly disturbed locations. The Ohio Rapid Assessment Method (ORAM v. 5.0) has been found to be an accurate predictor for vegetation assemblages in seiche-dominated coastal Lake Erie wetlands (Husat 2003). It was also found to be predictive for fish assemblages of similar seiche-dominated coastal Lake Erie wetlands. These fish assemblage data were not directly comparable to Thoma's 1999 lacustuary study, even though there are similar metrics for both studies. The reason for this is that Thoma (1999) used river mile as the measure of human disturbance, while this study focused on seiche-dominated wetlands with little or no in-stream flow; we needed a different measure of human disturbance.

Some common characteristics for sites that had high IBI scores included that they were protected from the direct actions of the seiche and had well-developed submerged and emergent vegetation assemblages. Metzger Marsh is protected by an engineered dike and has a relatively small "mouth," containing grates and a fish passage structure, between the lake and the marsh. This has allowed for the development of a diverse vegetation assemblage while controlling access of large spawning common carp to the marsh. East Harbor is also protected by a dike which has a relatively small opening from the marsh to the lake. This is maintained by the State Park system to allow for boat access. This has allowed for the development of a diverse vegetation assemblage in the shallow, protected area to the north of the boat channel. The majority of fish found in these two wetlands were young-of-year or small, wetland-obligate species. The most protected wetland was Beulah Beach with a dynamic barrier beach across the opening. This wetland also has a well-developed vegetation assemblage.

Little to no protection from the direct affect of the seiche and little to no development of the vegetation assemblage were two common characteristics of sites that had low IBI scores. Potters Pond has no protection from the direct affects of the seiche and is dominated by very shallow waters and mudflats with vegetation found only in the somewhat protected southwest corner. Crane Creek is also very shallow and turbid, mostly mudflats, though protected from direct impacts of the seiche. The vegetation assemblage of Crane Creek is not very developed and is found predominantly along the edges of the 323ha site. Crane Creek is subject to agriculture up-stream of the wetland and this likely has an affect on the wetland itself. Meadow Brook is a private site that was formerly farmed and only recently left fallow. The vegetation around the wetland was sprayed and re-seeded with prairie seeds the summer of our sampling. There was not a well-developed vegetation assemblage, terrestrial or aquatic, present at the time of sampling.

One family and one guild specifically relate to the classification of these wetlands. Sunfishes (family Centrarchidae) have a wide range of tolerance to human impacts. Green sunfish are often considered the most tolerant of the sunfish family when human induced changes and high turbidity are observed (Trautman 1980). Karr's (1981) list of relative ranking within the sunfish family putts smallmouth bass and rock bass on the "least tolerant" end of this spectrum and green sunfish as "most tolerant." We caught no green sunfish at any of our sites, but centrarchids were sampled at all sites with the exception of Potters Pond and Crane Creek, two of the poorest ranking sites. While smallmouth bass and rock bass were only found together in Metzger Marsh, one rock bass was found in East Harbor and one in Beulah Beach (Table 3), the three highest-ranking sites.

Phytophillic species were found at all sites including Crane Creek. Most sites that had few (<20) phytophillic individuals also had fewer than 10 species caught and a CPUE of less than 0.08 fish per meter. Sites with more (>70) phytophillic individuals had more than 12 species and a CPUE greater than 0.126. East Harbor had the highest number of phytophillic individuals present, with 252 from a total of 268 (94%) individuals caught. This wetland had a very well developed submerged vegetation assemblage. This was also the site with the highest catch per unit effort at 0.530 fish per meter (Table 4).

There is a common sentiment that diked wetlands should be allowed to return to the seiche-dominated, "natural," systems. One problem with this idea is that the diked wetlands allow managers to control populations of common carp and therefore, in theory, control the turbidity of these wetlands. We have found a correlation between the number of common carp and turbidity for the wetlands studied (Figure 4). It would be beneficial for all wetland managers for this line of research to continue so that the effect of common carp in both managed and seiche-dominated/open wetlands can be assessed further.

These data were collected during a time of mean water levels for Lake Erie (S. Mackey, U.S. Geological Survey, personal communication). This allows for a rare opportunity to make a baseline of fish assemblage data that can be used for future studies at different water levels and to be able to compare these systems over time. We may also be able to record changes that occur based on human disturbance or alterations to the local environment. It is possible that these metrics may change as water level continues to fluctuate, but there should be some consistency with the fish assemblages because, as Karr (1981) and Holcutt (1981) have noted, fish can move, but they will tend to remain in systems to which they are best adapted. Indices such as IBIs should not be viewed as static because the systems they are assessing are not static, but this IBI may be used as a baseline for seiche-dominated wetlands in Lake Erie.

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